

STS-107 SPACE SHUTTLE MISSION REPORT

July 2003



**National Aeronautics and
Space Administration**

**Lyndon B. Johnson Space Center
Houston, Texas**

NOTE

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STS-107
SPACE SHUTTLE

MISSION REPORT

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July 2003

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INTRODUCTION

The Mission Report provides information and data for the STS-107 mission up to entry interface (EI). Discussions of the events and activities following EI, which resulted in the loss of the vehicle and crew are contained in other documentation. The Columbia Accident Investigation Board was formed and controlled additional data and information concerning the remainder of the flight.

The Space Transportation System (STS) – 107 Space Shuttle Program Mission Report presents a discussion of the Orbiter activities of the mission up to EI as mentioned above, as well as presenting a summary of the External Tank (ET), Solid Rocket Booster (SRB), Reusable Solid Rocket Motor (RSRM), and Space Shuttle main engine (SSME) performance during this one-hundred and thirteenth mission of the Space Shuttle Program. STS-107 was the eighty-eighth mission since return to flight, and the twenty-eighth flight of the Orbiter vehicle (OV) - 102 (Columbia) vehicle.

The flight vehicle consisted of the OV -102 Orbiter; an ET, which was a Lightweight Tank (LWT), and it was designated ET-93; three Block II SSMEs that were designated as S/Ns 2055, 2053 and 2049 in positions 1, 2 and 3 respectively, and two SRBs that were designated B1116. The two RSRMs were designated RSRM-88 with one installed in each SRB. The individual RSRM serial numbers were 360W088A for the left SRB and 360W088B for the right SRB.

The primary objective of the STS-107 mission was to conduct an optimum science/research flight. The primary payload was the SPACEHAB Research Double Module (SHRDM), which accommodated a variety of multi-disciplined payloads for science and research. The Fast Reaction Experiments Enabling Science, Technology, Applications and Research (FREESTAR) was a complex secondary payload, which was a cross-bay carrier that was populated with various payloads. The FREESTAR payloads were:

1. Mediterranean Israeli Dust Experiment (MEIDEX);
2. Space Experiment Module (SEM);
3. Solar Constant Experiment-3 (SOLCON-3);
4. Shuttle Ozone Limb Sounding Experiment (SOLSE-2);
5. Critical Velocity of Xenon-2 (CVX-2); and
6. Low-Power Transceiver (LPT).

An additional secondary payload was the Ram Burn Observation (RAMBO).

The STS-107 flight was a 16-day plus 2-contingency-day flight. The two contingency days were available for landing weather avoidance or other Orbiter contingency operations. The sequence of mission events is shown in Table I.

All times during the flight are given in Greenwich mean time (G.m.t.) and mission elapsed time (MET). Appendix A lists the sources of data, both formal and informal, that were used in the preparation of this report. Appendix B provides the definition of acronyms and abbreviations used throughout this report.

The seven crewmembers that were on the STS-107 mission consisted of Rick D. Husband, Colonel, U. S. Air Force, Commander; William C. McCool, Commander, U.S. Navy, Pilot; Michael P. Anderson, Lt. Col., U. S. Air Force, Payload Commander and Mission Specialist 3; David M. Brown, M.D, Captain, U. S. Navy, Mission Specialist 1; Kalpana Chawla, PhD., Civilian, Mission Specialist 2; Laurel Blair Salton Clark, M. D., Captain, U. S. Navy; Mission Specialist 4; and Ilian Ramon, Colonel, Israeli Air Force, Payload Specialist 1.

STS-107 was the second Space Shuttle flight for the Commander, Payload Commander/Mission Specialist 3 and Mission Specialist 2, and the first space flight for the Pilot, Mission Specialist 1, Mission Specialist 4 and Payload Specialist 1.

MISSION SUMMARY

The STS-107 mission was launched at 16:15:38:59.994 G.m.t. on January 16, 2003. The primary payload was the Spacehab Research double module that accommodated a variety of multi-discipline payloads for science and research. The countdown was satisfactory with no unplanned holds, and the ascent was nominal with one problem identified.

At approximately 81.7 seconds mission elapsed time (MET), a large light-colored piece of debris was seen to originate from an area near the ET/Orbiter forward attach bipod. The debris appeared to move outboard and then fall aft along the left side of the Orbiter fuselage, striking near the leading edge of the left wing. An assessment of this event performed during the mission concluded that there was not a safety of flight issue. However, the Columbia accident investigation has concluded that this event was the most probable cause of the loss of Columbia and the crew. Analysis, test and flight data support the theory that the foam debris from the ET damaged the left wing reinforced carbon carbon (RCC) providing a pathway for hot gas to enter the left wing leading edge during entry. This ultimately resulted in significant damage to the left wing and subsequent loss of vehicle control leading to vehicle aerodynamic breakup.

An orbital maneuvering subsystem (OMS) assist maneuver was performed following SRB separation. The maneuver was initiated at 16:15:41:16.736 G.m.t. (00:00:02:16.742 MET) and was 102.2 seconds in duration. The OMS performed satisfactorily throughout the maneuver.

The OMS 2 maneuver was performed at 16:16:20:24 G.m.t. (00:00:41:24 MET) with a duration of 120.7 seconds. The differential velocity (ΔV) was 185.7 ft/sec and the orbit attained was 146.6 by 156.0 nmi.

The payload bay doors were opened as planned at 16:17:36:01 G.m.t. (00: 01:58:01 MET). All voltages were nominal and the motors opened the doors in nominal dual-motor time.

During the prelaunch/post-insertion time period, phase-B of ac-2 bus exhibited a sluggish current increase during motor operation of three different motors. The first occurrence of the sluggish performance was noted at T-31 seconds, and the second and third occurrences were noted during the post-insertion activities. Phases A and C of the ac-2 bus increased to their expected values, but phase B increased only to about half of the expected value, then recovered to the expected value within about a second. The affected motors were:

1. Vent doors 8 and 9;
2. Ku-band deploy motor 2; and
3. Port payload bay door open motor 2.

There was no impact to motor drive times. There is no common circuit breaker/motor control assembly. All other motor signatures analyzed were nominal, some of which are powered from the same circuit breaker/motor control assembly as the affected motors.

Continued data review uncovered several occurrences of "miniature" signatures of the same type (phase B dropping, phases A and C increasing). Most of these occurrences were less than one-second in duration and the phase-B drop was between 0.2 and 0.3 amperes. They were triggered sometimes by water-loop pump cycles, although several occurrences during prelaunch and on-orbit operations were observed when no loads were being cycled. There was also evidence of the signature in data analyzed by KSC from STS-107 flow processing. From the data, the problem appears to have been in the ac-2 bus phase-B inverter or the wiring between the ac-2 bus phase-B inverter and panels L4 and MA 73C.

Initial MPS data review revealed a potential dropout of the Space Shuttle main engine (SSME) 3 LH₂ prevalve open A indication. Additional data evaluation revealed multiple data dropouts in various Orbiter systems. A data integrity evaluation was performed that determined that all of the observed dropouts are actually data hits. There are no Orbiter anomalies associated with this issue, and the issue was closed as an explained condition.

During Spacehab activation, the crew reported that transmissions from the Orbiter on the intercommunications (ICOM) B loop were not being heard in the Spacehab module. Communications on the ICOM A loop were satisfactory. This loss of redundancy did not affect the continuing mission operations. Later in the flight, the crew was asked to troubleshoot the problem by reconfiguring the ICOM system to ICOM B and performing a communications check. The crew reported that ICOM B worked satisfactorily, and that the earlier problem was probably caused by a configuration error.

During performance of the oxygen (O₂) tank current-level detector checkout, it was noted that the O₂ tank 7 heaters A1 and A2 'on' discretes did not come on with the switch in the ON position. This checkout procedure calls for the tank heaters to be turned on manually and then verifying that the current-limiting sensor turns off the heater. Main bus current verified that the O₂ tank 7 A heaters did not come on. Subsequently, the crew was asked to enable the O₂ tank 7 A heaters in the AUTO position to determine if the heaters would operate in that mode. The 'on' discretes were received and a full cycle of the A heaters were observed, thus verifying satisfactory operation in the AUTO mode. There was no mission impact. The O₂ tank 7 current-level detector checkout was subsequently performed during one of the tank 7 heater cycles in the AUTO mode, and the results were nominal.

The crew reported that on one of the 70mm Hasselblad cameras, the motor drive binds or jams up after approximately three exposures. The crew changed the camera-body batteries, motor-drive batteries, and the film magazine. However, the motor drive still jammed. Manual advance of the film worked nominally. The film magazine was attached to a different 70mm Hasselblad camera assembly and it worked fine. The remaining 70mm Hasselblad was being used and further troubleshooting was performed.

The crew experienced problems when attempting to accomplish the fuel cell monitoring system (FCMS) data take. The crew reported that an error message was received on the Windecom Payload and General Support Computer (PGSC) indicating that the Windecom connection could not be made. The crew rebooted the PGSC and retried the data take with the same results. The crew verified the PGSC was configured correctly and then replaced the FCMS cable with a backup cable. With the backup cable

installed, the FCMS data take was completed successfully. Subsequent to this FCMS data take, a data take was attempted late in the mission. Once again, problems were encountered and the data take was not completed.

The crew reported that the DSR20 video tape recorder (VTR) tapes were not incrementing and an error code "C32" was displayed on the front of the VTR. The crew worked the photo/television (TV) malfunction procedure for this error message. This ejected the micro-tape that was in the VTR. Power cycles of VTR and digital television (DTV) system were performed with no effect. A visual inspection and cleaning of the VTR was performed; however, the VTR would not accept tapes and place the tapes into the correct configuration inside the VTR. Standard-sized tapes were also rejected. Ground testing was able to recreate this problem by failing parts of the tape transport. The workaround was to use a V10 recorder to record the payload video and a Camcorder for playback.

A second 70mm Hasselblad camera experienced a series of motor-drive jams similar to the problems experienced earlier in the flight with the other 70mm Hasselblad camera. Initial troubleshooting was unsuccessful, but the problem was cleared by replacement of the batteries.

