

# **STS-105 SPACE SHUTTLE MISSION REPORT**

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October 2001



**National Aeronautics and  
Space Administration**

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

### NOTE

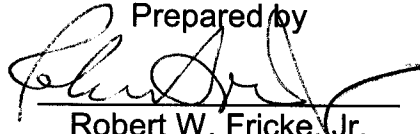
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STS-105  
SPACE SHUTTLE

MISSION REPORT

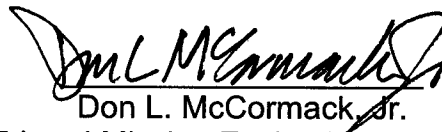
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## STS-105 Table of Contents

<u>Title</u>	<u>Page</u>
<u>INTRODUCTION</u> .....	1
<u>MISSION SUMMARY</u> .....	3
<u>PAYLOADS AND EXPERIMENTS</u> .....	9
<u>SUMMARY</u> .....	9
<u>VEHICLE PERFORMANCE</u> .....	11
<u>LAUNCH DELAY</u> .....	11
<u>SOLID ROCKET BOOSTERS</u> .....	11
<u>REUSABLE SOLID ROCKET MOTORS</u> .....	11
<u>EXTERNAL TANK</u> .....	12
<u>SPACE SHUTTLE MAIN ENGINES</u> .....	13
<u>SHUTTLE RANGE SAFETY SYSTEM</u> .....	14
<u>ORBITER SUBSYSTEMS PERFORMANCE</u> .....	14
<u>Main Propulsion Subsystem</u> .....	14
<u>Reaction Control Subsystem</u> .....	15
<u>Orbital Maneuvering Subsystem</u> .....	16
<u>Power Reactant Storage and Distribution Subsystem</u> .....	17
<u>Fuel Cell Powerplant Subsystem</u> .....	18
<u>Auxiliary Power Unit Subsystem</u> .....	18
<u>Hydraulics/Water Spray Boiler Subsystem</u> .....	19
<u>Electrical Power Distribution and Control Subsystem</u> .....	19
<u>Orbiter Docking System</u> .....	20
<u>Atmospheric Revitalization Pressure Control</u> <u>Subsystem</u> .....	20
<u>Atmospheric Revitalization Subsystem</u> .....	21
<u>Active Thermal Control Subsystem</u> .....	22
<u>Supply and Waste Water Subsystem</u> .....	23
<u>Waste Collection Subsystem</u> .....	23
<u>Smoke Detection and Fire Suppression Subsystem</u> ..	23
<u>Flight Data Subsystem</u> .....	23
<u>Flight Software</u> .....	24
<u>Flight Control Subsystem</u> .....	24
<u>Displays and Controls Subsystem</u> .....	25
<u>Communications and Tracking Subsystem</u> .....	25
<u>Operational Instrumentation/Modular</u> <u>Auxiliary Data System</u> .....	26
<u>Structures and Mechanical Subsystems</u> .....	27
<u>Integrated Aerodynamics, Heating and Thermal</u> <u>Interfaces</u> .....	27
<u>Thermal Control Subsystem</u> .....	28
<u>Aerothermodynamics</u> .....	28
<u>Thermal Protection Subsystem and Windows</u> .....	28
<u>Gas Sample Analysis</u> .....	30

STS-105 Table of Contents

<u>Title</u>	<u>Page</u>
<u>EXTRAVEHICULAR ACTIVITY</u> .....	31
<u>REMOTE MANIPULATOR SYSTEM</u> .....	32
<u>GOVERNMENT FURNISHED EQUIPMENT/FLIGHT CREW</u> <u>EQUIPMENT</u> .....	33
<u>POSTLAUNCH PAD INSPECTION</u> .....	34
<u>DEVELOPMENT TEST OBJECTIVES/DETAILED SUPPLEMENTARY</u> <u>OBJECTIVES</u> .....	35
DEVELOPMENT TEST OBJECTIVES .....	35
DETAILED SUPPLEMENTARY OBJECTIVES .....	35
HITCHHIKER EXPERIMENTS ADVANCING TECHNOLOGY .....	35
<u>PHOTOGRAPHY AND TELEVISION ANALYSIS</u> .....	37

List of Tables and Appendixes

TABLE I - STS-105 SEQUENCE OF EVENTS .....	38
TABLE II - SPACE SHUTTLE VEHICLE ENGINEERING OFFICE IN-FLIGHT ANOMALY LIST .....	41
A - <u>DOCUMENT SOURCES</u> .....	A-1
B - <u>ACRONYMS AND ABBREVIATIONS</u> .....	B-1

## INTRODUCTION

The Space Transportation System (STS) -105 Space Shuttle Program Mission Report presents a discussion of the Orbiter subsystem operation and the in-flight anomalies that were identified during the mission. The STS-105 report summarizes the activities of the mission, 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 sixth mission of the Space Shuttle Program. The STS-105 flight was the eleventh flight to the International Space Station (ISS). STS-105 was the eighty-first mission since the return to flight, and the thirtieth flight of the OV-103 (Discovery) vehicle.

The flight vehicle consisted of the OV (Orbiter vehicle) -103 Orbiter; an ET, which was the thirteenth Super Lightweight Tank (SLWT), and it was designated ET-110; three Block IIA SSMEs that were designated as S/Ns 2052, 2044, and 2045 in positions 1, 2, and 3, respectively; and two SRBs that were designated B1109. The two RSRMs were designated RSRM-81 with one installed in each SRB. The individual RSRM serial numbers were 360W081A for the left SRB and 360W081B for the right SRB.

The primary objective of the STS-105 mission was delivery and integration the 7A.1 launch package (LP) into the orbiting ISS Stage 7A, plus ISS crew rotation of the three crewmembers. The LP consisted of a Multi-Purpose Logistics Module (MPLM) with five Resupply Return Stowage Racks (RSRs), four Resupply Stowage Platforms (RSPs), and two EXPRESS Racks; an Integrated Cargo Carrier (ICC); two Assembly Power Converter Units (APCUs) and assorted middeck payloads/stowage items in the Orbiter crew compartment. The middeck payloads consisted of an Human Research Facility H-Reflex experiment, three powered middeck locker equivalents (MLEs) containing EXPRESS equipment: Advanced Protein Crystallization Facility (APCF), Biotechnology Refrigerator (BTR), and Dynamically Controlled Protein Crystal Growth – Vapor (DCPCG – V), and an unpowered Biotechnology Cell Science Stowage-4 (BCSS-4). The MPLM was removed from the Orbiter payload bay and attached to the nadir port of Node 1 and activated via the APCU power through the Orbiter Docking System (ODS). There were two scheduled extravehicular activities (EVAs) planned for the flight.

The secondary objectives of this flight were to perform Get-Away Special (G-780) payload operations, the requirements for the Program Support Package, and the requirements for the Hitchhiker Experiments Advancing Technology (HEAT) experiments.

The STS-105 flight was planned as an 11 day, plus 2-contingency-day flight, of which six days were planned to be docked to the ISS. The two contingency days were available for weather avoidance for landing or other Orbiter contingency operations. The sequence of mission events is shown in Table I, and the Orbiter In-Flight Anomaly List is shown in Table II.

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 10 crewmembers that were on the STS-105 mission consisted of the four Shuttle crewmembers, three Expedition 2 crewmembers and three Expedition 3 crewmembers. The four-person crew of the STS-105 Shuttle flight consisted of Scott J. Horowitz, PhD., Col., U. S. Air Force, Commander; Frederick W. Sturckow, Major, U. S. Marine Corps, Pilot; Patrick G. Forrester, Lt. Col., U. S. Army, Mission Specialist 1; and Daniel T. Barry, Ph. D., M.D.,

Civilian, Mission Specialist 2. The Expedition 2 crew, returning from over five months on the ISS, consisted of Yury V. Usachev, Civilian Cosmonaut, Expedition 2 Commander and pilot for the Soyuz; James S. Voss, Col. (Retired), U. S. Army, Flight Engineer for the Soyuz; and Susan J. Helms, Col., U. S. Air Force, Flight Engineer. The Expedition 3 crew, who were taking up residence in the ISS, consisted of Frank L. Culbertson, Jr., Capt. (Retired), U. S. Navy, Expedition 3 Commander; Mikhail Tyurin, Civilian Cosmonaut, Flight Engineer; and Vladimir N. Dezhurov, Cosmonaut; Lt. Col., Russian Air Force, Senior Pilot.

STS-105 was the fourth space flight for the Shuttle Commander, the third space flight for Mission Specialist 2, the second space flight for the Pilot, and the first space flight for Mission Specialist 1. The Expedition 2 Commander completed the fourth space flight of which two were long-duration flights to the Russian Mir Space Station. During this flight, the Commander completed over 500 days in space. The Expedition 2 flight engineer Voss completed his sixth space flight, and flight engineer Helms completed her fifth space flight. The Expedition 3 Commander completed three space flights in a Space Shuttle, Flight engineer Mikhail Tyurin completed his first flight in the Space Shuttle and Vladimir N. Dezhurov also completed his first Space Shuttle flight; however, he also commanded a 115-day mission to the Russian Mir Space Station.

## MISSION SUMMARY

The STS-105/International Space Station (ISS) –7A.1 mission was the eleventh Space Shuttle mission to the ISS, and the mission consisted of a seven-member crew of which three crewmembers were the Expedition 3 crew exchanging positions with the Expedition 2 crew, who were being returned to Earth as their ISS mission was completed. After a successful rendezvous and docking, the Leonardo Multi-Purpose Logistics Module (MPLM) was unberthed and installed on a Node 1 docking port. During the six docked days, the Expedition 3 crew handover and two extravehicular activities (EVAs) were performed, and all transfers between the Orbiter middeck, MPLM and ISS were completed. In addition, two reboost maneuvers were also performed, thus increasing the ISS altitude from 212 to 219 nautical mile (nmi.) (3.6 n.mi. total orbital altitude increase). All of the preplanned objectives of this logistics mission were successfully completed with the return of the MPLM to the Orbiter cargo bay. Following the successful completion of all major mission objectives, the Orbiter was undocked and a successful entry and landing were performed.

The launch of the STS-105 mission was scrubbed during the T-9 minute hold on August 9, 2001, because of unacceptable weather (lightning and rain) in the launch area. The launch was rescheduled for August 10, 2001.

During the stable-replenish period of External Tank (ET) loading at 222:20:13 G.m.t., the liquid oxygen (LO<sub>2</sub>) 100-percent sensor 1 failed wet and the control logic was switched to sensor 2. Loss of this sensor had no affect on either the prelaunch loading and drain or ascent operations. The 100-percent sensor is used only for loading control and has no criticality during ascent. Failure of the second 100-percent sensor would have necessitated the use of the 100-percent liquid-level sensor for control. This failure is similar to failures seen in the past that were attributed to a failed ET sensor. Post-flight, KSC performed a checkout of the Orbiter point-sensor electrical system and no anomalies were noted.

Approximately three seconds prior to launch, all four primary avionics software system (PASS) general-purpose computers (GPCs) annunciated two input/output (I/O) errors against the launch data bus. No crew or flight-controller actions were required, and there was no mission impact. Analysis shows that the flight software responded in accordance with requirements and as soon as the third I/O error was received, the GPCs were switched from launch data bus (LDB) 1 to LDB 2. Both LDB front-end processors (FEPs) saw all three errors. KSC performed troubleshooting on the launch processing system (LPS) lines and no anomalies were found. Troubleshooting was also performed on the connectors/wiring at the T-0 umbilical and the mobile launch platform (MLP). A terminal distributor was wet from condensation where the LDB 1 and 2 twin coaxial cables mate inside the MLP. Corrective action was taken to raise the temperature inside the unused compartment where the conduit runs. Additional testing of the LDB is being conducted to verify that there are no dropouts.

The launch of the STS-105 mission was completed after a flawless final countdown. The time of launch was 222:21:10:14.019 G.m.t. (5:10:14 p.m. e.d.t. on August 10, 2001). Systems performance during ascent was nominal and no problems or in-flight anomalies were identified from a review of the data. A determination of vehicle performance was made using vehicle acceleration and preflight propulsion prediction data. The average flight-derived engine specific impulse was 453.0 seconds as compared to a Space Shuttle main engine (SSME) tag value of 451.9 seconds at the 104.5-percent power level.

The orbital maneuvering subsystem (OMS) 2 maneuver was performed at 222:21:48:47.837 G.m.t. (00:00:38:33.837 MET) and was 63.4 seconds in duration. The



differential velocity ( $\Delta V$ ) was 96.1 ft/sec, and the orbit was 85.2 by 126.1 nautical miles (nmi.) following the maneuver. The OMS performed satisfactorily throughout the maneuver.

The payload bay doors were opened at 222:22:53:19 G.m.t. (00:01:43:05 MET). All voltages were nominal, and the motors opened the doors in nominal dual-motor time.

When the Ku-band system was placed in the communications mode at 222:23:16 G.m.t. (00:02:06 MET), the radio frequency (RF) power output varied between 18 and 23 watts for about 5 minutes after which it stabilized at a nominal value of 23 watts. Ku-band power output remained stable at 23 watts for about 19 minutes at which time the system stopped radiating at the Tracking and Data Relay Satellite (TDRS) handover. Approximately 21 minutes later at 222:23:56 G.m.t. (00:02:46 MET), the RF power output was about 14 watts and remained at that level until TDRS West was acquired at 223:01:08 G.m.t. (00:03:58 MET), at which time the indicated power level was 23 watts. It remained at that indicated power level for the remainder of the mission.

The White Sands Ground Terminal verified that while the Ku-band RF power output varied, the quality of the downlinked Ku-band signal was nominal. Therefore, it is believed that this condition is an indication problem only. A similar signature was observed on an earlier mission and analysis showed that the cause was a circuit in the deployed assembly that processed the measured data for the downlink telemetry. Also, data review indicates that similar performance was observed on the previous flight of this vehicle (STS-102) and it also occurred shortly after Ku-band activation. The condition lasted for approximately five hours before nominal power levels were observed. This condition did not impact the vehicle performance during this mission.

On flight day (FD) 1, when the payload data interleaver (PDI) was reconfigured from low to high data-rate for the hitchhiker experiments advancing technology (HEAT) experiments, decommutator 2 locked up as expected on the HEAT high data-rate but decommutator 4 still had bit synchronization. The source was zeroed to clear the bit synchronization, but the decommutator still retained bit and accuracy synchronization. When the command was sent again, the correct decommutator-4 configuration was obtained. Analysis indicates that it is anomalous performance because zeroing the source did not clear the decommutator-4 bit synchronization. This anomaly occurred in a system configuration where two decommutators (2 and 4) were tied to the same data source. Decommutator 2 had high data-rate format (DFL) and decommutator 4 was in low DFL. The HEAT data stream was switched from low data-rate to high data-rate and both decommutators indicated bit synchronization. This is a known condition when one source feeds two decommutators. There was no impact to the HEAT data from this anomaly.

The OMS 3 (NC1) maneuver was performed with both engines at 223:00:56:16 G.m.t. (00:03:46:02 MET) and was 55.2 seconds in duration. The  $\Delta V$  delivered was 84.6 ft/sec, and the resulting orbit was 109.9 by 146.1 nmi. following the maneuver.