The systems management (SM) general-purpose computer (GPC) logged two errors against the instrumentation/pulse-code modulated master unit (IP) data bus at approximately 18:04:10:34 G.m.t. (01:12:31:34 MET). An additional single error was logged at 27:11:14:26 G.m.t. (10:19:35:26 MET). The errors indicated that the SM GPC detected a problem reading data from the operational instrumentation (OI) random access memory (RAM) in the PCMMU. The errors were transient and no indications were visible to the crew. The data are indicative of an error between the PCMMU and an OI multiplexer/demultiplexer (MDM) or the payload data interleaver (PDI). The PCMMU set an invalid flag that was read by the SM GPC, which logged the errors. With the data available, it was impossible to isolate the source of the problem. There were no PCMMU or PDI BITE indications present during either instance of the errors. There was no mission impact.

The payload heat exchanger and total flow rates for the Spacehab water loop steadily decreased throughout the mission. It was noted that the Spacehab water pump outlet pressure was decreasing. Pump 2 was used early in the mission and at approximately 18:13:00 G.m.t. (01:21:21 MET), the switch to pump 1 was made.

The redundancy management (RM) deselected contact A of the forward digital-autopilot (DAP) automatic pushbutton switch. A switch tease, which has been observed in the past on switches of this type, is suspected to have been the cause of the deselection. The anomaly was not immediately seen since it occurred while in a Spacehab-dedicated downlist format. The failed measurement was observed after switching to the normal on-orbit format at 30:12:10 G.m.t. (13:20:31 MET). A review of the data indicated that when the forward DAP auto push button switch was used at 29:20:28 G.m.t. (13:04:49 MET), contact A did not close. This same signature was seen on the subsequent use of this switch at 29:21:32 G.m.t. (13:05:53 MET). Prior to and following these occurrences, the forward digital autopilot (DAP) auto push button switch performed nominally every time it was used. Contact A remained deselected and there was no mission impact.

The flight control system (FCS) checkout was performed satisfactorily using auxiliary power unit (APU) 1 to support the checkout with a start time of 31:10:41:19 G.m.t. (14:19:02:19 MET). The run time was 5 minutes, 27 seconds, and 16 pounds of fuel were used during the APU 1 operation. The total run time was too short to require spray cooling from the water spray boiler (WSB). The FCS, APU, and hydraulics systems performance was nominal.

Following FCS checkout, the reaction control system (RCS) hot-fire was performed nominally. The hot-fire began at 31:11:48 G.m.t. (14:20:09 MET) and ended at 31:11:56 G.m.t. (14:20:17 MET). All thrusters were fired at least once for a duration of at least 240-milliseconds. A review of thruster chamber-pressure data confirmed that all of the thruster firings were satisfactory.

The miniature airborne global positioning system (GPS) receiver (MAGR) failed to download the daily encryption key for the precise positioning service (PPS) mode when powered up prior to FCS checkout. This failure keeps the MAGR in the standard positioning service (SPS) mode. This condition is documented in a MAGR Program Note. No action was required and as expected, the MAGR corrected itself at the start of the next G.m.t. day by successfully downloading the daily encryption key. Even if the MAGR were to not update with the PPS key, its performance would still be acceptable for entry in the SPS mode.

After transition to high-rate data on entry day at 32:07:32 G.m.t. (15:15:53 MET), the MAGR was not tracking any satellites. This condition was observed for approximately 50 minutes, whereupon the condition cleared via an autonomous reset. The condition may be explained by one of two MAGR program notes. If the problem were to repeat, performing a reinitialization of the MAGR would clear the problem; however, the problem did not repeat during the remainder of the flight.

The Ku-band antenna was stowed for entry at 32:01:47 G.m.t. (15:10:08 MET).

The PLBDs were closed at 32:10:50:17 G.m.t. (15:19:11:17 MET) for the first landing opportunity at KSC on the planned landing day. The doors operation was nominal.

Prior to the deorbit maneuver, APU 2 was successfully started at 32:13:10:39 G.m.t. (15:21:31:39 MET). The deorbit maneuver for the first KSC landing opportunity on the planned landing day, a dual engine straight-feed firing, was performed on orbit 255 at 32:13:15:30 G.m.t. (15:21:36:30 MET). The maneuver was 158 seconds in duration with a ΔV of 260 ft/sec. The orbit after the deorbit maneuver was 4.5 by 159.6 nmi. Approximately 13-minutes prior to EI, APUs 1 and 3 were successfully started at 32:13:31:25 G.m.t. (15:21:52:25 MET) and 32:13:31:29 G.m.t. (15:21:52:29 MET), respectively.

PAYLOADS AND EXPERIMENTS

SUMMARY

The STS-107 mission provided more than 70 international scientists access to the microgravity environment of space. The mission was dedicated to a mixed complement of competitively selected and commercially sponsored research in space, life and physical sciences. The crew operated 24 hours a day using 2 shifts, thus providing continuous operations for the 16 days. The majority of the experiments were performed in the SPACEHAB Research Double Module (RDM) in the payload bay. This mission was the first flight of the RDM. The RDM provided a pressurized environment that was accessible to the crew via a tunnel that was connected to the Shuttle mid-deck. The RDM had a payload capacity of 9,000 lb, but carried only 7,500 lb during the STS-107 mission.

The non-propulsive consumables levels remained above the initial planning levels throughout the mission. This condition was in part the result of an over-conservatism of the thermal models, payload-energy use estimates, and operations interruptions resulting from SPACEHAB subsystem and payload anomalies. As a result, prior to entry a nominal end of mission (NEOM) landing weight waiver was required for a 234,000 lb vs. the 233,000 lb limit, and this condition was assessed for entry thermal and cargo interface loads. A positive assessment by ground personnel was provided to the Mission Management Team (MMT) and the waiver was successfully processed.

The primary payload was the SPACEHAB Research Double Module (RDM) consisting of 28 experiment facilities (payloads) in the middeck and RDM supporting over 80 life science, earth science, physical science and commercial investigations from around the world. This included 3 RDM roof-mounted experiments that focused on heat pipe design, as well as University and grade school-sponsored research. The complex secondary payload was the fast reacting experiments enabling science technology applications and research (FREESTAR) that used hitchhiker interface hardware to accommodate six separate experiments that concentrated on atmospheric and solar observation, fluid/vapor physics, and student experiment research. The Department of Defense (DoD) ram burn observation (RAMBO) secondary payload flew as a payload of opportunity, but unfortunately payload ground observations were not completed because the scheduled Orbiter orbital maneuvering subsystem (OMS) were not within the range of observation assets.

In addition to the normal crewmember complement, Columbia hosted a wide range of living organisms including viruses, bacteria, fungi, rodents, and cell cultures. This was the maiden flight for the RDM that included avionics enhancements that provided over 5kW of module power capability, and a new Ku-Band capability that provided experiment-data downlink-transmission rates as great as 48 megabytes. In addition, a new condensate removal system permitted crew exercise in the module until an unrecoverable malfunction of the condensate removal system occurred. Additionally, the high-visibility FREESTAR Mediterranean Israeli dust experiment (MEIDEX) marked a first for NASA in supporting the first Shuttle experiment and payload specialist from Israel.

MISSION SCIENCE SUCCESS

Problems with the Ku-band telemetry, the water pump package, and the condensate collection subsystems of the RDM impacted the mission success. As a result, the ESA facility to conduct biological experiments (BIOPACK), Zeolite Crystal Growth (ZCG), and Combustion Module-2 (CM-2) were slightly degraded, the overall mission-science success, assuming a successful return and early destowing activities, was approximately 92 percent for the SPACEHAB RDM and 95 percent for the FREESTAR payloads. As mentioned earlier the RAMBO payload did not complete any observations. The success of each individual experiment is shown in other documentation [STS-107 Customer Support Room (CSR) Final Report].

RESEARCH DOUBLE MODULE SUBSYSTEM OPERATIONS

Overall, the RDM subsystem performance supported the completion of payload and respective investigation functional objectives (all planned activities were completed). From a SPACEHAB perspective, 21 of 28 of the payload facilities achieved functional objective mission success. Based on crewmember comments throughout the mission, the crew was satisfied with operational and subsystem stowage enhancements that included a centralized location for experiment operations checklists and labeling for experiment connector-panel switches.

SPACEHAB RDM activation was completed behind schedule; however, deactivation activities were completed as planned. Initially, all RDM subsystems and the Ku-band Channel 3 playback systems performed nominally.

As early as flight day 1, it was noted that the actual power usage for the RDM was lower than the preflight predictions by approximately 800 W. This information was coordinated with the flight control team and the under-runs were attributed to the following:

1. Approximately 168 W (21 percent) of the lower power usage was the result of mission-dependent equipment that was double-booked under both the subsystem and experiment categories;
2. Approximately 138 W (17 percent) of the lower power usage was the result of subsystem items which were not active at the times reflected in the predictions timeline;
3. Approximately 68 W (8.5 percent) of the lower power usage was the result of over-predictions for subsystem loads on the main and emergency buses; and
4. The remaining 53.5 percent was the result of experiment power usage being in less than the preflight predictions.

These discrepancies along with subsystem in-flight anomalies impacted the performance of experiment operations; however, workarounds and experiment activity re-planning minimized the impacts to the success of the science experiments.

RDM In-flight Anomalies

Ku-Band Channel 2 Anomaly: The SPACEHAB experiment ground data assembly (EGDA) that was located at the JSC Payload Operations Control Center (POCC) was unable to lock onto Ku-band channel 2 at module activation. Subsequent

troubleshooting indicated an issue with the EGDA Ku-band channel 2 checksum that was originating from the EDS management unit that was onboard the RDM. When an EGDA command was issued to ignore the checksum, experiment data were good. Subsequently, a software patch was developed to override the checksum. However, EGDA crashes occurred as a result of the checksum disabling, which left the EGDA vulnerable to undetected downlink errors. These undetected errors in conjunction with loss of signal-to-acquisition of signal (LOS-AOS) transitions resulted in periodic 2 to 3 minute loss of experiment data. Eight experiments used the Ku-band system and experienced varying degrees of operational impacts; however, real-time replanning of the downlink activities prevented a significant loss of science. Onboard troubleshooting of the EGDA as well as in the POCC resulted in a workaround procedure that reduced the amount of data loss.