Following the FD 2 Orbiter space vision system (OSVS) checkout, the crew reported that several numeric digits were missing on the OSVS camera-aiming steering display. The same data downlinked to the Mission Control Center (MCC) was nominal. The problem was traced to the file associated with the graphics display, and was caused by the use of default-parameter values instead of the flight-specific values. The problem was limited to the digital data on the steering displays as the graphics and systems display data were nominal. The crew was instructed to use the graphics cues and systems display data for the FD 4 multi-purpose logistics module (MPLM) installation and its performance was nominal.

At 223:23:02:33 G.m.t. (01:01:52:19 MET), a single I/O error was annunciated against cathode ray tube (CRT) 2. The CRT major function was in GNC and GPC 1 annunciated the error. The error was logged for only one poll [the GPC polls the display electronics unit (DEU) twice every second]. The CRT 2 display was nominal, the DEU 2 built-in test equipment (BITE) status words were nominal, and there were no keystrokes entered at the time of the anomaly. During the mission, it was believed that the most probable cause for the error was a DEU/multiplex input adapter (MIA) transient anomaly. The CRT continued to function nominally for the remainder of the mission. At the crew debriefing, the crew stated that while the filter was being cleaned, a connector was bumped at the back of DEU 2 coincident with the I/O error. KSC performed a wire wiggle with connector P247 and an I/O error was annunciated. The display/keyboard (DK) bus cables connecting the DEU to the GPC were wiggled and by moving the DK bus, the anomaly was recreated. Troubleshooting is progressing to isolate the cause to a specific component in the circuit.

The trajectory control sensor (TCS) operated nominally with the following exception during the rendezvous tools checkout. During TCS checkout, several internal power supply under-voltage messages were annunciated to the crew. Telemetry from the TCS appeared nominal. Review of the data indicates that the actual power supply voltage, although closer than normal to the lower limit, was above the limit. It has been determined that the under-voltage annunciations were caused by the control firmware performing the limit checking with the incorrect lower-limit value. The incorrect limit value results from a round-off error in the software.

The OMS 4 (NC3) maneuver was performed with the right engine at 223:23:23:07 G.m.t. (01:02:12:53 MET) and was 13.2 seconds in duration. The  $\Delta V$  delivered was 10.2 ft/sec, and the orbit was 110.0 by 151.0 nmi. following the maneuver.

The following table shows the RCS maneuvers that were performed to complete the rendezvous with the ISS.

#### RCS RENDEZVOUS MANEUVERS

Maneuver	Time, G.m.t./MET	$\Delta V$ , ft/sec	Firing time, sec	Orbit, nmi.
NCC (Multi-axis RCS)	224:15:18:51 01:18:08:37	0.9	60.0	203.2 by 210.7
MC-1 (RCS)	224:16:36:33 01:19:26:19	1.2	5.0	205.7 by 216.1
Out of Plane Null (RCS)	224:16:38:30 01:19:28:16		10	
MC-2 (RCS)	224:17:13:27 01:20:03:13	2.2	10.0	206.0 by 216.0
MC-3 (RCS)	224:17:30:27 01:20:20:13	0.6	2.0	205.8 by 216.3
MC-4 (RCS)	224:17:40:27 01:20:30:13	0.7	4.0	206.1 by 216.6

The ODS captured the ISS at 224:18:41:41 G.m.t. (01:21:31:27 MET) and ring alignment was obtained in 15 seconds. Ring retraction was performed in four stages (retraction, retraction, extension, retraction). The first ring retraction started 2 minutes 13 seconds after capture and was halted after 22 seconds as the ring went out of alignment and exceeded the linear advance difference allowance. Data show that high-energy damper 1 was apparently

mechanically stuck and that was the cause of the misalignment. This phenomenon has been observed on previous flights. The crew waited 3 minutes and 20 seconds for the ring to re-align itself. Although the ring did not realign, the retraction sequence was re-initiated. However, the alignment was halted after 27 seconds when the misalignment persisted. To force the ring into alignment, a full ring-extension was performed. The third ring-retraction attempt from the fully extended position was successful and was automatically stopped after 4 minutes and 44 seconds. The hooks were then closed at 224:19:03:54 G.m.t. (01:21:53:40 MET).

The Remote Manipulator System (RMS) successfully grappled the MPLM at 225:12:52 G.m.t. (02:15:41:46 MET), unberthed it from the payload bay and moved it to the pre-installation-position at 225:14:51:30 G.m.t. (02:17:41:16 MET). The MPLM was installed to the Node at 225:15:45:51 G.m.t. (02:18:35:37 MET). The RMS was ungrappled from the MPLM and was cradled and latched at 225:16:30 G.m.t (02:19:19:46 MET).

At approximately 224:00:00 G.m.t. (01:02:49:46 MET), the Miniature Air-to-Ground Receiver-Shuttle (MAGR/S) hardware channel 5 began experiencing difficulty completing Y-code/L1 frequency satellite acquisitions. This caused the channel to mode to coarse-mode tracking only. The data signature was consistent with an anomaly discovered during Avionics Development Laboratory (ADL) testing. In ADL tests, the problem was successfully cleared with a MAGR-mode transition. The MAGR-mode transition was performed at 226:19:07:16 G.m.t. (03:21:57:02 MET), and this successfully cleared the anomaly. The exact cause of the anomaly has not been identified but appears to be related to poor satellite signal conditions (i.e., ISS blockage) at GPS end-of-week rollover. The MAGR continued to perform nominally following the second end-of-week rollover of the mission.

Camera D had a dark smudge on the lens that changed in size as the zoom was changed as well as rotating with the focus changes. The condition did not impact operations.

Attitude control was transferred from the ISS to the Orbiter at 226:17:08:57 G.m.t. (03:19:58:43 MET). The first reboost maneuver (primary/vernier thrusters) was started at 226:17:58:26 G.m.t. (03:20:48:12 MET) when thrusters L3A and R3A were fired. The reboost maneuver lasted one hour. The primary thruster pulse widths were 160 ms, and the firing period was 11.6 seconds from start of one pulse firing until the next firing. Approximately ten breaks for attitude maintenance using the vernier thrusters limited the maneuver to 258 primary-thruster pulses. The aft down-firing vernier thrusters had an average duty cycle of 8.08 seconds on and 3.52 seconds off and the resultant  $\Delta V$  was 6.0 ft/sec. The maneuver resulted in an overall average altitude increase of 1.7 nmi., and a final orbit of 218 by 208 nmi.

An evaluation of the data downlinked from operations recorder 1 indicated that unexpected 2-second dropouts occurred at the 6 and 23 percent tape segments on track 3. The data were dumped in both the forward and reverse directions at 120 in/sec and also at 15 in/sec with the same results. New data were recorded on these segments but there were still 2-second dropouts on these two segments. Subsequent to these findings, on flight day 8, data from track 4 (at 68- and 81-percent) and track 12 (at 6-percent) also experienced 2-second dropouts during recorder dumps. The most likely cause of the dropouts is bad segments on the tape. The recorder will be removed and sent to the vendor for repair.

After a 75-minute pre-breathe period, the first extravehicular activity (EVA) began on schedule at 228:13:57 G.m.t. (05:16:47 MET). Extravehicular mobility unit (EMU) performance during the EVA was excellent and no anomalies were noted. The EVA lasted 6 hours and

17 minutes. The early ammonia servicer (EAS) and two Materials International Space Station experiments (MISSEs) were installed on the ISS.

Attitude control was relinquished from the ISS to the Orbiter at 229:11:28:33 G.m.t. (06:14:18:19 MET). The second reboost maneuver (primary/vernier) was started at 229:12:12:27 G.m.t (06:15:02:13 MET) when L3A and R3A were fired. The reboost maneuver lasted one hour. The primary thruster pulse widths were 160 ms, and the firing period was 11.6 seconds from start of one pulse firing until the next firing. Approximately twelve breaks for attitude maintenance, using the vernier thrusters, limited the number of pulses to 253 pulses. The aft down-firing vernier thrusters had an average duty cycle of 8.08 seconds on and 3.52 seconds off and the resultant  $\Delta V$  was 6.4 ft/sec. The reboost resulted in an overall average altitude increase of 1.8 nmi. and a final orbit of 218.8 by 209.5 nmi.

After a nominal EVA preparation, EMU purge, and pre-breathe period, the second EVA began at 230:13:32 G.m.t. (07:16:32 MET). EMU performance during the EVA was excellent and no anomalies were noted. The EVA lasted 5 hours and 32 minutes. All planned EVA tasks were completed satisfactorily.

On several occasions, PDI decommutators 1 and 3 experienced momentary major frame (MF) dropouts. The flight controllers reported that PDI decommutator 1 had MF dropouts 15 different times from 224:23:45 G.m.t (02:02:35 MET) to 225:10:20 G.m.t. (02:13:10 MET). The source was the HEAT experiment format 27 and the payload customer indicated that a possibility existed that the HEAT experiment experienced the dropouts. Also, it was reported that PDI decommutator 3 had 3 MF dropouts between 224:16:24 G.m.t. (01:19:14 MET) and 225:20:34 G.m.t. (02:23:24 MET). For the first dropout, the source was sequential still video (SSV), and for the second and third dropouts, the source was the Orbiter Interface Unit (OIU). There was no indication of a problem with the OIU data source associated with the OIU MF dropouts. No additional MF dropouts occurred over the remainder of the mission.

Un-berthing of the MPLM from the ISS and returning it to the Orbiter payload bay was successfully completed. The RMS was used to support the MPLM un-berthing operations. The RMS operation was nominal throughout the MPLM operations.

Successful undocking from the ISS was completed at 232:14:51:00 G.m.t. (09:17:38:48 MET). In support of undocking, the Orbiter assumed attitude control of the mated stack at 232:14:19 G.m.t. (09:17:08 MET). Initial ISS separation was initiated with a +Z-axis pulse of primary RCS thrusters L4U, R4U, and F3U at 232:15:51:51 G.m.t. (09:18:41:37 MET). The ISS flyaround was performed nominally. Final separation from the ISS was accomplished with a 23.6-second +X-axis pulse of primary RCS thrusters L3A and R3A at 232:16:11:30 G.m.t. (09:19:01:16 MET). The  $\Delta V$  delivered was 5.7 ft/sec and the resulting orbit was 219 by 212 nmi.

A 13.4-second orbit-adjust maneuver was performed on the left OMS engine at 232:20:40:13 G.m.t. (09:23:29:59 MET). The  $\Delta V$  delivered was 10.7 ft/sec and the resulting orbit was 199.7 by 218.9 nmi.

At 232:16:43 G.m.t. (09:19:32:46 MET) during the stowing of the RMS manipulator positioning mechanisms (MPMs), the motors drove dual motor time; however, motor 2 had phase A missing. When the MPM was deployed, all three phases were present. During the mission, it was believed that the most probable cause of the phase-A failure was contaminated AC2 mid-motor controller-assembly (MMCA) 2 circuit-breaker contacts. All of the motors powered by the AC2 MMCA 2 bus will operate on two phases. Since no operational capabilities were lost,

the affected circuit breaker was not cycle during the flight in an attempt to clean the contacts. Postflight troubleshooting isolated this problem to the circuit breaker.

The FCS checkout was performed using auxiliary power unit (APU) 1 to support the checkout with a start time of 233:11:21:07 G.m.t. (10:14:10:53 MET). The run time was 4 minutes, 30 seconds, and 16 pounds of fuel were used during the APU 1 operation. APU 1 performance was nominal. The total run time was too short to require the water spray boiler (WSB) to provide spray cooling.

During FCS checkout, at approximately 233:11:41 G.m.t. (10:14:30 MET), when the crew took the nose wheel steering (NWS) switch from NWS 1 to NWS 2, they reported that it felt like it went into the proper position, but the voltage indicated zero. The switch was pushed a little harder while lifting up on the switch as the switch was pushed, and the switch went into the NWS 2 position. After cycling the switch a couple of times, it felt normal. Telemetry confirmed that no NWS servo currents were seen with the first selection of NWS 2. The crew cycled the switch five times and the servo currents were nominal during the cycles. Other than this one event, the NWS 1 and NWS 2 checkouts were nominal.

At approximately 233:18:03 G.m.t. (10:20:53 MET), the left OMS low-point oxidizer drain line temperature dropped below the expected heater turn-on temperature of 63 °F (Flight Problem STS-105-V-01). When the temperature dropped to 41 °F, the crew switched the crossfeed line heaters from system B to system A at 233:19:43 G.m.t. (10:22:33 MET). Nominal heater operation was observed after the heater reconfiguration.

The payload bay doors were closed and latched for the first KSC landing opportunity at 234:13:01:00 G.m.t. (11:15:50:46 MET). The port payload bay door drive-motor 2, starboard-aft-bulkhead-latch motor 2, and centerline latch 13-16 motor 2 are powered by AC2 MMCA2. As anticipated due to the anomaly noted during MPM stow, AC2 phase A current was missing from these motors. All payload bay door close and latch operations occurred in dual motor time.

The deorbit maneuver for the first KSC landing opportunity was waived because of a rain shower near the end of runway. The deorbit maneuver for the second KSC landing opportunity, a two-engine straight-feed firing, was performed on orbit 186 at 234:17:15:22.939 G.m.t. (11:20:05:08.920 MET). The maneuver was 194.5 seconds in duration with a  $\Delta V$  of 330.6 ft/sec.

Entry interface occurred at 234:17:51:15 G.m.t. (11:20:41:01 MET), and entry was completed satisfactorily. Main landing gear touchdown occurred on KSC concrete runway 15 at 234:18:22:59 G.m.t. (11:21:12:45 MET) on August 22, 2001. The drag chute was deployed at 234:18:23:01 G.m.t. The nose gear touchdown occurred at 234:18:23:10 G.m.t. The drag chute was jettisoned at 234:18:23:43 G.m.t. Wheels stop occurred at 234:18:24:05 G.m.t. The rollout was normal in all respects. The flight duration was 11 days 21 hours 12 minutes 45 second. The APUs were shut down 16 minutes 46 seconds after landing.

## PAYLOADS AND EXPERIMENTS

### SUMMARY

The STS-105/International Space Station (ISS) –7A.1 mission was the eleventh Space Shuttle mission to the ISS, and the mission consisted of a seven-member crew of which three crewmembers were the Expedition 3 crew exchanging positions with the Expedition 2 crew, who were being returned to Earth as their ISS mission was completed. After a successful rendezvous and docking, the Leonardo Multi-Purpose Logistics Module (MPLM) was unberthed and installed on a Node 1 docking port. During the six docked days, the Expedition 3 crew handover and two extravehicular activities (EVAs) were performed, and all transfers between the Orbiter middeck, MPLM and ISS were completed. In addition, two reboost maneuvers were also performed, thus increasing the ISS altitude from 212 to 219 n.mi. All of the preplanned objectives of this logistics mission were successfully completed with the return of the MPLM to the Orbiter cargo bay. Following the successful completion of all major mission objectives, the Orbiter was undocked and a successful entry and landing was completed.