RDM Water Loop Anomaly: As a part of the nominal RDM activation, the water pump package (WPP) was switched from system 2 to system 1 approximately two and one-half hours into the flight. At 17:19:58 G.m.t. (01:04:19 MET), RDM water loop degradation was reported following observation of decreased payload heat exchanger water flow. The clogged SPACEHAB subsystem 2 filter was the suspected cause of the observed conditions. In anticipation of the Vapor Compression Distillation (VCD) experiment activation at 19:14:39 G.m.t. (01:23:00 MET), system 2 was deactivated and system 1 was activated at 18:14:39 G.m.t. (01:21:21 MET). Initial telemetry indicated that the system 1 water flow was nominal, however, a short time later flow rate began to show the same symptoms as system 2 but at a degraded flow rate. This slower flow rate allowed the use of system 1 for the remainder of the mission with plans to switch to system 2 in the event of a total failure.

Condensate Collection System Component (Rotary Separator) Anomaly: Initially, the new mass accumulation in the condensate collection system storage tanks was slower than predicted primarily because of the initial condition of the relatively dry module air. The first condensate storage tank (CST) to contingency water container (CWC) transfer occurred at 17:08:47 G.m.t. (00:17:07 and was uneventful. The transfer took less than one minute to complete. However, as the mission progressed the condensate collection rate became less than expected and a request was submitted to delete the first three-planned CWC overboard dumps to save about 1.5 hours of crew time.

At 20:03:19 G.m.t. (03:11:40 MET), during a CST-to-CWC transfer, the crew found an estimated two-thirds of a gallon of water on the internal and external surfaces of the water separator assembly (WSA) noise cover, the aft power distribution unit (APDU), and on the foam pads mounted beneath the aft sub-floor panels. The crew cleaned up the water. Subsequently, rotary separator 1 (RS1) was turned off and RS2 was turned on; and the CST pressure began to increase. The water in the sub-floor was the result of carryover occurring in RS1. It was suspected that RS1 was damaged due to carryover caused by the air bypass valve assembly (ABVA) moving too rapidly. The ABVA was subsequently controlled from the POCC via the experiment computer unit - ground system (ECU-GS) to limit the rate of ABVA movement and make sure more carryover did not recur.

At approximately 20:19:04 G.m.t. (04:03:25 MET), an electrical current spike was observed on all three phases of the SPACEHAB aft inverter. An inspection of the sub-floor revealed that of the APDU circuit breakers (CBs) (CB 8 phase B and C) were

tripped off. Phase A was on. As a precaution, the phase A CB was set to off and both RSs were commanded off. The Orbiter flow-proportioning valves (FPVs) and the SPACEHAB air bypass valve (ABV) were reconfigured to allow the Orbiter to provide more cooling and humidity control and prevent module condensation. It is believed that water did not penetrate the conformal-coated APDU and that RS1 was operable, but required drying and unclogging. Orbiter and module heat loads stabilized and the crew reported that the temperatures were within acceptable limits. An existing, pre-flight approved in-flight maintenance (IFM) procedure was implemented. The procedure adjusted the module water flow control valve (WFCV) and increased the cooling capability for module payloads. The IFM allowed operation of the Vapor Compression Distillation (VCD) experiment that required water cooled to $65\text{ }^{\circ}\text{F} + 5^{\circ}$). Subsequently periodic adjustments of the WFCV and water metering valves provided acceptable control of RDM temperature and humidity levels so that experiment operations continued nominally for the remainder of the mission.

VEHICLE PERFORMANCE

SOLID ROCKET BOOSTERS

Analysis of the Solid Rocket Booster (SRB) systems data indicated nominal performance of all SRB subsystems with no in-flight anomalies identified from the analysis of the data. The prelaunch countdown was normal and no SRB Launch Commit Criteria (LCC) violations occurred. One Operations and Maintenance Requirements and Specifications Document (OMRSD) violation, the left-hand system A isolation-valve closed-indication that was off and should have been on, occurred and a waiver was written to accept this condition for launch. This condition prevented the performance of the frequency-bite test since the interlock requiring the valve-closed indication was not satisfied. This condition had no impact on the conduct of the mission.

All of the 48 seawater activated release (SWAR) links (8 links per parachute) fired and released properly. Both SRBs were recovered and returned to KSC for inspection, disassembly and refurbishment. The inspection revealed that both SRBs were in excellent condition. No anomalous SRB conditions were noted during the postflight operations.

REUSABLE SOLID ROCKET MOTORS

Data analysis of the flight performance of both reusable solid rocket motors (RSRMs) showed all parameters to be within the contract end item (CEI) specification limits, and the performance was typical of that observed on previous flights. The prelaunch countdown was normal, and no RSRM LCC or OMRSD violations were noted nor have any in-flight anomalies been identified in the data.

The maximum in-flight trace shape variation of pressure versus time during the 62- to- 80-second time frame was calculated to be 1.388 percent and 1.582 percent at 71 seconds for the left and right motors, respectively. These values were well within the 3.2-percent allowable limits.

Power application and operation of all field-joint heaters was accomplished routinely. Field-joint heaters operated for 11 hours 54 minutes during the launch countdown. Power was applied to the heating elements an average of 59 percent of the time during the LCC time frame. The left-hand forward field-joint heater was deactivated for 13 minutes in an attempt to fix a controller problem. The heater was reactivated when the minimum sensor temperature dropped to 87 °F.

Power application and operation of all igniter-joint heaters was accomplished routinely with the heaters operating for 18 hours 33 minutes. Power was applied to the heating elements 94 percent (average) of the time to maintain the igniter joints in their normal operating range.

All RSRM temperatures were maintained within acceptable limits throughout the countdown. The heated, ground-supplied, aft skirt purges maintained the case/nozzle joint and flex bearing temperatures within the required LCC ranges. The final flex bearing mean bulk temperature (FBMBT) was determined to be 80 °F.

All ground environmental instrumentation (GEI) and operational flight instrumentation (OFI) performed within established requirements. All available data were recorded, transmitted and analyzed. Reconstructed motor performance parameters adjusted to a 60 °F propellant mean bulk temperature (PMBT) are shown in the following tables. The calculated PMBT at launch was 60 °F.

RSRM PERFORMANCE

Parameter	CEI Specification Limit (60 °F)	Left Motor Actual	Right Motor Actual
Web time, seconds	105.4 - 116.7	110.7	110.0
Action time, seconds	115.2 - 131.2	124.3	124.0
Head end pressure, psia	847.9 - 965.7	900.6	904.2
Maximum sea level thrust, Mlbf	2.88 - 3.26	3.06	3.07
Web time average pressure, psia	629.9 - 700.5	666.4	666.9
Web time average vacuum thrust, Mlbf	2.46 - 2.74	2.61	2.61
Web time total impulse, MLbf sec	285.8 - 291.6	288.8	289.6
Action time impulse, MLbf seconds	293.7 - 299.7	296.7	296.7
ISP average delivered, Lbf sec/Lbm	266.5 - 270.3	269.4	269.5
Loaded propellant weight, Lbm	1103750	1105518	1105206

Note: All times referenced to lift-off time (when chamber pressure reaches 563.5 psia).

RSRM PROPULSION PERFORMANCE

Parameter	Left motor, 72 °F		Right motor, 72 °F	
	Predicted	Actual	Predicted	Actual
Impulse gates				
I-20, 106 lbf-sec	64.39	64.37	64.65	65.65
I-60, 106 lbf-sec	172.85	173.01	173.41	173.20
I-AT, 106 lbf-sec	296.74	296.87	296.66	297.83
Vacuum Isp, lbf-sec/lbm	268.4	269.4	268.4	269.5
Burn rate, in/sec @ 60 °F At 625 psia	0.3683	0.3670	0.3693	0.3677
Event times, seconds ^a				
Ignition interval	0.232	N/A	0.232	N/A
Web time ^b	110.7	110.7	110.3	110.9
50 psia cue time	120.9	121.9	120.4	121.6
Action time ^b	123.1	124.3	122.6	124.0
Separation command	125.3	-	125.3	-
PMBT, °F	60	60	60	60
Maximum ignition rise rate, psia/10 ms	90.8	N/A	90.8	N/A
Decay time, seconds (59.4 psia to 85 K)	3.2	3.4	3.2	3.5
Tailoff Imbalance Impulse Differential	Predicted N/A		Actual 591.2	

Impulse Imbalance = Integral of the absolute value of the left motor thrust minus right motor thrust from web time to action time.

^aAll times are referenced to ignition command time except where noted by a ^b

^b Referenced to liftoff time (ignition interval).

The postflight inspection of the external hardware thermal condition was performed with all thermal protection system (TPS) found to be in very good condition in all areas. The condition of both motors was similar to previous flight history.

EXTERNAL TANK

All External Tank (ET) objectives and requirements were met during the propellant loading and flight operations. No significant oxygen or hydrogen leakage concentrations were detected in the intertank. All ET electrical equipment and instrumentation operated satisfactorily. Purge and heater operations were also nominal. No ET LCC violations occurred.

One OMRSD waiver was written for the ET vent valves and LH₂ vent disconnect cavity purge Helium supply pressure. The waiver raised the maximum supply pressure from 800 psig to 850 psig. The supply pressure had shown a slight increase in trend and exceeded the original maximum of 800 psig as the sun rose and heated the Helium, causing a corresponding increase in pressure.

The pressurization systems functioned properly throughout engine start and flight. The minimum liquid oxygen (LO₂) ullage pressure experienced during the ullage pressure slump was 13.5 psid. No hazardous gas concentrations were noted during the prelaunch operations.

The ice/frost team reported the following conditions existed on the ET. The typical -Y strut crack approximately 12 inches in length with no offset, and no intertank stringer foam cracks were noted. Most regions of the ET showed indications of a minor frost covering.

The one ET in-flight anomaly concerns the loss of thermal protection system (TPS), which is discussed in this and following paragraphs. In-flight video photography revealed that at approximately 81.7 seconds, a piece of TPS, most probably from the left-hand bipod ramp, was shed and struck the left wing of the Orbiter.