All 7A.1 flight mission objectives for the ISS payloads were accomplished. The crews were exchanged early in the mission, and handover operations were conducted throughout docked operations. Seven new payloads were transferred from the Orbiter to the ISS to support the Increment 3 activities, and six payloads as well as numerous amounts of data were transferred back from the ISS to the Orbiter for return and scientific evaluation. Among the payloads transferred to the ISS was the first commercial payload, DREAMTiME, a high-definition camcorder that captured a number of activities on both the Orbiter and ISS. Also among the payloads transferred were the first external payloads, and two Materials International Space Station experiments (MISSEs) transferred and deployed during the first EVA. The Early Ammonia Servicer (EAS) was also transferred during the first EVA. During the second EVA, launch-to-activation cables for the S0 truss element were transferred and installed as a get-ahead task for the 8A mission. Both EVAs were successfully completed.

The Shuttle and MPLM-payload transfer items both to and from the ISS were completed. The powered payloads located within the Shuttle middeck operated as expected with no issues or anomalies noted. These payloads included the following:

1. Advanced Protein Crystallization Facility (APCF);
2. Dynamic Protein Crystal Growth – Vapor (DCPCG-V); and
3. Biotechnology refrigerator (BTR).

The following payloads were transferred from the ISS to the Orbiter middeck.

1. Commercial Protein Crystal Growth – High Density (CPCG-H); and
2. Protein Crystal Growth-Enhanced Gaseous Nitrogen (PCG-EGN) dewar.

In addition to the primary tasks planned for the mission, several tasks were added as well as several get-ahead tasks for following missions were added. All of these tasks were successfully completed. A total of 10 bags of water were delivered to the ISS containing 990 lb of water. All cargo transfers were also successfully completed with a total of 9657 lb of cargo being transferred from the MPLM, the Integrated Cargo Carrier (ICC) and the Orbiter middeck. A total of 3802 lb of cargo from the ISS was returned. Much of the returning cargo included food containers and clothing that will be recycled or refurbished for future flights. A summary of the cargo transfer is shown in the following table.

<b>Parameter</b>	<b>Weight, lb</b>	<b>From ISS</b>	<b>Weight, lb</b>
To ISS	9657 – total	From ISS	3802
From MPLM	6314	To Orbiter	2564
From ICC	1549	To ICC	0
From Middeck	1794	To Middeck	1238
Water to ISS	990	-	-
Total to ISS with water	10637	Total to/from with water	13459

The PCG-EGN is returning to the Earth after a two-month stay on the ISS.

The Expedition 3 crew performed both sessions of the Human Life Sciences (HLS) Hoffman-Reflex (H-Reflex) experiment scheduled for the Expedition 3 crew. The second session of this experiment was performed a day later than planned; however, that delay is not expected to impact the science results obtained. The Expedition 3 crew, by virtue of the crew taking their daily potassium citrate/placebo tablets, supported the HLS Renal Stone experiment.

The DREAMTiME payload camcorder was used by the crew to capture a number of desired activities both on the Orbiter and the ISS. These activities included the Orbiter approach to the ISS, the crew hatch opening, the MPLM and Node 1 hatch closure, the MPLM unberthing and a general educational tour of the ISS. It is believed that six tapes, totaling over 2 hours of video scenes, were recorded and returned on the Orbiter.

The MISSEs experiment payload Passive Experiment Carriers (PECs) were installed and deployed on the Joint Airlock during an EVA. PEC 1 is located on the high-pressure gas tank 2 on the Airlock, and PEC 2 is located on the end cone of the Airlock. The MISSE is the first externally attached ISS payload.

## **VEHICLE PERFORMANCE**

### **LAUNCH DELAY**

The launch of the STS-105 mission was scrubbed during the T-9 minute hold on August 9, 2001, because of unacceptable weather (lightning and rain) in the launch area. The launch was rescheduled for August 10, 2001. The launch was completed satisfactorily at 222:21:10:14.019 G.m.t. (5:10:14 p.m. e.d.t.) on August 10, 2001.

### **SOLID ROCKET BOOSTERS**

Analysis of the Solid Rocket Booster (SRB) systems data indicated nominal performance of all SRB subsystems. The prelaunch countdown was normal and no SRB Launch Commit Criteria (LCC) or Operations and Maintenance Requirements And Specifications Document (OMRSD) violations occurred. Likewise, no in-flight anomalies were identified in the evaluation of the data.

STS-105 was the first flight of the single-mission fuel isolation valve (SMFIV). All flight data and postflight assessment results indicate that the valve performed as expected with no problem noted.

This mission was the third flight of the C-band controller. No problems were encountered and all data indicate that the new system performed as designed.

All 48 of the sea water activated release (SWAR) links (8 SWAR links for each parachute) fired and released properly.

Both SRB's 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. The right-hand SRB top/left position forward booster separation motor (BSM) cover was missing. Preliminary examination of the fracture plane revealed no sooting effects, thus indicating that the damage most probably occurred at water impact.

### **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 occurred.

All RSRM temperatures were maintained within acceptable limits throughout the countdown. No in-flight anomalies were identified from the analysis of 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 0.619 percent at 70.5 seconds and 1.247 percent at 68.5 seconds for the left and right motor, respectively.

Power application and operation of all field-joint heaters was accomplished routinely. Field-joint heaters operated for 12 hours 41 minutes during the final launch countdown and 27 hours 52 minutes during the two launch countdowns. Power was applied to the heating elements an average of 26 percent of the time during the LCC time frame to maintain the field-joint temperatures in their normal operating range.



Power application and operation of all igniter-joint heaters was accomplished routinely. The igniter-joint heaters operated for 12 hours 32 minutes during the final launch countdown and 27 hours 43 minutes during both launch countdowns. Power was applied to the heating elements 31 percent of the time during the LCC time frame to maintain the igniter-joint temperatures in their normal operating range.

The heated, ground-supplied, aft skirt purges maintained the case/nozzle joint and flex bearing temperatures within the required LCC ranges. The purge was activated twice during the 97 hours of recorded data for a total of 3 hours 5 minutes. Only one aft-skirt purge-activation was performed and it lasted a total of 56 minutes. It was not necessary to activate the aft-skirt purge to maintain the nozzle-case joint temperatures above the minimum LCC temperature nor was the purge required to thermally condition the flex bearing above the minimum required temperature of 60 °F. However, it was necessary to activate the purge to inert the aft skirt compartments prior to launch. During the LCC time frame, the nozzle/case joint temperatures were nominal and ranged from 77 to 83 °F on both motors. The final flex bearing mean bulk temperature (FBMBT) was determined to be 79 °F.

Reconstructed motor performance parameters adjusted to a 60 °F propellant mean bulk temperature (PMBT) are shown in the following table. The predicted propellant mean bulk temperature was 80 °F. The predicted and actual propulsion systems performance is shown in the RSRM Propulsion Performance table on the following page. The predicted burn rates were 0.3696 and 0.3702 in/sec for the left and right motors, respectively.

#### MOTOR PERFORMANCE PARAMETERS

Parameter	CEI Specification Limit (60 °F)	Left Motor Delivered	Right Motor Delivered
Web time, seconds	105.4 – 116.7	110.2	109.5
Action time, seconds	115.2 – 131.2	122.4	122.3
Head end pressure, psia	847.9 – 965.7	919.0	923.5
Maximum sea level thrust, MLbf	2.88 – 3.26	3.09	3.10
Web time average pressure, psia	629.9 – 700.5	669.5	674.4
Web time average vacuum thrust, MLbf	2.46 – 2.74	2.62	2.64
Web time total impulse, MLbf sec	285.8 – 291.6	288.9	289.0
Action time impulse, MLbf seconds	293.7 – 299.7	296.9	297.5
ISP average delivered, Lbf sec/Lbm	266.5 – 270.3	268.5	269.2
Loaded propellant weight, Lbm	>1103750	1106342	1105672

Note: All times referenced to liftoff time (chamber pressure reaches 563.5 psia),

#### 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 violation was noted when the Orbiter propellant inlet temperature 2 exceeded the OMRSD limit of -291 °F during slow-fill for 44 seconds continuously (OMRSD allows 40 seconds). This condition did not impact the launch countdown.

## RSRM PROPULSION PERFORMANCE

Parameter	Left motor, 81 °F		Right motor, 81 °F	
	Predicted	Actual	Predicted	Actual
Impulse gates				
I-20, 10 <sup>6</sup> lbf-sec	66.40	66.60	66.51	66.86
I-60, 10 <sup>6</sup> lbf-sec	177.35	177.20	177.58	178.13
I-AT, 10 <sup>6</sup> lbf-sec	297.20	297.34	297.02	297.92
Vacuum Isp, lbf-sec/lbm	268.6	268.8	268.6	269.5
Burn rate, in/sec @ 60 °F At 625 psia	0.3696	0.3695	0.3702	0.3702
Event times, seconds <sup>a</sup>				
Ignition interval	0.232	N/A	0.232	N/A
Web time <sup>b</sup>	107.7	107.8	107.4	107.0
50 psia cue time	117.6	117.4	117.3	117.3
Action time <sup>b</sup>	119.8	119.7	119.5	119.7
Separation command	122.0	-	122.0	-
PMBT, °F	81	81	81	81
Maximum ignition rise rate, psia/10 ms	90.8	N/A	90.8	N/A
Decay time, seconds (59.4 psia to 85 K)	3.1	3.2	3.1	3.2
Tailoff Imbalance Impulse	Predicted		Actual	
differential, Klbf-sec	N/A		747.5	

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

<sup>a</sup>All times are referenced to ignition command time except where noted by a <sup>b</sup>

<sup>b</sup>Referenced to liftoff time (ignition interval).

During the stable replenish period of ET loading at 222:20:13 G.m.t., the liquid oxygen (LO<sub>2</sub>) 100-percent sensor 1 failed wet and the control logic was switched to sensor 2. Loss of this sensor had no affect on either the prelaunch loading and drain or ascent operations. The 100-percent sensor is used only for loading control and has no criticality during ascent. Failure of the second 100-percent sensor would have necessitated the use of the 100-percent liquid-level sensor for control. This failure is similar to failures seen in the past that were attributed to a failed ET sensor. Postflight, KSC performed a checkout of the Orbiter point-sensor electrical system and no anomalies were noted.

The pressurization systems functioned properly throughout engine start and flight. The minimum LO<sub>2</sub> ullage pressure experienced during the ullage pressure slump was 13.9 psid.

ET separation was confirmed. The postflight analysis of the impact point showed the ET impact to be 114 nautical miles downrange from the preflight predicted impact point.

### SPACE SHUTTLE MAIN ENGINES

Prelaunch operations of the Space Shuttle main engines (SSMEs) were smooth with no LCC or OMSRD violations noted. 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, mainstage, and shutdown was nominal and as predicted. Engine cutoff times were 512.94, 513.04, and 513.15 seconds for SSMEs 1, 2,

and 3, respectively. Controller and software performance was satisfactory with no anomalies. No in-flight anomalies were identified from the review of the data.

The flight-derived specific impulse ( $I_{sp}$ ) was 1.1 second higher than predicted. The Block IIA engines have typically delivered approximately 0.8-second higher flight  $I_{sp}$  than predicted from ground testing.

Main engine cutoff (MECO) occurred 506.5 seconds after SRB ignition. The commanded maximum dynamic pressure (max  $Q_d$ ) throttle-down was a single throttle step 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 System**

The main propulsion subsystem (MPS) performed satisfactorily. There were no LCC violations during the two loadings and countdowns, and there were no in-flight anomalies identified from the analysis of the data.

Tabulation data for the prelaunch, MECO, post-MECO and entry and landing events revealed no anomalous valve movements. All timings were within the required specification and within the current database. The aft hazardous gas concentrations during both loading sequences were nominal. The peak hydrogen concentration during the first loading was 90 ppm with a steady-state value of 13 ppm. The peak hydrogen concentration during the second loading was 117 ppm with a steady-state value of 8 ppm.

The liquid hydrogen ( $LH_2$ ) loading operations were normal throughout the entire process. Based on an analysis of loading system data, the  $LH_2$  load at the end of replenish was 231,678 lbm. Compared to the predicted inventory load of 231,385 lbm, this assessment yields a difference of 0.137 percent, which is well within the MPS loading accuracy requirements.

The  $LO_2$  loading operations were nominal throughout the entire process, except that the  $LO_2$  Orbiter inlet temperature 2 exceeded the OMRSD limit of  $-291$  °F during slow fill for 44 seconds. This condition was determined to be acceptable as the Orbiter inlet temperature 1 remained within limits and the  $LO_2$  manifold temperature showed no significant temperature rise. A second OMRSD violation occurred at T-3500 seconds in the countdown when the  $LO_2$  100-percent level sensor 1 failed wet. The  $LO_2$  100-percent sensor 2 was used to control liquid level for the remainder of replenish. Based on the analysis of predicted inventory load of 1,389,076 lbm, the load at the end of replenish was 1,391,007 lbm. This assessment yielded a difference of 0.137 percent, which is well within the required MPS loading accuracy.

Also, one File IX requirement was violated when the pneumatic outlet pressure decay data were approximately 3.3 psi/minute. The maximum allowable pressure decay is 2.4 psi/minute. During the turnaround operations following the previous flight of this vehicle

(STS-102), the leakage for the system was 3.21 psi/minute. This amount of leakage is attributed to four solenoids in the pneumatic leg of the subsystem. The standard troubleshooting procedure for a low-pressure pneumatic system leak is to perform a leak check as soon as practical after flight.

The overall gaseous hydrogen (GH<sub>2</sub>) system performance during the ascent phase was nominal. All three flow-control valves (FCVs) performed nominally. The gaseous oxygen (GO<sub>2</sub>) fixed orifice pressurization system performed as predicted. Reconstructed data from engine and MPS parameters closely matched the actual ET ullage pressure measurements. Helium system performance for the SSMEs and pneumatic Helium systems was also nominal. Entry Helium usage was 61.9 lbm, which is well within the allowable requirements.

### Reaction Control Subsystem

The reaction control subsystem (RCS) performed satisfactorily throughout the mission. No in-flight anomalies were noted in the evaluation of the data. The RCS was used to perform 10 translation maneuvers, which included two reboost periods that raised the altitude of the ISS a total of 3.5 nautical miles (nmi.)

The following table shows the major RCS maneuvers performed in support of the rendezvous with the ISS.

**RCS RENDEZVOUS MANEUVERS**

Maneuver	Time, G.m.t./MET	$\Delta V$ , ft/sec	Firing time, sec	Orbit, nmi.
NCC (Multi-axis RCS)	224:15:18:51 01:18:08:37	0.9	60.0	203.2 by 210.7
MC-1 (RCS)	224:16:36:33 01:19:26:19	1.2	5.0	205.7 by 216.1
Out of Plane Null (RCS)	224:16:38:30 01:19:28:16		10	
MC-2 (RCS)	224:17:13:27 01:20:03:13	2.2	10.0	206.0 by 216.0
MC-3 (RCS)	224:17:30:27 01:20:20:13	0.6	2.0	205.8 by 216.3
MC-4 (RCS)	224:17:40:27 01:20:30:13	0.7	4.0	206.1 by 216.6

A total of 3308.5 lbm propellants (2034 lbm - oxidizer, 1274.5 lbm - fuel) were used from the RCS during the mission. In addition, a total of 2204.3 lbm of the orbital maneuvering subsystem (OMS) propellants were used by the RCS during interconnect operations. The primary RCS thrusters had 4315 firings and a total firing time of approximately 1046.16 seconds. The vernier RCS thrusters had 10299 firings and a total firing time of 24688.35 seconds.

The RCS window protect maneuver was initiated at 222:21:12:15.04 G.m.t. (00:00:02:01.04 MET) and was terminated 2.08 seconds later. This maneuver provides a method of protecting the windows of the Orbiter from booster separation motor exhaust products. This maneuver results in improved clarity during the mission and a reduction in the turnaround effort following the mission.

Shortly after MECO, a maneuver was performed at 222:21:19:14.7 G.m.t. (00:00:09:00.7 MET) in support of photographing the ET. The maneuver was 11.52 seconds in duration.

Attitude control was transferred from the ISS to the Orbiter at 226:17:08:57 G.m.t. (03:19:58:43 MET). The first reboost maneuver (primary/vernier thrusters) was started at 226:17:58:26 G.m.t. (03:20:48:12 MET) when thrusters L3A and R3A were fired. The reboost maneuver lasted one hour. The primary thruster pulse widths were 160 ms, and the firing period was 11.6 seconds from start of one pulse firing until the next firing. Approximately ten breaks for attitude maintenance using the vernier thrusters limited the maneuver to 258 primary-thruster pulses. The aft down-firing vernier thrusters had an average duty cycle of 8.08 seconds on and 3.52 seconds off and the resultant  $\Delta V$  of the one-hour maneuver was 6.0 ft/sec. RCS performance was nominal. The maneuver resulted in an overall average altitude increase of 1.7 nmi., and a final orbit of 218 by 208 nmi..

Attitude control was again relinquished from the ISS to the Orbiter at 229:11:28:33 G.m.t. (06:14:18:19 MET). The second reboost maneuver (primary/vernier) was started at 229:12:12:27.36 G.m.t (05:15:02:13.34 MET) when L3A and R3A were fired. The reboost maneuver lasted one hour. The primary thruster pulse widths were 160 ms, and the firing period was 11.6 seconds from start of one pulse firing until the next firing. Approximately twelve breaks for attitude maintenance, using the vernier thrusters, limited the number of pulses to 253 pulses. The aft down-firing vernier thrusters had an average duty cycle of 8.08 sec on and 3.52 sec off and the resultant  $\Delta V$  from the one-hour maneuver was 6.4 ft/sec. The RCS performance was nominal. The reboost resulted in an overall average altitude increase of 1.8 nmi. ,and a final orbit of 218.8 by 209.5 nmi.

Successful undocking from the ISS was completed at 232:14:51:00 G.m.t. (09:17:38:48 MET). In support of undocking, the Orbiter assumed attitude control of the mated stack at 232:14:19 G.m.t. (09:17:08 MET). Initial ISS separation was initiated with a +Z-axis pulse of primary RCS thrusters L4U, R4U, and F3U at 232:15:51:51.3 G.m.t. (09:18:41:37.3 MET). The ISS flyaround was performed nominally. Final separation from the ISS was accomplished with a 23.6-second +X-axis pulse of primary RCS thrusters L3A and R3A at 232:16:11:30.6 G.m.t. (09:19:01:16.6 MET). The  $\Delta V$  delivered was 5.7 ft/sec and the resulting orbit was 219 by 212 nmi.

The RCS thruster hot-fire test was performed satisfactorily. The hot-fire test was initiated at 233:12:17:43.2 G.m.t. (10:15:07:27.2 MET). All RCS thrusters were fired at least twice and for at least 0.240 second on each pulse.

### **Orbital Maneuvering Subsystem**

The OMS performed satisfactorily throughout the mission. One in-flight anomaly was identified from the analysis of the data. A total of nine OMS maneuvers were performed during the mission.

A total of 21589 lbm (13,388 lbm - oxidizer and 8201 lbm - fuel) of OMS propellants were consumed during the mission. Of this total, the OMS provided 2204.3 lbm of propellants to the RCS during interconnect operations, and this represents 9.80 percent of the OMS propellants used during the mission. The table on the following page shows the OMS maneuvers performed to rendezvous and dock with the ISS as well as an orbit adjust maneuver for landing.

## OMS MANEUVERS

Maneuver	Time, G.m.t./MET	$\Delta V$ , ft/sec	Firing time, sec	Orbit, nmi.
OMS-2 (Orbit Insertion) (Dual engine)	222:21:48:48 00:00:38:34	96.1	63.3	85.2 by 126.1
OMS-3 (NC1) (Dual engine)	223:00:56:16 00:03:46:02	84.6	55.2	109.9 by 146.1
OMS-4 (NC3) (Right engine)	223:23:23:07 01:02:12:53	10.2	13.2	110.0 by 151.0
OMS-5 (NH) (Dual engine)	224:13:44:58.1 01:16:34:44	164.6	105.8	146.7 by 209.4
OMS 6 (NC4) (Dual engine)	224:14:37:36.1 01:17:27:22	103.6	65.8	203.3 by 210.9
OMS-7 (TI) (Left engine)	224:16:16:33.9 01:19:06:19	13.3	15.0	205.5 by 216.2
OMS 8 (Orbit Adjust) (Left engine)	232:20:40:13 09:23:29:59	10.7	13.4	199.7 by 218.9

At approximately 233:18:04 G.m.t. (10:20:53 MET), the left OMS low-point oxidizer drain line temperature dropped below the expected heater turn-on temperature of 63 °F (Flight Problem STS-105-V-01). The heater anomaly occurred after approximately four days of B heater operation (nearly 140 cycles). The fault detection annunciation for this measurement was lowered on flight day 1 to avoid nuisance alarms, and on the previous day to this occurrence, the measurement alarm limit was again lowered. When the temperature dropped to 41 °F, the crew was asked to switch the crossfeed line heaters from system B to system A at 233:19:43 G.m.t. (10:22:33 MET). Nominal heater operation was observed after the heater reconfiguration.

The deorbit maneuver for the first KSC landing opportunity was waived because of a rain shower near the end of runway. The deorbit maneuver for the second KSC landing opportunity, a two-engine straight-feed firing, was performed on orbit 186 at 234:17:15:22.939 G.m.t. (11:20:05:08.920 MET). The maneuver was 194.5 seconds in duration with a  $\Delta V$  of 330.6 ft/sec.

### Power Reactant Storage and Distribution Subsystem

The power reactant storage and distribution (PRSD) subsystem performance was nominal throughout the STS-105 mission. No LCC or OMRSD violations occurred during the countdown and mission, and no in-flight anomalies were noted during the analysis of the data. All File IX requirements were satisfied during the mission.

The PRSD subsystem supplied the fuel cells with 2703 lbm of oxygen and 340 lbm of hydrogen for the production of 3972 kW of electrical energy. In addition, the environmental control and life support system (ECLSS) was supplied 197 lbm of oxygen for life support. The average power level for the mission was 13.9 kW. A 73-hour mission extension was possible at the average power level with the reactants remaining at landing.

PRSD tanks 4 and 5 were depleted to residual quantities during the mission. The Orbiter landed with 994 lbm of oxygen and 110 lbm of hydrogen remaining in the PRSD subsystem.

At an extension-day power level of 12.4 kW, a 82-hour mission extension capability was available.

### Fuel Cell Powerplant Subsystem

The overall performance of the fuel cell powerplant (FCP) subsystem was nominal during the mission. There were no OMRSD or LCC violations, nor were any in-flight anomalies found during the analysis of the data. The average power level and load was 13.9 kW and 450 amperes. The fuel cells produced 3043 lbm of potable water and 3972 kWh of electrical energy while using 2703 lbm of oxygen and 340 lbm of hydrogen.

Four 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.

The actual fuel cell voltages at the end of the mission were 0.15 V above the predicted for fuel cell 1, 0.15V above predicted for fuel cell 2, and 0.20 V above the predicted for fuel cell 3. The voltage margin above the minimum performance curve at 200 amperes at the end of the mission was 1.2 V for fuel cell 1, 1.4 V for fuel cell 2, and 1.2 V for fuel cell 3.

The overall thermal performance of the fuel cell water relief, water line, and reactant purge heater systems was normal. System A was used during the countdown, ascent and through 6.8 days of the mission for the water relief and water line systems. The B system was selected at that time and it operated nominally for the remainder of the mission.

The fuel cell monitoring system (FCMS) was used to monitor individual cell voltages during prelaunch, on-orbit and postlanding operations. Full-rate data were recorded for 15 minutes beginning at 223:20:22:05 G.m.t. (00:23:11:51 MET) and all of the cell voltages were nominal. Cell 59 of fuel cell 1 was biased 12 mV high and cell 25 of fuel cell 2 was biased 12 mV low due to an FCMS instrumentation bias. Each of the fuel cells had the soldered connections.

### Auxiliary Power Unit Subsystem

The auxiliary power unit (APU) subsystem performed nominally during the mission with no in-flight anomalies or significant problems identified. The APU run times and fuel consumption for the mission are shown in the following table.

Flight phase	APU 1 (S/N 207)		APU 2 (S/N 203)		APU 3 (S/N 401)	
	(a) (b) Time, Min:sec	Fuel consumption, lb	(a) Time, Min:sec	Fuel consumption, lb	(a) Time, min:sec	Fuel consumption, lb
Ascent	19:37	51	19:36	53	19:38	51
FCS checkout	4:30	16				
Entry <sup>a</sup>	61:21	122	89:30	160	61:29	132
Total	85:28	189	109:06	213	81:07	183

<sup>a</sup> APUs were shut down 18 minutes 8 seconds after landing.

The APU 2 chamber pressure showed a slight stiction, approximately 0.235-second in duration, of the fuel pump start bypass valve during the start-up sequence for launch. This stiction contributed to the predicted long start time known to take place on the first start of an APU after a long static period. For this APU, it had been six months since it had been run. The start time was 4.75 seconds, which is well within the APU database for nominal operation.

This condition did not impact any flight operations during the mission, and the start-up for entry was nominal.

The flight control system (FCS) checkout was performed with no problems identified. APU 1 was used to support the checkout, with a start time of 204:00:31:03 G.m.t. (10:15:27:04 MET). The run time was 6 minutes 22 seconds, and 17 pounds of fuel were used during the APU 1 operation. APU performance was nominal, and the total run time was too short to require the WSB to provide spray cooling.

### **Hydraulics/Water Spray Boiler Subsystem**

The hydraulics/water spray boiler (WSB) subsystem performed satisfactorily throughout the mission. No in-flight anomalies were noted in the review of the data.

All three WSB cores used the water additive Propylene Glycol Monomethyl Ether (PGME) to preclude freezing during ascent. The additive performed as expected with one problem noted that was probably caused by a temperature sensor response-time delay. During ascent, WSB 2 initiated spray cooling of the APU lubrication oil at 276.7 °F. Spray cooling should have been initiated between approximately 252 and 275 °F. This same condition was observed during the previous flight of this vehicle, and corrective action has been scheduled to occur during the next Orbiter Major Modification (OMM) period.

The circulation pump lower temperature limit was changed during the mission as planned to minimize circulation pump operations and thus reduce cryogenics usage and increase margins for cryogenic-critical ISS missions. As a result, operation of the circulation pumps was limited to four occurrences. Circulation pump 1 ran three times and circulation pump 3 ran one time.

The FCS checkout was performed using APU 1 to support the checkout. The hydraulic and WSB performance on system 1 was nominal. Reservoir quantity and priority valve crack and reseal pressures were within specification. Because of the short run time (4 minutes 30 seconds), APU lubrication oil spray cooling was not required. The APU 1 lubrication oil temperature at APU shutdown was approximately 195 °F.

Hydraulic performance during entry was nominal. APU 2 was activated at deorbit maneuver minus 5 minutes, followed by APU 1 and 3 at entry interface (EI) minus 13 minutes. All hydraulic systems operated satisfactorily during entry.

### **Electrical Power Distribution and Control Subsystem**

The electrical power distribution and control (EPDC) subsystem performed nominally throughout the mission. No in-flight anomalies were identified from the data analysis, and all File IX requirements were satisfied.

At 232:16:42:30 G.m.t. (09:19:32:16 MET) when the manipulator positioning mechanisms (MPMs) for the remote manipulator system (RMS) were stowed, the AC2 data indicated a loss of phase A current for motor 2. Since the motors are certified to operate on two phases, the MPMs were stowed in dual motor time. The affected three-phase circuit breaker is CB7, which passes AC2 current to the mid motor controller assembly 2 (MMCA2) that is used to operate the MPM motors. All prior motor drives using MMCA2 drove on all three phases. A decision was made to not cycle the circuit breaker during the flight since no operational capabilities were lost. During the closing of the payload bay doors, the motors controlled by



MMCA2 also operated on two phases. During postlanding operations, the circuit breaker was cycled and the problem was corrected by this action.

### **Orbiter Docking System**

The Orbiter docking system (ODS) performed satisfactorily throughout the mission. The ODS valves were used during the docked operation and for EVAs. The Orbiter was docked to the ISS pressurized mating adapter (PMA) 2, the vestibule was pressurized from the ISS and the vestibule leak check after docking was nominal.

The ODS ring extension to the initial position started at 223:16:38:31 G.m.t. (00:19:28:17 MET) and lasted 3 minutes and 37 seconds.

The ODS captured the ISS at 224:18:41:41 G.m.t. (01:21:31:27 MET) and ring alignment was obtained in 15 seconds. Ring retraction was performed in four stages (retraction, retraction, extension, retraction). The first ring retraction started 2 minutes 13 seconds after capture and was halted after 22 seconds as the ring went out of alignment and exceeded the linear advance difference allowance. Data show that high-energy damper 1 was apparently mechanically stuck and that was the cause of the misalignment. This phenomenon has been observed on previous flights. The crew waited 3 minutes and 20 seconds for the ring to re-align itself. Although the ring did not realign, the retraction sequence was re-initiated. However, the alignment was halted after 27 seconds when the misalignment persisted. To force the ring into alignment, a full ring-extension was performed. The third ring-retraction attempt from the fully extended position was successful and was automatically stopped after 4 minutes and 44 seconds. The hooks were then closed at 224:19:03:54 G.m.t. (01:21:53:40 MET).

The vestibule depressurization valves were used to depressurize the vestibule to vacuum before undocking. The vestibule leak check, which was conducted 20 minutes after closing the vestibule depressurization valves, was nominal.

Successful undocking from the ISS was completed at 232:14:51:00 G.m.t. (09:17:38:48 MET). In support of undocking, the Orbiter assumed attitude control of the mated stack at 232:14:19 G.m.t. (09:17:08 MET).

The external airlock waterline heater reconfiguration from string A heaters to String B heaters was performed as part of the in-flight checkout. String C heaters were not required. The active system monitor parameters indicated normal output throughout the duration of the flight.