All ET subsystems performed satisfactorily with the exception of the anomaly mentioned in the previous paragraph. No propulsion system performance abnormalities were noted in the review of the data. All ET measurements performed successfully during the flight.

ET separation occurred 502.48 seconds after lift-off. The postflight analysis of the impact point showed the ET impacted 47 nmi uprange, which was at 2.283 degrees North and 139.42 degrees West, well within the preflight predicted impact point.

SPACE SHUTTLE MAIN ENGINES

Prelaunch operations of the Space Shuttle main engines (SSMEs) were smooth with no LCC or OMRSD violations noted. All SSME parameters were normal throughout the prelaunch countdown and were typical of previous flights.

The ignition confirm limits and mainstage redline margins were satisfactory. All Interface Control Document (ICD) start and shutdown transient requirements were met. Engine performance during start, throttling, mainstage, shutdown and postflight dump operations were normal. Engine cutoff times were within the nominal limits for SSME 1, 2 and 3,

were 508.84, 508.97 and 509.09 seconds, respectively. Controller and software performance was satisfactory with no SSME in-flight anomalies identified from the review of the data.

The preliminary reconstructed specific impulse (Isp) was 452.9 seconds and the tag value was 452.08 seconds, so the flight-derived Isp was 0.82 second higher than predicted. The Block II engines Isp are typically approximately 0.8 to 1.3 seconds higher than that predicted from ground testing data.

The commanded maximum dynamic pressure (max Q_d) throttle-down was a one-step throttle-down to 72 percent.

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 appropriate times. The system operated as expected throughout the countdown and flight. As planned, the SRB S&A devices were safed and SRB system power was turned off prior to SRB separation.

ORBITER SUBSYSTEMS PERFORMANCE

Main Propulsion Subsystem

The main propulsion subsystem (MPS) performed nominally throughout the mission from the prelaunch loading of the ET to the entry interface (EI) phase of the mission. There were no LCC violations and one OMRSD violation, and there were no in-flight anomalies identified from the analysis of the data. The peak hydrogen concentration during the final loading was 180 ppm, which compares favorably with previous data from this vehicle.

Initial MPS data review revealed a potential dropout of the Space Shuttle main engine (SSME) 3 LH2 prevalve open A indication. Additional data evaluation revealed multiple data dropouts in various Orbiter systems. A data integrity evaluation was performed that determined that all of the observed dropouts are actually data hits. There are no Orbiter anomalies associated with this issue, and the issue was closed as an explained condition.

A postflight review of the data showed two times that the liquid oxygen (LO₂) fixed orifice ullage pressure 0.8-psi requirement was violated. The first time that the condition was noted was during throttle-up coming out of the throttle bucket. During dynamic transients, parameters such as SSME outlet temperatures and ET nose-cap pressures can lag other parameters used in the reconstruction, thus causing the mass-flow calculations to be in error. The second time was noted just prior to MECO. The violation was very small (0.82 psi), but it was not within the limit. As a result of these occurrences, an evaluation is being made to determine if modifications need to be made to the criteria or the time period of the reconstruction model.

The gaseous hydrogen (GH₂) system in-flight performance was nominal. All three of the flow control valves performed nominally, and the cycle count for the valves was one cycle for SSME 1, three cycles for SSME 2, and five cycles for SSME 3. The Helium

system performance for the SSME and pneumatic Helium systems was nominal. All other parameters were nominal. Some of the tanks for the Helium systems for SSME 2 and 3 were located on the left side of the midbody and no anomalous behavior was noted.

The LH2 manifold was vented to vacuum for the duration of the flight prior to opening the return to launch site (RTL) dump valves, so no pressure decay was noted upon opening the valves.

Reaction Control Subsystem

The reaction control subsystem (RCS) performed nominally throughout the mission from prelaunch to the EI phase of the mission. No LCC or OMRSD violations were noted, nor were any in-flight anomalies identified from the review of the data up through EI.

The RCS window protect maneuver with a duration of 2.077 seconds was performed satisfactorily at 16:15:41:07.7 G.m.t. (00:00:02:17.7 MET). This maneuver provided a method of protecting the windows of the Orbiter from SRB separation motor exhaust products. This maneuver results in improved window clarity during the mission and a reduction in the turnaround effort following the mission.

The RCS was also fired for the ET photographic maneuver, for attitude control and for the RCS hot-fire prior to entry. Performance during these activities was nominal.

A total of 4216.5 lbm propellants (2565.3 lbm - oxidizer, 1651.2 lbm - fuel) were used from the RCS during the mission. A total of 1281.3 lbm of orbital maneuvering subsystem (OMS) propellants were also used by the RCS during the mission. The primary RCS thrusters had 2504 firings and a total firing time of approximately 833.9 seconds. The vernier RCS thrusters had 38971 firings and a total firing time of 35,190.6 seconds.

Following FCS checkout, the RCS hot-fire was performed nominally. The hot-fire began at 31:11:48:11.8 G.m.t. (14:20:09:11.8 MET). All thrusters were fired at least once for a minimum duration of at least 240-milliseconds. A review of thruster chamber-pressure data confirmed that all of the thruster firings were satisfactory.

Orbital Maneuvering Subsystem

The OMS performed satisfactorily throughout the mission from prelaunch to EI with no in-flight anomalies identified from the data analysis. There were no LCC violations prior to launch. One new OMRSD waiver (right OMS fuel check valve – CV501 – failed open) was written. This waiver had no impact on the mission.

A total of 15,977 lbm (9959 lbm - oxidizer and 6018 lbm - fuel) of OMS propellants were consumed during the mission. A total of 1281.3 lbm of the OMS propellants were provided to the RCS during interconnect operations.

The following table lists the OMS maneuvers that were performed during the mission.

OMS MANEUVERS

Maneuver	Time, G.m.t./MET	ΔV , ft/sec	Firing time, sec	Orbit, nmi.
OMS Assist (Dual engine)	16:15:41:17 00:00:02:17	N/A	102.2	N/A
OMS-2 (Dual engine)	16:16:20:24 00:00:41:24	185.7	120.7	146.6 by 156.0
Deorbit Maneuver (Dual Engine)	32:13:15:30 15:21:36:30	259.5	158.4	4.5 by 150.6

Power Reactant Storage and Distribution

The power reactant storage and distribution (PRSD) subsystem performed nominally during all phases of the mission. During entry, all PRSD parameters were nominal at EI.

The PRSD subsystem supplied the fuel cells with 4505 lbm of oxygen and 567 lbm of hydrogen for the production of 6440 kWh of electrical energy. In addition, the environmental control and life support system (ECLSS) was supplied 201 lbm of oxygen for life support. A 3-day mission extension was possible at the average power level of 16.8 kW with the reactants remaining at EI.

During the prelaunch period, an O₂ offload was performed to reduce the nominal end-of-mission (EOM) landing weight. Oxygen tanks 1, 2 and 3 were offloaded by approximately 100 lb each and tanks 4 and 5 were offloaded by approximately 25 lb each for a total O₂ offload of approximately 350 lb.

At liftoff, the PRSD subsystem oxygen (O₂) and hydrogen (H₂) tank sets 1 and 2 heater switches were in nominal ascent configuration. The O₂ and H₂ tanks 1 and 2 A heaters were in AUTO. All of the seven other tank set heater switches were configured to OFF. All four manifold isolation valves were open. The extended duration Orbiter (EDO) pallet, installed in the aft part of the payload bay with four tank sets, was deactivated.

On-orbit, during performance of the oxygen (O₂) tank current-level detector checkout, it was noted that the O₂ tank 7 heaters A1 and A2 'on' discretes did not come on with the switch in the ON position (Flight problem STS-107-V-02). This checkout procedure calls for the tank heaters to be turned on manually and then verifying that the current-limiting sensor turns off the heater. Main bus current verified that the O₂ tank 7 A heaters did not come on. Subsequently, the crew was asked to enable the O₂ tank 7 A heaters in the AUTO position to determine if the heaters would operate in that mode. The 'on' discretes were received and a full cycle of the A heaters were observed, thus verifying satisfactory operation in the AUTO mode. There was no mission impact. The O₂ tank 7 current-level detector checkout was subsequently performed during one of the tank 7 heater cycles in the AUTO mode, and the results were nominal.

All of the PRSD system tank pressure cycles that were regulated by internal electrical heater operation were nominal, and were controlled by the heater AUTO function. All of the tank internal fluid and heater assembly temperatures were nominal for the entire on-orbit operation. The EDO pallet was activated throughout the on-orbit operations, and was deactivated during deorbit preparations.

Fuel Cell Powerplant Subsystem

The fuel cell powerplant (FCP) subsystem performed nominally throughout the mission up to EI. There were no OMRSD or LCC violations, nor were any in-flight anomalies found during the analysis of the data. During entry, all FCP parameters were nominal through entry interface.

The average power level and load was 16.8 kW and 559 amperes. The fuel cells produced 6440 kWh of electrical energy and 5072 lbm of potable water while using 4505 lbm of oxygen and 567 lbm of hydrogen.

Ten purges of the fuel cells were performed, all of which achieved nominal results. The fuel cell reactant purge system operated nominally in both the automatic and manual modes.

During vent door opening at approximately T-18 seconds during pre-launch operations, the fuel cell 2 hydrogen (H₂)-motor status jumped approximately 0.1 V from 0.59 to 0.69 V for one data sample. This change did not violate the LCC limit of 1.0 V. The voltage returned to the normal level on the next data sample one second later. Fuel cell operation continued to be nominal. This indication appears to be associated with the suspected ac bus-2 phase B anomaly. The voltage change was also observed during a seat adjustment as well as during the payload bay door opening.

The prelaunch cell performance monitor (CPM) data were documented during the prelaunch operations. A review of the fuel cell monitoring system single cell data did not yield any crossover indications. Many of the cells on half of the sub-stack had gained 1 to 2 mV in performance while the other half had remained the same.

The fuel cell monitoring system (FCMS) was activated and provided full-rate data during on-orbit operations for 12 minutes. None of the fuel cell individual cell voltages indicated any problems and no pin sharing was indicated.

Auxiliary Power Unit Subsystem

The auxiliary power unit (APU) subsystem performed nominally throughout the mission up to EI. The APU subsystem had no off-nominal events or deviations from nominal. No in-flight anomalies were identified during the analysis of the flight data.