### **Atmospheric Revitalization Pressure Control Subsystem**

The atmospheric revitalization pressure control system (ARPCS) performed normally throughout the duration of the flight. Prior to docking with the ISS, cabin pressure was maintained using oxygen (O<sub>2</sub>) through the direct O<sub>2</sub> valve to minimize the use of nitrogen (N<sub>2</sub>) consumables. After docking with the ISS, the hatches were opened at 224:20:41 G.m.t. (01:23:31 MET), and the pressure was equalized at 14.39 psia. A 14.7-psia ISS/Orbiter stack repressurization was completed at 225:12:53 G.m.t. (02:15:43 MET), and pressure control system (PCS) system 1 was placed in automatic to maintain the pressure for the Orbiter and the ISS combination.

The common hatches with the ISS were closed at 227:21:51 G.m.t. (05:00:41 MET), and the crew began the cabin depressurization to 10.2 psia at 227:22:26 G.m.t. (05:01:16 MET). The

cabin remained at 10.2 psia until the crew had egressed the airlock for the first EVA. The cabin was then repressurized to 14.7 psia, and the airlock repressurization for crew ingress from the EVA was performed at a cabin pressure of 14.7 psia.

The internal pressure was equalized between the ISS and the Orbiter and the hatches were reopened to the ISS at 228:20:59 G.m.t. (05:23:49 MET). The PCS 1 system was configured for overnight to maintain stack pressure while the hatches were open.

The common hatches with the ISS were again closed at 229:22:01 G.m.t. (07:00:51 MET) for the second EVA and a depressurization to 10.2 psia was performed. Repressurization to 14.7 psia was performed after the crew had egressed for the second EVA, and the airlock was repressurized to 14.7-psia. The common hatches with the ISS were reopened following the completion of the second EVA, and the Orbiter maintained pressure control for the Orbiter/ISS stack.

An O<sub>2</sub> repressurization to 14.9-psia in preparation for undocking was completed at 232:11:36 G.m.t. (09:14:26 MET). The common hatches with the ISS were closed for the final time during this mission approximately one hour later. Normal pressure control was maintained by PCS system 1 for the remainder of the mission. Full switchover of O<sub>2</sub>/N<sub>2</sub> flow on PCS system 1 was observed. Switchover to PCS system 2 was not observed on this mission.

The active system monitor parameters indicated normal output throughout the duration of the flight.

### **Atmospheric Revitalization Subsystem**

The atmospheric revitalization subsystem (ARS) performed nominally throughout the duration of the flight. All file IX checkout requirements were performed and satisfied.

At approximately 222:23:13 G.m.t. (00:02:03 MET), the A airlock booster fan successfully powered up on all three phases and the fan operated satisfactorily throughout the flight. The crew has the option of powering either the A or B fan and remained on the selected fan for the entire mission.

The partial pressure carbon dioxide (ppCO<sub>2</sub>) peaked at 7.6 mmHg at 223:17:59:27 G.m.t. (00:18:49:07 MET), about 3 hours after crew had awakened. About 45 minutes earlier the indicated ppCO<sub>2</sub> was 6.47 mmHg, and the crew was notified that the ppCO<sub>2</sub> level was approaching the cabin limit of 7.6 mmHg. The crew performed a dual-cartridge change approximately 45 minutes after being informed of the approaching limit. A second occurrence of high cabin ppCO<sub>2</sub> occurred at 230:13:19 G.m.t. (07:16:09 MET) when the sensor indicated a ppCO<sub>2</sub> concentration of 6.03 mmHg during 10.2-psia cabin-pressure operations in preparation for an EVA. The sensor is calibrated at 14.7 psia, and the indicated ppCO<sub>2</sub> at lower cabin pressures is biased lower than the actual ppCO<sub>2</sub> present in the cabin. The vendor for this sensor has provided information that shows when a 4.9-mmHg ppCO<sub>2</sub> is indicated at 10.2 psia, it is equivalent to 7.6 mmHg at a 14.7-psia cabin-pressure. The indicated 6.03-mmHg translates to a ppCO<sub>2</sub> of 9.35 mmHg. The ppCO<sub>2</sub> was above 4.9 mmHg for 1 hour and 28 minutes.

The floodlight coldplate temperature location on the 576 bulkhead remained above 65 °F for the duration of the flight. On the previous mission (STS-104), the temperature decreased to 35.1 °F during a cold attitude. The postflight investigation of the water coolant loop (WCL) 1 return line revealed that the coolant line was not properly wrapped. The aluminum wrapping

tape that thermally connects the active WCL 2 to the passive WCL 1 was missing. The wrapping tape allows the necessary heat transfer and prevents loop 1 from freezing.

### **Active Thermal Control Subsystem**

The active thermal control subsystem (ATCS) performed nominally for the STS-105 mission. During ascent, very little pre-evaporative cooling was observed. The flash evaporator system (FES) outlet temperatures climbed steadily with a slight decrease in the heating rate about 88 seconds into the flight. This rate change indicated that a very small amount of condensate had collected in the FES cores. At 2 minutes and 6 seconds after liftoff, the FES outlet temperatures began decreasing indicating that the general-purpose computer (GPC) had commanded the FES on. After MECO and the switch from primary A GPC to command events, very minor oscillations were observed in the FES outlet temperatures as the primary A controller brought the outlet temperature into the control band. These small oscillations had no impact to the mission.

For the post-insertion phase, a real-time change to the procedures was to reconfigure the FES from primary A command to primary B before the radiator valves were configured from the bypass to the flow position. The FES was to be configured from primary A to primary B to support the accumulation of water in tanks A and B for contingency water container (CWC) transfers to the ISS. The change to the procedures was done to avoid a repeat of the STS-104 FES shutdown occurrence. In this flight, the crew configured from primary A to primary B at 222:22:31:26 G.m.t. (00:01:21:12 MET). About 13 seconds later, the radiators were configured from the bypass to the flow position. This precluded the temperature transient from the radiators reaching the FES at a time when the newly configured controller is still trying to bring outlet temperatures into the control band. Some outlet temperature oscillations occurred as the primary B controller brought the outlet temperature into the control band, but the mission was not impacted.

A total of five FES water dumps were performed. The first two FES water dumps were performed using the primary B controller. The next three were performed using primary A control after the supply water tanks were configured from the CWC-fill configuration to the nominal on-orbit configuration.

The radiator bypass/FES checkout for entry was nominal. An oscillation on the FES outlet temperature was observed during the secondary high-load FES checkout, but the mission was not impacted. After the payload bay doors were closed for entry, the FES was reconfigured from primary B command to primary B GPC command in accordance with the deorbit procedures. There was a one-revolution delay for the deorbit maneuver, which added about 1.5 hours to the amount of time the doors were closed prior to the deorbit maneuver. Approximately 11 minutes prior to landing, the radiators were commanded to the flow position, and about 3 minutes after main landing gear touchdown, the radiators flow control valves (FCV) were commanded to high setpoint in preparation for ammonia boiler use. The ammonia boiler system A secondary controller was commanded on and about 40 minutes later, tank A blowdown was observed indicating the start of depletion of tank A. The system A controller was commanded off about 1 minute later and the system B primary controller was commanded on. About 4 minutes later, the radiator flow control valves were reconfigured to the normal setpoint and the ammonia system B primary commanded off when ground cooling was established.

### **Supply and Waste Water Subsystem**

The supply water and waste management systems performed nominally throughout the mission and all of the scheduled in-flight checkout requirements were satisfied.

Supply water was managed through the use of the FES, water transfer to the ISS and the overboard-nozzle dump system. Three supply water nozzle dumps were performed at a nominal dump rate of 1.6 percent/minute (2.64 lb/min). The line heater maintained the supply water dump line temperature between 66 °F and 95 °F throughout the mission.

Five wastewater nozzle dumps at an average rate of 1.94 percent/minute (3.2 lb/min) were performed. During this mission, two contingency water containers (CWCs) containing ISS-Laboratory condensate were nominally dumped through the Orbiter dump nozzle. The first CWC with approximately 97 lb of ISS condensate was dumped immediately after the completion of the third wastewater nozzle dump, and the second CWC with approximately 75 lb of ISS condensate was dumped following the fifth wastewater nozzle dump. The two CWC condensate water dumps were performed with the waste dump isolation valve closed and the CWCs connected to the waste cross-tie quick-disconnect (QD) using hose. Cabin pressure was at 14.7 psia during the ISS condensate CWC dumps. The wastewater dump line temperature was maintained between 58.3 °F and 86.7 °F throughout the mission. The vacuum vent line temperature was maintained between 59.8 °F and 83°F.

A leaking half-full CWC that held technical water from a previous flight was placed inside an empty Russian water container (similar to American CWC) and returned in the MPLM for failure analysis.

Ten CWCs were filled with supply water and transferred to the ISS, for a total of 990 lb. Seven of the CWCs transferred were potable water and three were technical water. The calculated average fill rate for the CWCs was 120 lb/hr.

### **Waste Collection Subsystem**

The waste collection subsystem (WCS) performed satisfactorily throughout the mission. The crew noted no anomalous performance.

### **Smoke Detection and Fire Suppression Subsystem**

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

### **Flight Data Subsystem**

Four seconds prior to launch, all four primary avionics software system (PASS) GPCs annunciated two input/output (I/O) errors against the launch data bus. No crew or flight-controller actions were required, and there was no mission impact. Analysis shows that the flight software responded in accordance with requirements and as soon as the third I/O error was received, the general purpose computers (GPCs) were switched from launch data bus (LDB) 1 to LDB 2. Both LDB front-end processors (FEPs) saw all three errors. KSC performed troubleshooting on the launch processing system (LPS) lines and no anomalies were found. Troubleshooting was also performed on the connectors/wiring at the T-0 umbilical and the mobile launch platform (MLP). A terminal distributor was wet from condensation where the LDB 1 and 2 twin coaxial cables mate inside the MLP. Corrective

action was taken to raise the temperature inside the unused compartment where the conduit runs. Additional testing of the LDB is being conducted to verify that there are no dropouts.

At 223:23:02:33 G.m.t. (01:01:52:19 MET), a single I/O error was annunciated against cathode ray tube (CRT) 2. The CRT major function was in GNC and GPC 1 annunciated the error. The error was logged for only one poll [the GPC polls the display electronics unit (DEU) twice every second]. The CRT 2 display was nominal, the DEU 2 built-in test equipment (BITE) status words were nominal, and there were no keystrokes entered at the time of the anomaly. During the mission, it was believed that the most probable cause for the error was a DEU/multiplex input adapter (MIA) transient anomaly. The CRT continued to function nominally for the remainder of the mission. At the crew debriefing, the crew stated that while the filter was being cleaned, a connector was bumped at the back of DEU 2 coincident with the I/O error. KSC performed a wire wiggle with connector P247 and an I/O error was annunciated. The display/keyboard (DK) bus cables connecting the DEU to the GPC were wiggled and by moving the DK bus, the anomaly was recreated. Troubleshooting is progressing to isolate the cause to a specific component in the circuit.

At 225:17:30 G.m.t. (002:20:19:46 MET), an I/O error was annunciated against CRT 2 that was consistent with User Note D027. There was no associated I/O error log entry, the CRT 2 display was nominal, and the resume key had been entered just prior to the I/O error. A DEU control-program (DCP) timing window exists in which subsequent to entering a complete keyboard message, an I/O error is annunciated with no associated I/O error log entry. The error is due to a failed health check caused by the poll request interrupting the DCP keyboard processing. This I/O error is unrelated to the error discussed in the previous paragraph.

### **Flight Software**

The flight software performed as expected during the mission. No in-flight anomalies were identified in the review of the data.

### **Flight Control Subsystem**

Flight control subsystem and hardware performance was nominal throughout the mission.

The inertial measurement units (IMUs) performance was satisfactory throughout the mission. Only one adjustment of the onboard accelerometer compensation values was performed for the three units.

The star tracker performance was nominal throughout the mission. The -Y solid-state star tracker (SSST) annunciated Tracker Good twice during the mission. Neither of the annunciations were accompanied by any other flags. Thus these annunciations are considered nominal.

The entry guidance navigation and control performance was nominal. Navigation sensor [drag, tactical air navigation (TACAN), air data transducer assembly (ADTA) and microwave landing system (MLS)] data were incorporated into the onboard navigation state vectors at their expected region of operation with no navigation editing observed.

During FCS checkout, at approximately 233:11:41 G.m.t. (10:14:30 MET), when the crew took the nose wheel steering (NWS) switch from NWS 1 to NWS 2, they reported that it felt like it went into the proper position, but the voltage indicated zero. This problem is discussed in detail in the Displays and Control Subsystem that follows this heading.

During the landing operations, the left outboard wheel speed sensor indicated weight-on-wheels approximately three seconds after the left inboard wheel speed sensor. Since data (skid marks) show that the left outboard wheel did not spin as quickly as the other wheels, the flight control hardware (redundant weight on wheel sensor) performed nominally.

### **Displays and Controls Subsystem**

The displays and controls performed satisfactorily with no problems or in-flight anomalies identified.

During FCS checkout, at approximately 233:11:41 G.m.t. (10:14:30 MET), when the crew took the NWS switch from NWS 1 to NWS 2, they reported that it felt like it went into the proper position, but the voltage indicated zero. The switch was pushed a little harder while lifting up on the switch as the switch was pushed, and the switch went into the NWS 2 position. After cycling the switch a couple of times, it felt normal. Telemetry confirmed that no NWS servo currents were seen with the first selection of NWS 2. The crew cycled the switch five times and the servo currents were nominal during the cycles. Other than this one event, the NWS 1 and NWS 2 checkouts were nominal.

At 232:16:43 G.m.t. (09:19:32:46 MET) during the stowing of the RMS manipulator positioning mechanisms (MPMs), the motors drove dual motor time; however, motor 2 had phase A missing. When the MPM was deployed, all three phases were present. During the mission, it was believed that the most probable cause of the phase-A failure was contaminated AC2 mid-motor controller-assembly (MMCA) 2 circuit-breaker contacts. All of the motors powered by the AC2 MMCA 2 bus will operate on two phases. Since no operational capabilities were lost, the affected circuit breaker was not cycle during the flight in an attempt to clean the contacts. Postflight troubleshooting isolated this problem to the circuit breaker.

### **Communications and Tracking Subsystem**

The communications and tracking subsystem performed satisfactorily throughout the mission. No significant problems or in-flight anomalies were identified from the analysis of the data.

When the Ku-band system was placed in the communications mode at 222:23:16 G.m.t. (00:02:06 MET), the radio frequency (RF) power output varied between 18 and 23 watts for about 5 minutes after which it stabilized at a nominal value of 23 watts. Ku-band power output remained stable at 23 watts for about 19 minutes at which time the system stopped radiating at the Tracking and Data Relay Satellite (TDRS) handover. Approximately 21 minutes later at 222:23:56 G.m.t. (00:02:46 MET), the RF power output was about 14 watts and remained at that level until TDRS West was acquired at 223:01:08 G.m.t. (00:03:58 MET), at which time the indicated power level was 23 watts. It remained at that indicated power level for the remainder of the mission.