The flight control subsystem (FCS) checkout was performed satisfactorily using auxiliary power unit (APU) 1 to support the checkout with a start time of 31:10:41:19 G.m.t. (14:19:02:19 MET). The run time was 5 minutes and 27 seconds, and 16 pounds of fuel were used during the APU 1 operation. The total run time was too short to require spray cooling from the water spray boiler. FCS, APU, and hydraulics performance was nominal.

The following table presents the APU run times and fuel consumption for the mission.

APU RUN TIMES AND FUEL CONSUMPTION

Flight phase	APU 1 (S/N 207)		APU 2 (S/N 203)		APU 3 (S/N 311)	
	Time, min:sec	Fuel Usage, lb	Time, min:sec	Fuel Usage, lb	Time, min:sec	Fuel Usage, lb
Ascent	20:10	47	20:15	51	20:23	56
FCS Checkout	5:27	16				
Entry ^a	27:56	39	48:42	74	27:53	41
Total	53:33	102	68:57	125	48:16	97

^a APU run data for Entry is shown until EI plus 16 minutes.

The thrust vector control (TVC) isolation valves of two of the three hydraulic systems were opened during hydraulic normal pressure to stow the Space Shuttle main engine (SSME). These periods of load on the corresponding APUs are evidenced in the APU turbine-speed and chamber-pressure plots. APU performance was nominal during the stowing of the SSMEs on the STS-107 mission.

Hydraulics/Water Spray Boiler Subsystem

The hydraulics/water spray boiler (HYD/WSB) subsystem performed nominally throughout the mission up to the EI phase of the mission.

The OV-102 vehicle used the water additive, Propylene Glycol Monomethyl Ether (PGME), in all three WSBs. No overcooling or undercooling conditions were noted in the data. Spray cooling was noted at 1 minute 68 seconds, 52 seconds and 1 minute 2 seconds after MECO on systems 1, 2 and 3, respectively.

Hydraulic system 1 was selected for FCS checkout. Hydraulic system 1 operation was nominal. As a result of the short run time of APU 1 (5 minutes 27 seconds), APU 1 lubrication oil spray cooling was not required.

Electrical Power Distribution and Control Subsystem

The electrical power distribution and control (EPDC) subsystem performed nominally except for the sluggish ac 2 bus phase-B current response initially noted post-ascent. During entry, all EPDC subsystem parameters were nominal through EI.

During vent-door opening, PLBD opening and Ku-band antenna deployment, the ac 2 bus phase-B current exhibited a sluggish response (Flight problem STS-107-V-01). The phase-B current increased to about one-half of the expected value, then increased to its nominal value within 0.5 to 1.5 seconds. During this time period, the ac 2 bus phases A and C current increased a similar amount. During steady-state periods, there were periodic occurrences of smaller magnitude signals of the same type (phase B dropping, phases A and C increasing). As before, most of these occurrences lasted between 0.5 and 1.5 seconds, and the phase B drop was between 0.2 and 0.3 ampere (between 3 and 4 telemetry counts). Water-loop pump cycling on the ac 2 bus sometimes triggered the described response. The occurrence of this condition was very sporadic and unpredictable. During a couple of 24-hour periods, no occurrences were noted. The cause of this anomaly was believed to be the ac 2-bus phase-B inverter or the wiring between the ac 2 phase-B inverter and panels L4 and MA73C.

Atmospheric Revitalization Pressure Control Subsystem

The atmospheric revitalization pressure control subsystem (ARPCS) performed normally throughout the mission up to EI. No anomalies were recorded for the ARPCS systems during launch and on-orbit operations.

Prior to launch, the 2-psid check was performed nominally, with the cabin pressure reaching a pressure of 16.8 psid. After launch, visor flow was verified and the oxygen flow was stopped when the visors were opened two minutes after launch.

ARPCS system 1 performed nominally with nitrogen (N₂)/O₂ switchovers taking place at 17:19:32 G.m.t. (01:03:53 MET) and 18:16:48 G.m.t. (02:01:09 MET). ARPCS system 2 also performed nominally with N₂/O₂ switchovers taking place at 25:17:47 G.m.t. (09:02:08 MET) and 27:15:08 G.m.t. (10:23:29 MET).

Atmospheric Revitalization Subsystem

The atmospheric revitalization subsystem (ARS) performed nominally throughout the mission to the EI phase. Hardware checkout was performed in accordance with the OMRSD File IX requirements, which were completed satisfactorily.

The SPACEHAB double module was located in the payload bay and as a result, active water coolant loop (WCL) 2 was left in the manual bypass mode. The water loop flowed between 921 and 1024 lb/hr maintaining the cabin air temperature at a 76 °F average for the duration of the flight. The loop is operated in this mode to obtain maximum heat transfer from the WCL to the Freon coolant loop at the interchanger interface.

The 72 °F indicated cabin air temperature at launch is 1 degree cooler than the predicted preflight temperature of 73 °F provided through the STS-107 ECLSS/Payload Thermal Compatibility Verification Analysis. The launch temperature is 3 °F cooler than the flight rule limit of 75 °F air temperature. The cabin air temperature climbed to 78 °F at 3 hours and 24 minutes after launch where it remained for approximately 25 minutes before dropping back down. The cabin temperature peaked to just slightly above 78 °F for a period of 2.5 hours on flight day 5 and averaged 76 °F for the duration of the flight.

At launch, the cabin ppCO₂ sensor indicated a value of 1.04 mmHg and peaked at 1.5-mmHg ppCO₂ 35 minutes into the flight. During on-orbit operations, the cabin ppCO₂ peak of 6.47 mmHg occurred at 31:22:45 G.m.t. (15:07:06 MET). The ppCO₂ averaged 3.0 mmHg for the mission.

Cabin humidity during the launch phase was 33.2 percent and peaked to 36.8 percent 2 hours and 52 minutes after launch. For the flight duration through EI, the humidity averaged approximately 37.5 percent with a peak to 44.percent occurring at 25:00:50 G.m.t. (08:09:11 MET). The heat exchanger outlet air temperature at launch was 47.8 °F and peaked at 69.3 °F approximately 2 minutes 36 seconds into the flight.

The OMRSD File IX requirements included the checkout of the secondary cabin temperature controller and the checkout of the primary WCL 1 actuator and its response to temperature. The cabin temperature controller was switched from the primary controller to the secondary controller and the checkout of the primary WCL 1 actuator was also completed satisfactorily.

The data through EI for the vehicle crew compartment parameters showed a cabin air temperature of 72.0 °F, a cabin humidity of 37.2 percent and a ppCO₂ of 1.89 mmhg. The heat exchanger air outlet temperature was at 60.05 °F.

Active Thermal Control Subsystem

The active thermal control subsystem (ATCS) performed nominally throughout the mission up to EI. No pre-evaporative cooling was observed in the flash evaporator system (FES) during the ascent phase and the FES duct temperatures were nominal. At 16:16:15:55 G.m.t. (00:00:15:16 MET), the FES controller was switched from primary A general purpose computer (GPC) to primary A command. The radiator flow was initiated at 16:16:17:23 G.m.t. (00:00:01:44 MET).

The Freon coolant loop (FCL) 1 flow proportioning valve (FPV) was placed in payload position at 16:17:59 G.m.t. (00:01:20 MET) and then returned to interchanger position approximately 4 days later at 20:21:08 G.m.t. 04:05:29 MET). The FCL 2 FPV was placed in payload position 16:21:04 G.m.t. (00:05:25 MET) and then returned to interchanger position prior to the deorbit maneuver.

There were five FES water dumps during the mission.

After the payload bay doors were closed, the ATCS used the FES as the primary heat sink. Because the primary B controller was active, the FES was using water out of the feedline B system and the feedline A system was stagnant. Both FCLs had the radiators in bypass mode and the flow proportioning valves were in interchanger flow position. All radiator temperature parameters remained nominal throughout the period. The crew configured the FES controller from primary B command to primary B GPC in accordance with nominal entry procedures. This temporarily allowed the FES outlet temperature sensors to register a brief increase in Freon temperatures because the controller resets itself after such a configuration change. The resulting temperature profile was nominal. All FCL flow rate sensors showed normal rates; all pressure sensors and accumulator quantity readings showed nominal values through EI.

Supply and Waste Water Subsystem

The supply and waste water and subsystems performed nominally throughout the mission up to EI and all of the scheduled in-flight checkout requirements were satisfied.

Supply water was managed through the use of the FES and the overboard nozzle dump system. Six supply water nozzle dumps were performed at a nominal dump rate of 1.76 percent per minute (2.9 lb/min). The line heater maintained the supply water dump line temperature between 75 °F and 108 °F throughout the mission. A total of 900.8 lb of supply water was dumped during the mission.

Seven wastewater nozzle dumps were performed at an average rate of 2.0-percent per minute (3.3 lb/min). The wastewater dump line temperature was maintained between 59 °F and 78 °F throughout the mission. A total of 593.2 lb of waste water was dumped during the mission.

At 18:00:12:41 G.m.t. (01:08:33:41 MET), the supply water tank “D” quantity sensor exhibited a quantity dropout at a tank quantity of 24 percent. The tank quantity dropped

to 1 percent for one second and recovered. At 19:09:50:18 G.m.t. (02:18:11:18 MET), the supply water tank C quantity sensor showed a quantity dropout at a tank quantity of 32 percent. The tank dropped 26 percent for one second and recovered. At 22:17:47:04 G.m.t. (06:02:08:04 MET), the supply water tank "B" quantity sensor exhibited a quantity dropout at a tank quantity of 53 percent. The tank quantity dropped to a negative 1 percent for one second and recovered. Such dropouts have been experienced in previous flights and the problem was caused by either contamination on the collector bar and/or a surface defect on the collector bar of the potentiometer resulting in an intermittent break in continuity. These dropouts are understood problems.

Waste Collection Subsystem

The waste collection subsystem performed satisfactorily throughout the mission.

Airlock Subsystem

The airlock subsystem performed nominally during all phases of the mission. No in-flight anomalies were identified in the data analysis.