The White Sands Ground Terminal verified that while the Ku-band RF power output varied, the quality of the downlinked Ku-band signal was nominal. Engineering evaluation of the indications point to this problem being a measurement transducer-problem only. A similar signature was observed on an earlier mission and analysis showed that the cause of the condition was a circuit in the deployed assembly that processed the measured data for the downlink telemetry. Also, data review indicates that similar performance was observed on the previous flight of this vehicle (STS-102) and it also occurred shortly after Ku-band activation. The condition lasted for approximately five hours before nominal power levels were observed. This condition did not impact the vehicle performance during this mission.

During the rendezvous, the Ku-band radar acquired the ISS at 224:15:35 G.m.t. (01:18:25 MET) at a range of 144,800 feet (approximately 24 nmi.) and tracked the ISS until 224:18:17 G.m.t (01:21:07 MET). At a range of 240 feet, the crew placed the Ku-Band system in the communications mode.

After undocking from the ISS, the Ku-band system was placed in the radar mode at 232:15:02 G.m.t. (09:17:51:46 MET) and acquired the ISS at a range of 191 ft. The radar maintained lock on the ISS during the flyaround. The Ku-band system was placed in the communications mode at 232:16:18 G.m.t. (09:19:07:46 MET).

### **Operational Instrumentation/Modular Auxiliary Data System**

The operational instrumentation/Modular Auxiliary Data System (MADS) performed nominally during the mission. Minor problems were noted during the mission and these are discussed in the following paragraphs.

On flight day (FD) 1, when the payload data interleaver (PDI) was reconfigured from low to high data-rate for the hitchhiker experiments advancing technology (HEAT) experiments, decommutator 2 locked up as expected on the HEAT high data-rate but decommutator 4 still had bit synchronization. The source was zeroed to clear the bit synchronization, but the decommutator still retained bit and accuracy synchronization. When the command was sent gain, the correct decommutator-4 configuration was obtained. Analysis indicates that it is anomalous performance because zeroing the source did not clear the decommutator-4 bit synchronization. This anomaly occurred in a system configuration where two decommutators (2 and 4) were tied to the same data source. Decommutator 2 had high data-rate format (DFL) and decommutator 4 was in low DFL. The HEAT data stream was switched from low data-rate to high data-rate and both decommutators indicated bit synchronization. This is a known condition when one source feeds two decommutators. There was no impact to the HEAT data from this anomaly.

An evaluation of the data downlinked from operations recorder 1 indicated that unexpected 2-second dropouts occurred at the 6 and 23 percent segments on track 3. The data were dumped in both the forward and reverse directions at 120 in/sec and also at 15 in/sec with the same results. New data were recorded on these segments but there were still 2-second dropouts on these two segments. Subsequent to these findings, on flight day 8, data from track 4 (at 68- and 81-percent) and track 12 (at 6-percent) also experienced 2-second dropouts during recorder dumps. The most likely cause of the dropouts is bad segments on the tape. The recorder will be removed and sent to the vendor for repair

On several occasions, PDI decommutators 1 and 3 experienced momentary major frame (MF) dropouts. The flight controllers reported that PDI decommutator 1 had MF dropouts 15 different times from 224:23:45 G.m.t (02:02:35 MET) to 225:10:20 G.m.t. (02:13:10 MET). The source was the HEAT experiment format 27 and the payload customer indicated that a possibility existed that the HEAT experiment experienced the dropouts. Also, it was reported that PDI decommutator 3 had 3 MF dropouts between 224:16:24 G.m.t. (01:19:14 MET) and 225:20:34 G.m.t. (02:23:24 MET). For the first dropout, the source was sequential still video (SSV), and for the second and third dropouts, the source was the Orbiter Interface Unit (OIU). There was no indication of a problem with the OIU data source associated with the OIU MF dropouts. No additional MF dropouts occurred over the remainder of the mission.

## Structures and Mechanical Subsystems

The structures and mechanical subsystems performed satisfactorily throughout the mission. The following table presents the landing and braking parameters for the flight.

Parameter	From Threshold, ft	Speed, Keas	Sink rate, ft/sec	Pitch rate, deg/sec
Main gear touchdown	1594.6	201.5	-1.22	N/A
Nose gear touchdown	5002.8	149.4	N/A	-5.3
Brake initiation speed		102.0 keas		
Brake-on time		41.12 seconds		
Rollout distance		11642.2 feet		
Rollout time		65.55 seconds		
Runway		15 (Concrete) KSC		
Orbiter weight at landing		222,486.1 lb		
Brake sensor Location	Peak Pressure, Psia	Brake assembly	Gross energy, million ft-lb	
Left-hand inboard 1	726.9	Left-hand inboard	14.34	
Left-hand inboard 3	726.4			
Left-hand outboard 2	687.2	Left-hand outboard	10.94	
Left-hand outboard 4	687.2			
Right-hand inboard 1	925.1	Right-hand inboard	12.26	
Right-hand inboard 3	925.1			
Right-hand outboard 2	713.7	Right-hand outboard	10.41	
Right-hand outboard 4	713.7			

The payload bay doors were opened at 222:22:53:19 G.m.t. (00:01:43:05 MET). All voltages were nominal, and the motors opened the doors in nominal dual-motor time.

The payload bay doors were closed and latched for the first KSC landing opportunity at 234:13:01:00 G.m.t. (11:15:50:46 MET). As discussed in the Electrical Power Distribution and Control (EPDC) section of this report, several motors drove on two phases, with AC2 phase A missing due to a circuit breaker problem. The port payload bay door drive-motor 2, starboard aft-bulkhead-latch motor 2, and centerline latch 13-16 motor 2 are powered by AC2 MMCA2. As anticipated due to the anomaly noted during MPM stow, AC2 phase A current was missing from these motors. All payload bay door close and latch operations occurred in dual motor time.

The main landing gear deployed when commanded and main landing gear touchdown occurred on KSC concrete runway 15 at 234:18:22:59 G.m.t. (11:21:12:45 MET) on August 22, 2001. The drag chute was deployed at 234:18:23:01 G.m.t. The nose gear touchdown occurred at 234:18:23:10 G.m.t. The drag chute was jettisoned at 234:18:23:43 G.m.t. Wheels stop occurred at 234:18:24:05 G.m.t. The rollout was normal in all respects.

### Integrated Vehicle Heating and Thermal Interfaces

The prelaunch thermal interface purges were normal with no problems noted. Likewise, the ascent aerodynamic heating and plume heating was nominal with no problems noted. The



entry aerodynamic heating on the SSME nozzles was also normal with no bluing of the metal noted during the postflight inspection.

### **Thermal Control Subsystem**

The thermal control subsystem performed satisfactorily in maintaining vehicle temperatures well within established limits. The mission beta angle profile ranged from +34 degrees at orbital insertion to -21 degrees prior to the deorbit maneuver. The flight was performed with the vehicle mainly in the local vertical, local horizontal (LVLH) attitudes, which resulted in benign thermal environments throughout the mission. The end-of-mission thermal conditioning attitude provided adequate margin for the main landing gear tire lower limit. With the exception of one heater failure, the performance of the Orbiter thermal subsystem was nominal and none of the Orbiter thermal constraints were exceeded.

At approximately 233:18:03 G.m.t. (10:20:53 MET), the left OMS low-point oxidizer drain line temperature dropped below the expected heater turn-on temperature of 63 °F (Flight Problem STS-105-V-01). When the temperature dropped to 41 °F, the crew switched the crossfeed line heaters from system B to system A at 233:19:43 G.m.t. (10:22:33 MET). Nominal heater operation was observed after the heater reconfiguration.

### **Aerothermodynamics**

Structural thermocouple temperature data, aileron deflection data, and yaw thruster firings all indicated a normal symmetric boundary layer transition that occurred along the centerline of vehicle at Mach 7.2 (1279 seconds after entry interface). All centerline fuselage thermocouples recorded similar onset times. Unsteady flow was recorded starting approximately 20 seconds earlier (Mach 7.7). The acreage heating data indicate that the vehicle experienced normal entry heating. Local heating was also normal.

### **Thermal Protection Subsystem and Windows**

The thermal protection subsystem (TPS) performed satisfactorily. Entry heating was normal based on lower-surface structural temperature response data. Boundary layer transition from laminar flow to turbulent flow was nominal and occurred at Mach 7.2 or 1279 seconds after entry interface (EI).

The postlanding inspection of the Orbiter TPS identified a total of 144 damage sites of which 25 had a major dimension of 1-inch or larger. This total does not include the numerous damage sites on the base heat shield that are attributed to the flame arrestment sparkler system, SSME vibration/acoustics and exhaust plume recirculation. The distribution of these impacts on the vehicle is shown in the table on the following page.

The Orbiter lower surface sustained 108 damage sites of which 15 had a major dimension of 1-inch or larger. The majority of the hits (57 damage sites with 11 larger than 1-inch in length) were located in the area from the nose gear to the main landing gear wheel wells on both the left and right chines. The pattern and size ratio of these sites is indicative of damage from ET foam loss. This is the highest number of hits in this area since the implementation of ET intertank foam venting. Film analysis will be used to determine the source of the debris.

### TPS DAMAGE SITES

Orbiter Surfaces	Hits > 1 Inch	Total Hits
Lower Surface	15	108
Upper Surface	2	3
Window Area	8	32
Right Side	0	0
Left Side	0	0
Right OMS Pod	0	1
Left OMS Pod	0	0
Total	25	144

Approximately 31 of the total lower surface hits were around the LH<sub>2</sub> umbilical area. Most of these damage sites around the ET/Orbiter umbilical were most likely caused by pieces of the umbilical purge barrier flailing in the airstream and contacting tiles before pulling loose and falling aft. The largest lower-surface tile damage site was located inboard of the left-hand chine and measured 4-inches wide by 0.0625-inch deep. Umbilical well camera film will be used in an attempt to determine the cause of this damage.

Typical amounts of tile damage occurred on the base heat shield. All SSME dome heat shield closeout blankets were in good condition.

Three vertical tail leading edge tile damage sites were observed with two having a major dimension greater than one inch. There was also one tile damage site on the leading edge of the right-hand OMS pod.

A total of 32 damage sites, with 8 having one dimension greater than one inch, were identified on the window perimeter tiles. The hazing and streaking of the forward-facing windows appeared to be normal.

In summary, the total number of Orbiter TPS damage sites and the number of sites that were 1-inch or larger were within the established family; however, the number of damage sites between the main landing gear wheel well and the nose landing gear wheel well was higher than normal.

A comparison of lower surface damage sites for the previous 10 flights is shown in the following table.

#### COMPARISON OF LOWER SURFACE DAMAGE SITE DATA FROM LAST TEN FLIGHTS

Parameter	STS -93	STS -103	STS -101	STS -92	STS -97	STS -98	STS -102	STS -100	STS -104	STS -105
Lower surface, total hits	161	84	70	86	78	73	44	42	108	144
Lower surface, hits > 1 in.	42	13	19	14	10	8	10	4	4	25
Longest damage site, in.	6.0	1.5	8.0	2.0	3.0	3.0	1.0	2.5	4.5	5
Deepest damage site, in.	0.5	0.25	0.75	0.75	0.5	0.5	0.12	0.12	0.25	0.06

The post-landing walkdown of runway 15 was performed immediately after landing, and many pieces of foreign object damage (FOD) were found on the runway. All of the debris was found within 10 feet of the runway centerline. The debris items found were:

1. A 13-inch long, 10 gauge, metallic wire;
2. A 1-inch long by 0.625 inch wide by 0.250 inch long thick metal fragment; and
3. Numerous pieces of Shuttle Landing Facility concrete.

In addition, numerous pieces of asphalt were found on the approach threshold of runway 15.

### **Gas Sample Analysis**

The analysis of the gas samples contained in the six bottles showed the samples to be acceptable and within the nominal range for percentage of hydrogen.

The analysis was performed using an AeroVac Mass Spectrometer and the backup analysis was accomplished using a Finnegan 9001 Gas Chromatograph with Discharge Ionization Detection.

Computations to determine the amount of hydrogen contributed by the pyrotechnic used to open and close the sampling bottle assumed the composition would match that of experimental values obtained under controlled conditions. These conditions indicated that the ratio of hydrogen to carbon monoxide was 0.54.

The percent air and the oxygen-from-air were calculated from the amount of argon in the sample. The calculations assume normal air to be made up of 78.08-percent nitrogen, 20.95-percent oxygen, and 0.934-percent argon.

## EXTRAVEHICULAR OPERATIONS

Two extravehicular activities (EVAs) were completed, and all planned tasks were completed. The first EVA duration was 6 hours 17 minutes, and the second EVA had a duration of 5 hours 32 minutes. Get-ahead EVA tasks for the next mission were deleted to provide more time for the internal transfer operations.

The tasks performed during the first EVA were as follows:

1. Installed the Early Ammonia System (EAS) on P6;
2. Deployed two Materials International Space Station (ISS) experiments (MISSEs);
3. Relocated the articulating portable foot restraint (APFR); and
4. Retrieved the rectangular scoop tool (get-ahead task for next mission).

The tasks completed during the second EVA were as follows:

1. Installation of handrails on the U. S. Laboratory; and
2. Installation of S0 cable.

Extravehicular mobility unit (EMU) checkout was completed with both units performing nominally. The two EMUs were ready to support the two extravehicular activities (EVAs) that were planned for this flight. The backup unit, EMU 3, was transferred to the Shuttle prior to closing the hatch between the vehicles.

A fit check was performed on the ground of the Kentaver g-suit with the usual complement of entry and landing garments. Cooling was determined to be adequate, even with the added thickness of the Kentaver g-suit. No discomfort or interference with operations was noted.

After a 75-minute pre-breathe period, the first EVA began on schedule at 228:13:57 G.m.t. (05:16:47 MET). EMU performance during the EVA was excellent and no anomalies were noted. The early ammonia servicer (EAS) and two materials International Space Station experiments (MISSEs) were installed on the ISS. The EMUs were re-filled with water and new lithium hydroxide (LiOH) canisters were installed following the completion of the EVA.

After a nominal EVA preparation, EMU purge, and pre-breathe period, the second EVA began at 230:13:32 G.m.t. (07:16:32 MET). EMU performance during the EVA was excellent and no anomalies were noted. All planned EVA tasks were completed satisfactorily.

In support of the second EVA, the RMS translated both EVA crewmen to the U. S. Laboratory worksite with handrails and launch-to-activation (LTA) cable bags tethered to the RMS end effector. Following installation of the handrails and LTA cables on the U. S. Laboratory module, the RMS translated the two EVA crewmen back to the integrated cargo carrier (ICC) in the payload bay.

## REMOTE MANIPULATOR SYSTEM

The remote manipulator system (RMS) performed satisfactorily throughout the mission. A minor problem is discussed in the final paragraph that was caused by a circuit breaker on the Orbiter. No problems were identified for the RMS.

The RMS was powered up at 223:17:21:42 G.m.t. (00:20:11:28 MET) and uncradled at 223:17:36:00 G.m.t (00:20:25:46 MET). RMS checkout was performed and completed at 223:18:30:00 G.m.t. (00:21:19:46 MET). Following the checkout, a payload bay survey was performed. The RMS was cradled and power down at 223:19:22:30 G.m.t. (00:22:12:16 MET).