Smoke Detection and Fire Suppression Subsystem

The smoke and fire suppression subsystem performed nominally during all phases of the mission and showed no indications of smoke generation during the duration of the flight through EI. Use of fire suppression system was not required.

Flight Data Subsystem

The flight data subsystem performed satisfactorily throughout the mission up to EI. . No in-flight anomalies were identified in the data review and analysis.

No unexpected GPC errors occurred during prelaunch or ascent operations. The mass memory unit (MMU) hardware was used successfully during the OPS 1 transition at T-20 minutes on launch day as the program was obtained from MMU 1 area 1 on the tape. Prior to launch, the Kennedy Space Center (KSC) performed a dump and compare of the entire software of GPC 1 with no miscompares identified. The multiplexer/demultiplexer (MDM) hardware performance was satisfactory as exhibited in the data review conducted after the contingency.

The DPS on-orbit and entry operations were nominal.

Flight Control Subsystem

The flight control subsystem (FCS) performed satisfactorily through the EI phase of the mission. No in-flight anomalies were identified in the data.

At all times, the Solid Rocket Booster (SRB) thrust vector controllers (TVC), MPS TVC, and aerosurface actuators were positioned exactly as the GPC commands were given with normal driver currents, secondary differential pressures, and elevon primary differential pressures. The reaction jet driver (RJD) operation was also normal with no thruster-fail indications or other anomalies noted. The rotational hand controller (RHC)

and translation hand controller (THC) were both used and exhibited normal channel tracking.

At no time during the ascent of STS-107 did the flight controls fail to accomplish the task of implementing GPC commands. Actuator positions closely tracked GPC commands, and at no time did secondary differential pressures used in the fault detection mechanism approach the limits that would initiate a failure response.

The FCS checkout was performed satisfactorily using APU 1 to support the checkout with a start time of 31:10:41:19 G.m.t. (14:19:02:19 MET). FCS performance was nominal.

The star tracker was powered off during ascent and entry; consequently, no data are available for those periods. The performance of the star trackers was satisfactory during the on-orbit operations. Review of the star tracker subsystem data from the on-orbit period indicated no anomalous or off-nominal performance.

The inertial measurement unit (IMU) pre-launch, ascent and on-orbit operations were nominal through EI. The IMUs measured and reflected the Orbiter changes in attitude and velocity due to the nominal ascent activities. Review of the IMU prelaunch and ascent data did not show any anomalous conditions. The overall performance of the three IMUs through EI was nominal. The IMUs measured and reflected the Orbiter changes in attitude and velocity due to the normal activities. The deorbit firing and energy reduction maneuvers were accurately tracked by all three IMUs.

Flight Software

STS-107 was the fifth flight of the OI-29 software. The flight software performed satisfactorily throughout the mission with no in-flight anomalies identified during the data review and analysis.

Displays and Controls Subsystem

Review of the displays and controls (D&C) subsystem pre-launch, ascent and on-orbit through EI indicated nominal system performance with no anomalous conditions observed.

The redundancy management (RM) deselected contact A of the forward digital-autopilot (DAP) automatic pushbutton switch. A switch tease, which has been observed in the past on switches of this type, is suspected to have been the cause of the deselection. The anomaly was not immediately seen since it occurred while in a SPACEHAB-dedicated downlist format. The failed measurement was observed after switching to the normal on-orbit format at 30:12:10 G.m.t. (13:20:31 MET). A review of the data indicated that when the forward DAP auto push button switch was used at 29:20:28 G.m.t. (13:04:49 MET), contact A did not close. This same signature was seen on the subsequent use of this switch at 29:21:32 G.m.t. (13:05:53 MET). Prior to and following these occurrences, the forward digital autopilot (DAP) auto push button switch performed nominally every time it was used. Contact A remained deselected and there was no mission impact.

Multifunction Electronic Display Subsystem

The overall performance of the MEDS was nominal throughout the mission up to the EI phase of the mission with no in-flight anomalies identified during the analysis of the data.

There were no significant deviations from the nominal/expected operation of the MEDS subsystem during the prelaunch/ascent period; all downlisted Edge Key inputs reflect those that would be expected during normal operations.

Communications and Tracking Subsystem

The communications and tracking subsystem performed nominally in support of the mission and no in-flight anomalies were noted in the data. All communications and tracking subsystem OMRSD File IX requirements were fulfilled.

All S-Band subsystems and processors including S-Band phase-modulated (PM) system 2 and S-Band frequency modulated (FM) system 1 performed nominally during the prelaunch, ascent and on-orbit phases of STS-107.

The payload signal processor (PSP) was configured and tested satisfactory during prelaunch and then powered off per procedures prior to launch. S-Band PM system string 1 and 2 and the S-Band FM system were powered on and a checkout of these systems was completed prior to-launch. The S-Band PM system string 2 provided nominal S-Band Orbiter telemetry and air-to-ground (A/G) voice communication coverage. There were no off-nominal telemetry indications from any S-Band subsystems or processors.

The PSP was powered on, configured for SpaceHab support, and operated nominally until powered off at SpaceHab de-activation prior to the deorbit maneuver. During on-orbit operations, the S-Band FM system was occasionally powered on for operations recorder dumps via ground stations and powered off again when not in use. The S-Band PM systems string 2 provided nominal S-Band Orbiter telemetry and A/G voice communication coverage in the Tracking and Data Relay Satellite (TDRS) mode during the majority of the on-orbit phase. There were no off-nominal telemetry indications from either of the S-Band PM subsystems in any operational mode, and S-Band communication coverage was nominal throughout the on-orbit phase.

The overall performance of the Ku-Band subsystem was nominal with no in-flight anomalies found during data analysis. The Ku-Band deployed assembly was stowed for ascent. The Ku-Band assembly was deployed at 16:17:54 G.m.t. (00:02:15 MET) in the expected dual motor time of 23 seconds. All telemetry measurements indicated the Ku-Band deployed assembly transitioned from the stowed to the deployed position. The Ku-Band system was activated at 16:17:58 G.m.t. (00:02:19 MET), passed the self-test, and functioned properly throughout the mission until it was nominally stowed and powered off at 32:01:47 G.m.t. (15:10:08 MET).

During SPACEHAB activation, the crew reported that transmissions from the Orbiter on the intercommunications (ICOM) B loop were not being heard in the SPACEHAB module. Communications on the ICOM A loop were satisfactory. This loss of redundancy did not affect the continuing mission operations. Later in the flight, the crew was asked to troubleshoot the problem by reconfiguring the ICOM system to ICOM B

and performing a communications check. The crew reported that ICOM B worked satisfactorily, and that the earlier problem was probably caused by a configuration error.

Operational Instrumentation/Modular Auxiliary Data System

The operational instrumentation (OI) subsystem and modular auxiliary data system (MADS) performed satisfactorily throughout the mission. No in-flight anomalies were identified during the review and analysis of the data.

The OEX recorder was recovered and the data were successfully retrieved indicating that the hardware performed nominally. These data were extremely helpful to the investigation as data were recorded until the breakup of the vehicle.

Structures and Mechanical Subsystems

The mechanical subsystem performed nominally through the EI phase of the mission. All mechanisms operated in nominal dual-motor time with all limit switches transferring properly.

The overall performance of the mechanical systems was nominal and no in-flight anomalies were noted. The port radiator was deployed and stowed twice, and all involved mechanisms operated in nominal dual-motor time with all limit switches transferring properly.

During the vent-door opening, payload bay door (PLBD) opening and Ku-band antenna deployment, an intermittent signature occurred on ac bus 2, phase-B where the current was slow to increase at motor startup. This anomaly is discussed in Electrical Power Distribution and Control subsystem section of this report.

Motor control assembly (MCA) operational status (Op Stat) indications show that the appropriate MCA relays were operating to supply ac power to the motors. During deorbit preparations, all mechanisms operated in nominal dual-motor time with all limit switches and op stats transferring properly.

During payload bay door (PLBD) closure, after the starboard door closure had been stopped for the nominal alignment check, a 0.7-second period of additional current draw occurred on ac bus 1. The amplitude and signature of the trace appear to correspond to starboard door drive motor 1. However, a scenario could not be determined that would explain why one door drive motor would run without the bulkhead latches running as well. Because the sample rate for limit switch and op stat data is only 1 Hz, it is impossible to determine whether any changes occurred in these indications within the 0.7-second time period.

During vent door closure, a 0.1-second period of additional current draw was noted on ac bus 1 phases A and C. It is possible that a momentary limit switch failure could have caused a motor to drive for this short period. Because the ac current sample rate is 0.1 Hz and the op stat and limit switch data sample rate is only 1 Hz, this could have occurred without showing up in the phase B, op stat, or limit-switch data.

Landing and Deceleration Subsystem

This subsystem was not used during this mission.

Navigational Aids Subsystem

All navigational aids subsystem (NAVAIDS) operations were nominal through the EI phase of the mission.

All three tactical air navigation (TACAN) systems remained locked on to KSC during the ascent and broke lock when the station was out of range. The NAVAIIDS were powered off after the transition to operational sequence (OPS) 2.

The NAVAIIDS are normally powered off during the on-orbit phase until the transition to OPS 8 for the FCS checkout approximately 24 hours prior to the predicted landing. All of the NAVAIIDS successfully passed the self-test during the FCS checkout. The NAVAIIDS were then powered off after the transition to OPS 2. No deviations or significant events were observed in the NAVAIIDS performance.

All NAVAIIDS subsystems were powered on at 32:09:30:05 G.m.t., and were functioning nominally at EI. The TACAN systems had locked on to various channel 111X ground stations during the pass over the United States just prior to the de-orbit maneuver and that was nominal operation.

Air Data Transducer Assembly

The ADTA probes were not deployed so no data were received on that subsystem operation through EI.

Purge, Vent, and Drain Subsystem

The purge, vent and drain (PV&D) subsystem and hazardous gas detection subsystem (HGDS) performed nominally through EI.

The purge temperatures and flow rates were set to predetermined levels and stayed within nominal tolerances. Orbiter circuit 2 was supplied with a higher-than-normal flow rate (225 lb/min) because of the extended duration Orbiter (EDO) pallet requirement agreed to in the payload integration plan. The higher flow rate was within Orbiter purge system certification. During the T minus 9-minute hold, the flow-rate of circuit 2 was reduced to 170 lb/min to alleviate the need for a post-flight inspection of the Orbiter T-0 purge-circuit quick-disconnect flappers. The inspection is required if separation occurs at a flow rate at or above 180 lb/min.

Thermal Control Subsystem

The thermal control subsystem performed nominally throughout the mission up to entry interface. No LCC violations were noted. The thermal control subsystem responses were nominal and compared favorably with those of previous missions. No in-flight anomalies were identified in the evaluation of the data through the EI phase of the mission.

As a result of a problem detected on the STS-109 mission, modifications were made to the OMS crossfeed line heater. These modifications reduced the heater interaction between the aft compartment heater zones and the doghouse heater zones.

The on-orbit performance of the passive thermal control subsystem was nominal and compared favorably with that of previous missions. The on-orbit temperature responses for the bottom bondline and main landing gear were nominal. Numerous attitude adjustments were made for the nominal end-of-mission thermal conditioning for water production and radiator protection concerns. This attitude change had no adverse effect on the vehicle thermal performance.

Thermal Protection Subsystem

At approximately 81.7 seconds MET, a large light-colored piece of debris was seen to originate from an area near the ET/Orbiter forward attach bipod. The debris appeared to move outboard and then fall aft along the left side of the Orbiter fuselage, striking near the leading edge of the left wing. An assessment of this event performed during the mission concluded that there was not a safety of flight issue. However, the Columbia accident investigation has concluded that this event was the most probable cause of the loss of Columbia and the crew. Analysis, test and flight data support the theory that the foam debris from the ET damaged the left wing reinforced carbon carbon (RCC) providing a pathway for hot gas to enter the left wing leading edge during entry. This ultimately resulted in significant damage to the left wing and subsequent loss of vehicle control leading to vehicle aerodynamic breakup.

Gas Sample Analysis

The six bottles that provide data for the gas sample analysis were lost during the Columbia tragedy. Consequently, the gas sample analysis data were unavailable.

GOVERNMENT FURNISHED EQUIPMENT/FLIGHT CREW EQUIPMENT

The Government Furnished Equipment/Flight Crew Equipment (GFE/CFE) performed nominally throughout the mission. Some minor problems surfaced and these are discussed along with other GFE/CFE that operated properly in the following paragraphs.

The crew reported that on one of the 70mm Hasselblad cameras (S/N 1036), the motor drive binds or jams up after approximately 3 shots. The crew swapped the camera-body batteries, motor-drive batteries, and the film magazine. However, the motor drive still jammed. Manual advance of the film worked nominally. The film magazine was attached to a different 70 mm Hasselblad camera assembly and it worked fine. Further troubleshooting was performed and the camera initially worked for 20 shots and then began jamming on every shot. The remaining 70 mm Hasselblad camera was used. The crew subsequently reported that the second 70 mm Hasselblad camera experienced a series of motor drive jams similar to S/N 1036 earlier in the flight. Troubleshooting failed to clear the jam. Batteries in the motor drive were replaced a second time and the problem cleared.

The crew experienced problems when attempting to accomplish the fuel cell monitoring system (FCMS) data take. The crew reported that an error message was received on the Windecom PGSC. The message was: Windecom connection could not be made. The crew rebooted the PGSC and retried the data take with the same results. The crew verified the PGSC was configured correctly and then replaced the FCMS cable with a backup cable. With the backup cable installed, the FCMS data take was completed successfully. Subsequent to the first FCMS data take, a second data take was attempted late in the mission. Once again, problems were encountered and the data take was not completed.

The crew reported that the DSR20 VTR tapes were not incrementing and an error code "C32" was displayed on the front of the VTR. The crew worked the Photo TV malfunction for the error message. This ejected the micro tape that was in the VTR. Power cycles of the VTR and DTV system were performed with no effect. Visual inspection and cleaning of the VTR was performed, but the VTR would not accept tapes and place them into the correct configuration inside the VTR. Standard-sized tapes were also rejected. Ground testing was able to recreate this problem by failing parts of the tape transport. The on-orbit workaround was to use a V10 recorder to record the payload video and a Camcorder for playback.

POST LAUNCH PAD INSPECTION

The postlaunch inspection of the main launch platform –1 (MLP-1), Pad A fixed service structure, rotating service structure, north flame trench, and Pad A apron was completed by 3.5 hours after launch. No flight hardware was found.

The Orbiter lift-off lateral acceleration data that is used to predict stud hang-ups was evaluated and no solid rocket booster (SRB) holddown stud hang-up had occurred. An inspection was performed and the south holddown studs were visually assessed as having no indication of hang-up. Erosion was typical for both the north and south posts. The north holddown post blast covers and T-0 umbilical exhibited minimal exhaust plume damage.

Both SRB aft skirt GN₂ purge lines were intact and erect; however the protective tape layering was partially eroded.

The LO₂ and LH₂ Tail Service Masts appeared undamaged with both bonnets closed properly. The MLP deck was generally in good shape. Two broken bolts were found on the center raised-deck ramp and one screw was missing from the joint plate. This screw was found on the north flame trench. The GH₂ vent line latched on the eighth tooth on the latching mechanism. The ground umbilical carrier plate 7-inch quick disconnect was accessible for inspection and appeared to be undamaged with the sealing surface in good shape. The deceleration cable was also in the nominal configuration, and the vent line blanket was sooted.

The Orbiter access arm (OAA) appeared to be intact with no evidence of plume impingement. All slide-wire baskets were secured with no evidence of damage. The GO₂ vent arm, ducts and structure appeared to be in nominal condition.

Overall damage to the pad appeared to be nominal.

TABLE 1. - STS-107 SEQUENCE OF EVENTS

EVENT	DESCRIPTION	ACTUAL
APU Activation	APU-1 GG chamber pressure APU-2 GG chamber pressure APU-3 GG chamber pressure	016:15:34:13.661 016:15:34:16.235 016:15:34:18.705
*SRB HPU Activation	LH HPU System A start command RH HPU System A start command	016:15:38:32.48 016:15:38:32.76
*Main Propulsion System Start	ME-3 Start command accepted ME-2 Start command accepted ME-1 Start command accepted	016:15:38:53.440 016:15:38:53.564 016:15:38:53.686
*SRB Ignition Command (Liftoff)	SRB Ignition command	016:15:38:59.994
*Throttle to 104.5 Percent	ME-1 Command accepted ME-3 Command accepted ME-2 Command accepted	016:15:39:04.386 016:15:39:04.400 016:15:39:04.404
*Throttle to 72 Percent	ME-1 Command accepted ME-3 Command accepted ME-2 Command accepted	016:15:39:35.586 016:15:39:35.601 016:15:39:35.604
*Throttle to 104.5 Percent	ME-1 Command accepted ME-3 Command accepted ME-2 Command accepted	016:15:39:49.826 016:15:39:49.841 016:15:39:49.844
Maximum Dynamic Pressure	Derived ascent dynamic performance	016:15:40:01
*Both RSRMs Chamber Pressure at 50 psi	LH RSRM chamber pressure RH RSRM chamber pressure	016:15:41:01.514 016:15:51:01.514
*End RSRM Action Time	LH RSRM chamber pressure RH RSRM chamber pressure	016:15:41:05 016:15:41:05
*SRB Physical Separation	LH APU B turbine speed – LOS	016:15:41:06.554
SRB Separation Command	SRB separation command flag	016:15:41:07
OMS Assist Maneuver ignition	Left engine bi-prop valve position Right engine bi-prop valve position	016:15:41:17 016:15:41:17
OMS Assist Maneuver Cutoff	Left engine bi-prop valve position Right engine bi-prop valve position	016:15:43:59 016:15:43:59
*Throttle Down for 3g Acceleration	ME-1 Command accepted ME-3 Command accepted ME-2 Command accepted	016:15:46:23.588 016:15:46:23.609 016:15:46:23.610
3g Acceleration	Total load factor	016:15:47:05.8
*Throttle Down to 67 Percent for Cutoff	ME-1 Command accepted ME-3 Command accepted ME-2 Command accepted	016:15:47:16.069 016:15:47:16.090 016:15:47:16.091
*SSME Shutdown	ME-1 Command accepted ME-3 Command accepted ME-2 Command accepted	016:15:47:22.509 016:15:47:22.530 016:15:47:22.531
MECO	MECO Command Flag MECO Confirmed Flag	016:15:47:23 016:15:47:24
ET Separation	ET separation command flag	016:15:47:44
APU Deactivation	APU-2 GG chamber pressure APU-1 GG chamber pressure APU-3 GG chamber pressure	016:15:54:20.360 016:15:54:28.387 016:15:54:40.360
OMS 1 Ignition	Left engine bi-prop valve position Right engine bi-prop valve position	Not Performed – direct insertion trajectory flown

* Data supplied by Marshall Space Flight Center

** Data not available

TABLE 1. - STS-107 SEQUENCE OF EVENTS

EVENT	DESCRIPTION	ACTUAL
OMS 1 Cutoff	Left Engine bi-prop valve position Right engine bi-prop valve position	N/A
OMS 2 Ignition	Left Engine bi-prop valve position Right engine bi-prop valve position	016:16:20:23.8 016:16:20:23.8
OMS 2 Cutoff	Left Engine bi-prop valve position Right engine bi-prop valve position	016:16:22:24.8 016:16:22:24.8
Flight Control Subsystem Checkout APU 1 Start APU 1 Stop	APU-1 GG chamber pressure APU-1 GG chamber pressure	031:10:41:18.740 031:10:46:43.794
Start RCS Hot-Fire	As reported by the MER	031:11:48:11.8
Payload Bay Doors Closed	Left payload bay door closed Right payload bay door closed	032:10:49:11 032:10:50:17
APU Activation	APU-2 GG chamber pressure APU-1 GG chamber pressure APU-3 GG chamber pressure	032:13:10:39 032:13:31:25 032:13:31:29
Deorbit Burn Ignition	Left Engine bi-prop valve position Right engine bi-prop valve position	032:13:15:30 032:13:15:30
Deorbit Burn Cutoff	Right Engine bi-prop valve position Left engine bi-prop valve position	032:13:18:08 032:13:18:08
Entry Interface	Current orbital altitude above ellipsoid	032:13:44:09