Berthing of the MPLM to the ISS was successfully completed. At 225:12:18 G.m.t. (02:15:07:46 MET), the RMS was powered up and uncradled in preparation for MPLM unberthing and installation operations. The RMS successfully grappled the MPLM at 225:12:52 G.m.t. (02:15:41:46 MET), unberthed it from the payload bay and moved it to the pre-installation-position at 225:14:51:30 G.m.t. (02:17:41:16 MET). The MPLM was installed to the Node at 225:15:45:51 G.m.t. (02:18:35:37 MET). The RMS was ungrappled from the MPLM and was cradled and latched at 225:16:30 G.m.t (02:19:19:46 MET). The RMS performance was nominal.

The RMS was powered and uncradled in preparation for the first EVA operations. The RMS was used to move the EAS from the payload bay to the ISS as well as provide support to the crew.

In support of the second EVA, the RMS translated both EVA crewmen to the U. S. Laboratory worksite with handrails and launch-to-activation (LTA) cable bags tethered to the RMS end effector. Following installation of the handrails and LTA cables on the U. S. Laboratory module, the RMS translated the two EVA crewmen back to the integrated cargo carrier (ICC) in the payload bay. Following completion of EVA activities, the RMS was cradled and powered down at 230:19:07 G.m.t. (07:21:56 MET). The RMS operation was nominal throughout the EVA.

Un-berthing of the MPLM from the ISS and returning it to the Orbiter payload bay was successfully completed. The RMS was used to support the MPLM un-berthing operations. The RMS operation was nominal throughout the MPLM operations.

At 232:16:43 G.m.t. (09:19:32:46 MET) during the stowing of the RMS manipulator positioning mechanisms (MPMs), the motors drove dual motor time; however, motor 2 had phase A missing. When the MPM was deployed, all three phases were present. The most probable cause of the phase A failure is a contaminated AC2 mid-motor-controller assembly (MMCA) 2 circuit-breaker contact. All of the motors powered by the AC2 MMCA 2 bus will operate on two phases. Since no operational capabilities were lost, the affected circuit breaker was not cycled during flight in an attempt to clean the contacts. The circuit breaker was cycled five times after landing and the loss of phase A was corrected.

## GOVERNMENT FURNISHED EQUIPMENT/FLIGHT CREW EQUIPMENT

The government furnished equipment/flight crew equipment (GFE/FCE) performed nominally during the mission. No in-flight anomalies were identified; however, a number of minor problems were noted and these are discussed in the following paragraphs.

Following the flight day (FD) 2 checkout of the Orbiter space vision system (OSVS), the crew reported that several numeric digits were missing on the OSVS camera-aiming steering display. The same data downlinked to the Mission Control Center (MCC) was nominal. The problem was traced to the file associated with the graphics display, and was caused by the use of default-parameter values instead of the flight-specific values. The problem was limited to the digital data on the steering displays as the graphics and systems display data were nominal. The crew was instructed to use the graphics cues and systems display data for the FD 4 multi-purpose logistics module (MPLM) installation and its performance was nominal.

The trajectory control sensor (TCS) operated nominally with the following exception during the rendezvous tools checkout. During TCS checkout, several internal power supply under-voltage messages were annunciated to the crew. Telemetry from the TCS appeared nominal. Review of the data indicates that the actual power supply voltage, although closer than normal to the lower limit, was above the limit. It has been determined that the under-voltage annunciations were caused by the control firmware performing the limit checking with the incorrect lower-limit value. The incorrect limit value results from a round-off error in the software.

During the ISS rendezvous and docking, the TCS operated nominally. The TCS was activated and initialized at a range of approximately 7 miles from the ISS at 224:16:55 G.m.t. (01:19:45 MET). The unit provided accurate range and range-rate data throughout its operational period.

The TCS was used following undocking and performed nominally. The TCS provided valid data throughout the flyaround activities and to a range of 598 ft. At that range, the TCS lost track and was deactivated.

Camera D had a dark smudge on the lens that changed in size as the zoom was changed as well as rotating with the focus changes. The condition did not impact operations.

## POSTLAUNCH LAUNCH PAD INSPECTION

The postlaunch inspection of the mobile launch platform-3 (MLP-3), launch pad A fixed service structure (FSS) and rotating service structure (RSS) was completed within 3.5 hours of launch. No flight hardware was found, and the overall damage to the launch complex was minimal. Likewise, minimal debris was noted on or near the pad apron and FSS.

The Orbiter lift-off lateral acceleration data, which was used to determine if stud hang-ups had occurred, indicated that no SRB holddown stud hang-up had occurred. Evaluation of the MLP zero-level was performed and the south holddown studs were visually assessed as having no indication of stud hang-up. Erosion was typical on the north posts with some evidence of missing room temperature vulcanizing (RTV) material at the holddown post interface with the launch. The north holddown post blast covers and T-0 umbilical exhibited minimal exhaust plume damage.

The liquid oxygen (LO<sub>2</sub>) and liquid hydrogen (LH<sub>2</sub>) tail service masts (TSMs) appeared undamaged and the LO<sub>2</sub> bonnet had closed properly. The MLP deck was in generally good condition; however, a section of MLP handrail on the west side was bent and had loose bolts. The camera located on the east side of the MLP received extensive launch damage but no hardware was missing. All MLP deck communications connector caps were intact and secured.

The gaseous hydrogen (GH<sub>2</sub>) vent line latched in the eighth of eight teeth of the latching mechanism. The ground umbilical carrier plate (GUCP) 7-inch quick disconnect sealing surface exhibited no damage. The deceleration cable was in nominal configuration with the vent line blanket sooted but in generally good condition.

The Orbiter access arm (OAA) was intact with no evidence of plume impingement. All slide-wire baskets were secured with no evidence of damage.

The gaseous oxygen vent arm, hood, ducts and structure were in generally good shape with no indications of plume damage.

The debris findings were:

1. A piece of twisted sheet metal that was 10 feet long by 18 inches wide was found near the box car area; and
2. An air conditioning duct clamp was found on deck grating at the 175-foot level.

## **DEVELOPMENT TEST OBJECTIVES/DETAILED SUPPLEMENTARY OBJECTIVES**

### **DEVELOPMENT TEST OBJECTIVES**

**DTO 700-14 - Single String Global Positioning System** - The miniature air-to-ground receiver (MAGR) performance based on analysis of downlisted data was nominal with no unexpected or anomalous behavior observed. Overall, the Development Test Objective (DTO) provided valuable information this mission.

At approximately 224:00:00 G.m.t. (01:02:49:46 MET), the Miniature Air-to-Ground Receiver-Shuttle (MAGR/S) hardware channel 5 began experiencing difficulty completing Y-code/L1 frequency satellite acquisitions. This caused the channel to mode to coarse-mode tracking only. The data signature was consistent with an anomaly discovered during Avionics Development Laboratory (ADL) testing. In ADL tests, the problem was successfully cleared with a MAGR-mode transition. The observance of the satellite tracking difficulty anomaly confirmed that this anomaly was not just a laboratory-related condition. The MAGR-mode transition was performed at 226:19:07:16 G.m.t. (03:21:57:02 MET), and this successfully cleared the condition. The exact cause of the condition has not been identified but initial indications are that the condition is related to poor satellite signal conditions (i.e., ISS blockage) at Global Positioning System (GPS) end-of-week rollover. The MAGR continued to perform nominally following the second end-of-week rollover of the mission. A fix for the anomaly is, however, being actively pursued.

**DTO 701 - Space Vision Laser Camera System** - The Space Vision Laser Camera System (SVLCS) objectives for the mission were accomplished. The laser made a high-resolution scan of the International Space Station (ISS) structure. The SVLCS was also used to track targets on the Multi-Purpose Logistics Module (MPLM) prior to and during the unberthing operations from the ISS. The SVLCS appeared to switch to its secondary data interface, which resulted in slightly slower data acquisition. The SVLCS also experienced an apparent lock-up that was cleared by performing a reboot of both the controller and the camera head.

**DTO 805 - Crosswind Landing Conditions** - The crosswinds did not meet the minimum criteria for this DTO; consequently, the DTO of opportunity was not performed.

### **DETAILED SUPPLEMENTARY OBJECTIVES**

**DSO 498 - Spaceflight and Immune Function** - Samples were collected from the crew during the preflight and postflight periods as planned. The results will be reported in other documentation when the postflight analysis is complete.

**DSO 635 - Spatial Reorientation Following Spaceflight** - Samples were collected from the crew during the preflight and postflight periods as planned. The results will be reported in other documentation when the postflight analysis is complete.

### **HITCHHIKER EXPERIMENTS ADVANCING TECHNOLOGY**

The landing of STS-105 marked the end of a very successful mission for the Hitchhiker Experiments Advancing Technology (HEAT) payload. HEAT was comprised of the SimpleSat ejectable satellite, the Advanced Carrier Equipment (ACE) avionics system, Get Away Special (GAS) payload 774 (G-774) and the Space Experiment Module (SEM).



The SimpleSat is an engineering test satellite designed to evaluate the use of inexpensive commercial hardware on board a spacecraft. After the Orbiter undocked from the ISS on flight day (FD) 11, the crew executed a flawless deployment of the Simple-Sat satellite. The nominal deployment met 100 percent of the SimpleSat STS-105 mission success criteria. SimpleSat will orbit the Earth for approximately 5 months before atmospheric drag will cause it to reenter.

The ACE was designed as an enhancement and eventual replacement for the existing Hitchhiker (HH) avionics as the power and data interface to the Orbiter electronics for HH payloads. The ACE provides the same services and electrical interfaces as the HH avionics, but with enhancements and system redundancy. This mission was the first flight of the ACE assembly. Over the course of the 12-day flight, ACE met the mission success objectives. The ACE operators exercised both Hitchhiker central units (HCUs) of the new avionics in many modes and at four different data rates (8 kbps, 16 kbps, 32 kbps and 2 Mbps). In addition to the on-orbit objectives, STS-105 provided the opportunity to demonstrate the functionality of the upgraded Advanced Carrier Customer Equipment Support System (ACCESS) ground system for supporting ACE operations. These demonstrations included, but were not limited to, command generation, telemetry receipt, telemetry page displays, and the LR and MR analysis.

The STS-105 crew successfully commanded the operations of the G-774 payload with no anomalies. This GAS experiment had the objective of validating the model for theoretical predictions of smolder propagation, and thereby enhance the understanding of the smolder hazard. The SEM canister was comprised of passive experiments requiring no crew interaction.

## **PHOTOGRAPHY AND TELEVISION ANALYSIS**

A total of eleven 16 mm films, nine 35 mm films and 22 launch videos were screened. No anomalies were identified during the review and evaluation. The film of the External Tank (ET) taken with the three cameras in the umbilical wells was also reviewed and no anomalous conditions were noted in that photography. The landing videos were also reviewed and no anomalous conditions were noted.

A separate report, which contains a detailed discussion of the evaluation, is published by JSC photographic personnel and may be obtained from those personnel.

**TABLE I.- STS-105 SEQUENCE OF EVENTS**

<b>Event</b>	<b>Description</b>	<b>Actual time, G.m.t.</b>
APU Activation	APU-1 GG chamber pressure APU-2 GG chamber pressure APU-3 GG chamber pressure	222:21:05:25.808 222:21:05:27.706 222:21:05:29.578
SRB HPU Activation <sup>a</sup>	LH HPU System A start command LH HPU System B start command RH HPU System A start command RH HPU System B start command	222:21:09:45.989 222:21:09:46.149 222:21:09:46.309 222:21:09:46.469
Main Propulsion System Start <sup>a</sup>	ME-3 Start command accepted ME-2 Start command accepted ME-1 Start command accepted	222:21:10:07.474 222:21:10:07.578 222:21:10:07.695
SRB Ignition Command (Liftoff)	Calculated SRB ignition command	222:21:10:14.019
Throttle up to 104.5 Percent Thrust <sup>a</sup>	ME-1 Command accepted ME-3 Command accepted ME-2 Command accepted	222:21:10:17.974 222:21:10:17.993 222:21:10:17.997
Throttle down to 72 Percent Thrust <sup>a</sup>	ME-1 Command accepted ME-3 Command accepted ME-2 Command accepted	222:21:10:43.414 222:21:10:43.434 222:21:10:43.438
Throttle up to 104.5 Percent Thrust <sup>a</sup>	ME-1 Command accepted ME-3 Command accepted ME-2 Command accepted	222:21:11:06.134 222:21:11:06.154 222:21:11:06.158
Maximum Dynamic Pressure (q)	Derived ascent dynamic pressure	222:21:11:15
Both RSRM's Chamber Pressure at 50 psi <sup>a</sup>	RH SRM chamber pressure mid-range select LH SRM chamber pressure mid-range select	222:21:12:11.419 222:21:12:11:459
End RSRM <sup>a</sup> Action <sup>a</sup> Time	LH SRM chamber pressure mid-range select RH SRM chamber pressure mid-range select	222:21:12:13.929 222:21:12:13:989
SRB Physical Separation <sup>a</sup>	LH rate APU turbine speed - LOS	222:21:12:16.019
SRB Separation Command	SRB separation command flag	222:21:12:17
Throttle Down for 3g Acceleration <sup>a</sup>	ME-1 command accepted ME-3 command accepted ME-2 command accepted	222:21:17:38.775 222:21:17:38.801 222:21:17:38.802
3g Acceleration	Total load factor	222:21:17:46.5
Throttle Down to 72 Percent Thrust <sup>a</sup>	ME-1 command accepted ME-3 command accepted ME-2 command accepted	222:21:18:34.135 222:21:18:34.162 222:21:18:34.163
SSME Shutdown <sup>a</sup>	ME-1 command accepted ME-3 command accepted ME-2 command accepted	222:21:18:40.615 222:21:18:40.642 222:21:18:40.643
MECO	MECO command flag MECO confirm flag	222:21:18:41 222:21:18:42
ET Separation	ET separation command flag	222:21:19:00
APU Deactivation	APU-1 GG chamber pressure APU 2 GG chamber pressure APU 3 GG chamber pressure	222:21:24:54.480 222:21:24:59.672 222:21:25:04.446