TABLE II- STS-107 SPACE SHUTTLE VEHICLE ENGINEERING OFFICE IN-FLIGHT ANOMALY LIST

No.	Title	Reference	Comments
STS-107-V-01	AC 2 Phase B Sluggish Current Signature	016 15:38 G.m.t. IPR 118-V-0002 SPR 107RF01	<p>During the prelaunch/post-insertion time period, AC2 phase B exhibited sluggish current increase during motor operations on three motors. The first occurrence of the sluggish performance was noted at T-31 seconds, and the second and third occurrences were noted during the post-insertion activities. AC2 phases A and C would increase to their expected values, but phase B would increase only to about half the expected value, then recover to the expected value within about a second. The affected motors were: vent doors 8 and 9, Ku-band deployment motor 2, and port payload bay door-open motor 2. There was no impact to motor drive times. There is no common circuit breaker/motor control assembly for these motors. All other motor signatures analyzed were nominal, some of which were powered from the same circuit breaker/motor control assembly for these motors. All other motor signatures analyzed were nominal, some of which were powered from the same circuit breaker/motor control assemblies as the affected motors.</p> <p>Continued data review throughout the mission uncovered several occurrences of miniature signatures of the same type (phase B dropping, phases A and C increasing). Most of these occurrences were less than one-second in duration and the phase B drop was between 0.2 and 0.3 amperes. They were sometimes triggered by water loop pump cycles; although several occurrences from prelaunch and on-orbit were also observed even when no loads were being cycled. These was also evidence of the signature in data analyzed by KSC from STS-107 flow processing.</p> <p>From the data pulled during the mission, the problem appeared to be in the AC2 phase B inverter or the wiring between the AC2 phase B inverter and panels L4 and MA 73C</p>
STS-107-V-02	Oxygen Tank 7 Heater A Failed Off in Manual Mode	017:13:25 G.m.t. 000:21:46 MET IPR 118-V0001 SPR 107RF02	<p>During performance of the O₂ tank current-level detector checkout, it was noted that the O₂ tank 7 heater A1 and A2 "on" discretes did not come on. The heater switch "on" indication was present. The checkout procedure calls for the tank heaters to be turned on manually and then verify that the current-limiting sensor trips out the heaters. Main bus current verified that verified that the O₂ tank 7A heaters did not come on. Subsequently, the crew was asked to enable the O₂ tank 7A heaters in the automatic mode to determine if the heaters would operate in that mode. The heater switch automatic mode "on" indication was present and this time the heater A1 and A2 "on" indication was present and this time the heater A1 and A2 "on" discretes were received. A full cycle of the A heaters was observed, thus verifying satisfactory operation in the automatic mode. There was no mission impact. The O₂ tank 7 current-level sensor detector checkout was performed during one of the tank 7 heater cycles in the automatic mode.</p>

TABLE II- STS-107 SPACE SHUTTLE VEHICLE ENGINEERING OFFICE IN-FLIGHT ANOMALY LIST

No.	Title	Reference	Comments
STS-107-V-03	Loss of Vehicle During Entry	032:13:59 G.m.t. 015:22:20 MET	Accident investigation is on going. A report will be published by the Columbia Accident Investigation Board.

DOCUMENT SOURCES

In an attempt to define the official as well as the unofficial sources of data for the STS-107 Space Shuttle Program Mission Report, the following list is provided.

1. Flight Requirements Document
2. Public Affairs Press Kit
3. Customer Support Room (CSR) Daily Reports and Final CSR Report
4. MER Daily Reports
5. MER Mission Summary Report
6. SSVEO In-Flight Anomaly List
7. MER Funny/Problem Tracking List
8. MER Event Times
9. Subsystem Manager Reports/Inputs
10. MOD Systems Anomaly List
11. MSFC Flash and Executive Summary Reports
12. MSFC Event Times
13. MSFC Interim Report
14. Crew Debriefing comments
15. Shuttle Operational Data Book
16. STS-107 Summary of Significant Events
17. Contractor Reports of Subsystem Operation

**TABLE II- STS-107 SPACE SHUTTLE VEHICLE ENGINEERING OFFICE IN-
FLIGHT ANOMALY LIST
ACRONYMS AND ABBREVIATIONS**

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

ABVA	air bypass valve assembly
ac	alternating current
ADTA	air data transducer assembly
AOS	acquisition of signal
APDU	aft power distribution unit
APU	auxiliary power unit
ARPCS	atmospheric revitalization pressure control system
ARS	atmospheric revitalization system
ATCS	active thermal control system
BIOPACK	biological experiments facility
CB	circuit breaker
CEI	contract end item
CM-2	combustion module-2
CSR	Customer Support Room
CVX-2	Critical Velocity of Xenon-2
CWC	contingency water container
CST	condensate storage tank
DAP	digital autopilot
DoD	Department of Defense
DSO	Detailed Supplementary Objective
DTO	Developmental Test Objective
DTV	digital television
ΔV	differential velocity
ECLSS	environmental control and life support system
ECU-GS	experiment computer unit-ground systems
EDO	Extended Duration Orbiter
e.d.t.	Eastern daylight time
EGDA	experiment ground data assembly
EI	entry interface
EOM	end of mission
EPDC	electrical power distribution and control
ET	External Tank
ET/Orb	External Tank/Orbiter
FBMBT	flexible bearing mean bulk temperature
FCL	Freon coolant loop
FCMS	fuel cell-monitoring system
FCP	fuel cell powerplant
FCS	flight control system/subsystem
FES	flash evaporator system
FM	frequency modulation
FREESTAR	Fast Reaction Experiments Enabling Science, Technology, Applications and Research
FPV	flow proportioning valve
ft/sec	feet per second
GEI	ground environmental instrumentation
GFE	Government furnished equipment

**TABLE II- STS-107 SPACE SHUTTLE VEHICLE ENGINEERING OFFICE IN-
FLIGHT ANOMALY LIST**

GH ₂	gaseous hydrogen
G.m.t.	Greenwich mean time
GPC	general purpose computer
GPS	Global Positioning System
GSE	Ground Support Equipment
H ₂	hydrogen
HGDS	hazardous gas detection system
HYD	hydraulics
ICD	Interface Control Document
ICOM	intercommunications
IFM	in-flight maintenance
IMU	inertial measurement unit
IP	instrumentation/pulse code modulated
I _{sp}	specific impulse
JSC	Johnson Space Center
KSC	Kennedy Space Center
kW	kilowatt
kWh	kilowatt/hour
lb	pound
lbm	pound mass
lb/min	pound per minute
LCC	Launch Commit Criteria
LH ₂	liquid hydrogen
LMSO	Lockheed Martin Space Operations
LO ₂	liquid oxygen
LOS	loss of signal
LPT	low power transceiver
LWT	lightweight tank
MAGR	Miniature Air-to-Ground Receiver
Max q α	maximum dynamic pressure
MCA	motor control assembly
MC	midcourse correction (rendezvous maneuver)
MCC	Mission Control Center
MDM	multiplexer/demultiplexer
MECO	main engine cutoff
MEDS	multifunction electronics display systems
MEIDEX	Mediterranean Israeli Dust Experiment
MET	mission elapsed time
MLP	Mobile Launch Platform
Mlbf	million pounds force
mmHg	millimeter mercury
MMT	Mission Management Team
MMU	mass memory unit
MPS	main propulsion system
N ₂	nitrogen
NASA	National Aeronautics and Space Administration
NAVAIDS	navigational aids system
NEOM	nominal end of mission
nmi	nautical mile
O ₂	oxygen
OAA	Orbiter Access Arm

**TABLE II- STS-107 SPACE SHUTTLE VEHICLE ENGINEERING OFFICE IN-
FLIGHT ANOMALY LIST**

OEX	Orbiter Experiments
OI	operational instrumentation
OMRSD	Operations and Maintenance Requirements and Specifications Document
OMS	orbital maneuvering subsystem
OPSTAT	operational status
OV	Orbiter Vehicle
PCMMU	pulse code modulation master unit
PCS	pressure control system
PCU	power control unit
PDI	payload data interleaver
PGME	Propylene Glycol Monomethyl Ether
PGSC	payload and general support computer
PLBD	payload bay door
PM	phase modulated
PMBT	propellant mean bulk temperature
POCC	Payload Operations Control Center
ppCO ₂	partial pressure carbon dioxide
ppm	parts per million
PPS	precise positioning system
PRSD	power reactant storage and distribution/Prototype Synchrotron Radiation Detector
PSP	payload signal processor
psia	pound per square inch absolute
psid	pound per square inch differential
psig	pound per square inch gravity
PVD	purge, vent and drain subsystem
RAM	random access memory
RAMBO	Ram Burn Observation
RCC	reinforced carbon carbon
RCS	reaction control subsystem
RDM	Research Double Module
RHC	rotational hand controller
RJD	reaction jet driver
RM	redundancy management
RS	rotary separator
RSRM	Reusable Solid Rocket Motor
S&A	safe and arm
SEM	Space Experiment Module
SHRDM	SPACEHAB Research Double Module
SM	system management
S/N	serial number
SOLCON-3	Solar Constant Experiment-3
SOLSE-2	Shuttle Ozone Limb Sounding Experiment
SPS	standard positioning system
SRB	Solid Rocket Booster
SRSS	Shuttle range safety system
SSME	Space Shuttle main engine
STS	Space Transportation System
SWAR	Sea water activated release
T	time of launch
TACAN	Tactical Air Navigation System
TDRS	Tracking and Data Relay Satellite

**TABLE II- STS-107 SPACE SHUTTLE VEHICLE ENGINEERING OFFICE IN-
FLIGHT ANOMALY LIST**

THC	translation hand controller
TPS	thermal protection system/subsystem
TSM	tail service mast
TV	television
TVC	thrust vector control
V	Volts
VCD	Vapor Compression Distillation
VTR	video tape recorder
W	watts
WCL	water coolant loop
WFCU	water flow control valve
WPP	water pump package
WSA	water separation assembly
WSB	water spray boiler
ZCG	Zeolite Crystal Growth