<sup>a</sup>MSFC supplied data

**TABLE I.- STS-105 SEQUENCE OF EVENTS  
(Continued)**

<b>Event</b>	<b>Description</b>	<b>Actual time, G.m.t.</b>
OMS-1 Ignition	Left engine bi-prop valve position Right engine bi-prop valve position	Not performed - direct insertion trajectory flown
OMS-1 Cutoff	Left engine bi-prop valve position Right engine bi-prop valve position	Not performed
OMS-2 Ignition	Left engine bi-prop valve position Right engine bi-prop valve position	222:21:48:48.0 222:21:48:48.1
OMS-2 Cutoff	Right engine bi-prop valve position Left engine bi-prop valve position	222:21:49:51.6 222:21:49:51.7
Payload Bay Doors (PLBDs) Open	PLBD right open 1 PLBD left open 1	222:22:52:01 222:22:53:20
OMS-3 Ignition	Right engine bi-prop valve position Left engine bi-prop valve position	223:00:56:16.4 223:00:56:16.5
OMS-3 Cutoff	Right engine bi-prop valve position Left engine bi-prop valve position	223:00:57:12.0 223:00:57:12.1
OMS-4 Ignition	Left engine bi-prop valve position Right engine bi-prop valve position	N/A 223:23:23:07.4
OMS-4 Cutoff	Left engine bi-prop valve position Right engine bi-prop valve position	N/A 223:23:23:21.0
OMS-5 Ignition	Left engine bi-prop valve position Right engine bi-prop valve position	224:13:44:58.3 224:13:44:58.4
OMS-5 Cutoff	Left engine bi-prop valve position Right engine bi-prop valve position	224:13:46:44.3 224:13:46:44.4
OMS-6 Ignition	Left engine bi-prop valve position Right engine bi-prop valve position	224:14:37:36.3 224:14:37:36.4
OMS-6 Cutoff	Left engine bi-prop valve position Right engine bi-prop valve position	224:14:38:42.3 224:14:38:42.4
OMS-7 Ignition	Left engine bi-prop valve position Right engine bi-prop valve position	224:16:16:34.1 N/A
OMS-7 Cutoff	Left engine bi-prop valve position Right engine bi-prop valve position	224:16:16:49.3 N/A
OMS-8 Ignition	Left engine bi-prop valve position Right engine bi-prop valve position	224:20:40:14.1 N/A
OMS-8 Cutoff	Left engine bi-prop valve position Right engine bi-prop valve position	224:20:40:27.7 N/A
Initial ISS Contact	Initial contact	224:18:41:42
Docking with ISS	Docking ring final position	224:19:04:13
Cabin Depressurization (end)	Cabin pressure	224:22:45:23
First Reboost Maneuver (start)	As reported	226:17:58:26
Airlock Depressurization (end)	Airlock differential pressure no. 1	228:13:53:39
Begin First Extravehicular Activity	Airlock differential pressure no. 1	228:13:57
Cabin Repressurization (start)	Cabin pressure	228:15:00:21
End Second Extravehicular Activity	Airlock differential pressure no. 1	228:20:14
Airlock Repressurization (start)	Airlock differential pressure no. 1	228:20:14:26
Cabin Depressurization (end)	Cabin pressure	228:20:25:15
Cabin Repressurization (start)	Cabin pressure	228:20:46:39
Second Reboost Maneuver (start)	As reported	229:12:12:27

**TABLE I.- STS-105 SEQUENCE OF EVENTS  
(Continued)**

<b>Event</b>	<b>Description</b>	<b>Actual time, G.m.t.</b>
Cabin Depressurization (end)	Cabin pressure	229:22:35:21
Airlock Depressurization (end)	Airlock differential pressure no. 1	230:13:39:14
Begin Second Extravehicular Activity	Airlock differential pressure no. 1	230:13:32
Cabin Repressurization (start)	Cabin pressure	230:15:09:29
End Second Extravehicular Activity	Airlock differential pressure no. 1	230:19:04
Airlock Repressurization (start)	Airlock differential pressure no. 1	230:19:12:15
Cabin Repressurization (start)	Cabin pressure	230:20:07:59
Undocking from ISS	Undock complete	232:14:51:26
ISS Separation Maneuver (RCS)	As reported	232:16:11:30.6
Flight Control System Checkout		
APU Start	APU 1 GG chamber pressure	233:11:21:06.617
APU Stop	APU 1 GG chamber pressure	233:11:25:34.066
Payload Bay Doors Close	PLBD left close 1 PLBD right close 1	234:12:58:06 234:12:59:59
APU Activation for Entry	APU-2 GG chamber pressure APU-1 GG chamber pressure APU-3 GG chamber pressure	234:17:10:20.787 234:17:38:24.058 234:17:38:26.690
Deorbit Burn Ignition	Left engine bi-prop valve position Right engine bi-prop valve position	234:17:15:23.2 234:17:15:23.3
Deorbit Burn Cutoff	Left engine bi-prop valve position Right engine bi-prop valve position	234:17:18:36.1 234:17:18:36.2
Entry Interface (400K feet)	Current orbital altitude above	234:17:51:15
Blackout end	Data locked (high sample rate)	No blackout
Terminal Area Energy Management	Major mode change (305)	234:18:16:38
Main Landing Gear Contact	LH main landing gear tire pressure 1 RH main landing gear tire pressure 2	234:18:22:59 234:18:22:59
Drag Chute Deployment	Drag chute jettison 1 CP Volts	234:18:23:01.4
Main Landing Gear Weight on Wheels	LH MLG weight on wheels RH MLG weight on wheels	234:18:23:05 234:18:23:05
Nose Landing Gear Contact	NLG LH tire pressure 1	234:18:23:10
Nose Landing Gear Weight On Wheels	NLG weight on wheels 1	234:18:23:10
Drag Chute Jettison	Drag chute jettison 1 CP Volts	234:18:23:42.5
Wheel Stop	Velocity with respect to runway	234:18:24:05
APU Deactivation	APU-1 GG chamber pressure APU-2 GG chamber pressure APU-3 GG chamber pressure	234:18:39:44.205 234:18:39:48.770 234:18:39:53.493

TABLE II- STS-105 SPACE SHUTTLE VEHICLE ENGINEERING OFFICE IN-FLIGHT ANOMALY LIST

No.	Title	Reference	Comments
STS-105-V-01	Nose Wheel Steering (NWS) Switch Anomaly	233:11:41 G.m.t. 10:14:30 MET IPR 118V-0016	<p>During FCS checkout at approximately 233:11:41 G.m.t. (10:14:30 MET), when the crew took the NWS switch from NWS 1 to NWS 2, the crew reported that it felt like it went into the proper position, but the voltage indicated zero. The switch was pushed a little harder, lifting up on the switch a little as the crew pushed a little harder, and the switch went into the NWS position. After cycling the switch a couple of times, it felt normal. Telemetry confirmed that no NWS servo currents were seen with the first selection of NWS 2. The crew cycled the switch a total of five times and the servo currents were nominal during the cycles. Other than this one event, the NWS 1 and NWS 2 checkouts were nominal.</p> <p>It is suspected that this event was a "switch tease" and that the switch is functioning properly. However, the Commander was skeptical of that explanation so a mechanical evaluation of the switch was performed. The evaluation revealed that the switch felt nominal when cycled from off to the 1 or 2 position several times with and without the extension attached to the switch. However, the extension could travel or be forced, without much effort, vertically down on the switch enough to create a tendency for the switch to slip back into the 1 (center) position after having been physically cycled to the 2 or off position. When told of this event, the Commander stated that he did not believe the problem that was experienced was with the extension.</p> <p>KSC: KSC will perform further troubleshooting.</p>
STS-105-V-02	Loss of AC2 Phase A During MPM Stow	232:16:43 G.m.t. 09:19:32 MET IPR 118V-0007	<p>At 232:16:43 G.m.t. (09:19:32 MET) during the stowing of the Remote Manipulator System (RMS) manipulator positioning mechanisms (MPMs), the motors drove in dual motor time; however, motor 2 had phase A missing. When the MPM was deployed, all three phases were present. The most probable cause of the phase A failure was a contaminated AC2 mid-motor controller assembly (MMCA) 2 circuit breaker contact, although a failed contact on one of the relays in the MMCA could not be ruled out initially. The affected 3 phase AC circuit breaker (CB) is CB 7 on panel MA73C. The failed relays could have been on one of the two relays that forms the AC2 PPM2 bus or the relay that provides power to the MPM stow motor 2. All of the motors powered by the AC2 MMCA 2 bus will operate on two phases. Since no operational capabilities were lost, the affected circuit breaker was</p>

TABLE II- STS-105 SPACE SHUTTLE VEHICLE ENGINEERING OFFICE IN-FLIGHT ANOMALY LIST

No.	Title	Reference	Comments
STS-105-V-02 (Continued)	Loss of AC2 Phase A During MPM Stow (Continued)	232:16:43 G.m.t. 09:19:32 MET IPR 118V-0007 (Continued)	<p>not cycled in an attempt to clean the relay contacts. The port payload bay door drive motor 2, starboard aft bulkhead latch motor 2, and centerline hatch 13-16 motor 2 are also powered by AC2 MMCA 2. During the payload bay door closure, AC2 phase A current was missing from these motors. All payload bay door close and latch operations occurred in dual motor time. Additionally, the left vent door 3 motor 2 is powered by AC2 MMCA 2. It too had AC2 phase A current missing during vent door operations. This performance eliminated a failed relay as a potential cause of the problem.</p> <p>KSC: Prior to payload bay door opening in the Orbiter Processing Facility (OPF), the circuit breaker was cycled one time. During the payload bay door opening, phase A current was still missing from port payload bay door drive motor 2, starboard aft bulkhead latch motor 2, and centerline latch 13-16 motor 2. The circuit breaker was cycled a second time prior to a cycle of the left vent door 3 using motor 2. The second cycle of the circuit breaker recovered phase A current. The circuit breaker will be removed for fail.</p>

## DOCUMENT SOURCES

In an attempt to define the official as well as the unofficial sources of data for the STS-105 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-105 Summary of Significant Events
17. Contractor Reports of Subsystem Operation



## ACRONYMS AND ABBREVIATIONS

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

ACCESS	Advanced Carrier Customer Equipment Support System
ACE	Advanced Carrier Equipment
ADL	Avionics Development Laboratory
ADTA	air data transducer assembly
APCF	Advanced Protein Crystallization Facility
APCU	Assembly Power Converter Units
APFR	articulated portable foot restraint
APU	auxiliary power unit
ARPCS	atmospheric revitalization pressure control system
ARS	atmospheric revitalization system
ATCS	active thermal control system
BCSS	Biotechnology Cell Science Stowage
BITE	built-in test equipment
BSM	Booster Separation Motor
BTR	Biotechnology Refrigerator
CEI	contract end item
CPCG-H	Commercial Protein Crystal Growth-High Density
CRT	cathode ray tube
CWC	contingency water container
DCP	DEU control program
DCPCG-V	dynamically controlled protein crystal growth-vapor
DEU	display electronics unit
DFL	data-rate format
DSO	Detailed Supplementary Objective
DTO	Developmental Test Objective
$\Delta V$	differential velocity
EAS	early ammonia servicer
ECLSS	environmental control and life support system
e.d.t.	eastern daylight time
EI	entry interface
EMU	extravehicular mobility unit
EO	ET/Orbiter
EPDC	electrical power distribution and control
ET	External Tank
EVA	extravehicular activity
FBMBT	flexible bearing mean bulk temperature
FCMS	fuel cell monitoring system
FCP	fuel cell powerplant
FCS	flight control system/subsystem
FCV	flow control valve
FD	flight day
FEP	front end processor
FES	flash evaporator system
FOD	foreign object damage

FOM	figure of merit
FSS	Fixed Service Structure
ft/sec	feet per second
GAS	Get-Away Special
GFE	Government furnished equipment
GH <sub>2</sub>	gaseous hydrogen
G.m.t.	Greenwich mean time
GN <sub>2</sub>	gaseous nitrogen
GO <sub>2</sub>	gaseous oxygen
GPC	general purpose computer
GPS	Global Positioning System
GSE	ground support equipment
GUCP	ground umbilical carrier plate
HH	Hitchhiker
HCU	Hitchhiker central unit
HEAT	Hitchhiker Experiment Advancing Technology
HLS	Human Life Sciences
H-Reflex	Hoffman-Reflex
ICC	Integrated Cargo Carrier
ICD	Interface Control Document
IMU	inertial measurement unit
In/sec	inch per second
I/O	input/output
I <sub>sp</sub>	specific impulse
ISS	International Space Station
JSC	Johnson Space Center
keas	knots estimated air speed
KSC	Kennedy Space Center
kW	kilowatt
kWh	kilowatt/hour
lbf	pound force
lbm	pound mass
lb/min	pound per minute
LCC	Launch Commit Criteria
LDB	launch data bus
LH <sub>2</sub>	liquid hydrogen
LMSO	Lockheed Martin Space Operations
LO <sub>2</sub>	liquid oxygen
LP	Launch Package
LPS	Launch Processing System
LTA	launch-to-activation
LVLH	local vertical-local horizontal
MADS	Modular Auxiliary Data System
MAGR-S	Miniature Air to Ground Receiver-Shuttle
Max q $\alpha$	maximum dynamic pressure
MC	midcourse correction (rendezvous maneuver)
MCC	Mission Control Center
MECO	main engine cutoff
MET	mission elapsed time
MF	major frame

MIA	multiplexer input adapter
MISSes	Materials ISS experiments
MLE	middeck locker equivalent
MLP	Mobile Launch Platform
MLS	microwave landing system
MMCA	mid-motor controller assembly
mmHg	millimeter mercury
MPEV	manual pressure equalization valve
MPLM	Multi-Purpose Logistics Module
MPM	manipulator positioning mechanism
MPS	main propulsion system
MSFC	Marshall Space Flight Center
N <sub>2</sub>	nitrogen
NASA	National Aeronautics and Space Administration
NC1, NC2	circularization maneuvers (rendezvous maneuver)
NC3, NC4	circularization maneuvers (rendezvous maneuver)
nmi.	nautical mile
NPSP	net positive suction pressure
NWS	nose wheel steering
O <sub>2</sub>	oxygen
OAA	Orbiter Access Arm
ODS	Orbiter Docking System
OIU	Orbiter interface unit
OMM	Orbiter major modification
OMRSD	Operations and Maintenance Requirements and Specifications Document
OMS	orbital maneuvering subsystem
OSVS	Orbiter Space Vision System
OV	Orbiter Vehicle
PASS	primary avionics software system
PCG-EGN	Protein Crystal Growth-Enhanced Gaseous Nitrogen
PCS	pressure control system
PDI	payload data interleaver
PEC	Passive Experiment Carriers
PGME	Propylene Glycol Monomethyl Ether
PMA	pressurized mating adapter
PMBT	propellant mean bulk temperature
ppCO <sub>2</sub>	partial pressure carbon dioxide
ppm	parts per million
PRSD	power reactant storage and distribution
psia	pound per square inch absolute
QD	quick disconnect
RCS	reaction control subsystem
RF	radio frequency
RMS	Remote Manipulator System
RSP	Resupply Stowage Platforms
RSR	Resupply Return Stowage Rack
RSRM	Reusable Solid Rocket Motor
RSS	rotating service structure/range safety system
RTV	room temperature vulcanizing (material)
S&A	safe and arm

SEM	Space Experiment Module
SLF	Shuttle Landing Facility
SLWT	super lightweight tank
S/N	serial number
SMFIV	single-mission fuel isolation valve
SRB	Solid Rocket Booster
SRSS	Shuttle range safety system
SSME	Space Shuttle main engine
SSST	solid-state star tracker
SSV	sequential still video
STS	Space Transportation System
SVLCS	Space Vision Laser Camera System
SWAR	Sea water activated release
TACAN	Tactical Air Navigation
TCS	trajectory control sensor
TDRS	Tracking and Data Relay Satellite
TPS	thermal protection system/subsystem
TSM	tail service mast
V	Volts
WCL	water coolant loop
WCS	waste collection system
WSB	water spray boiler