

# **STS-97 SPACE SHUTTLE MISSION REPORT**

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February 2001



**National Aeronautics and  
Space Administration**

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

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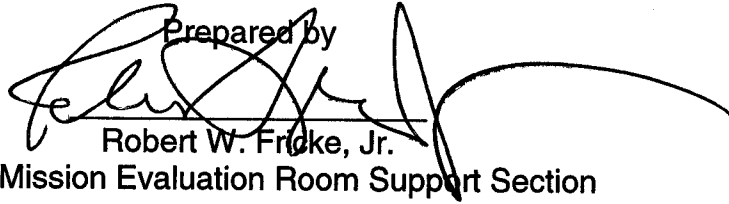
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STS-97

SPACE SHUTTLE

MISSION REPORT

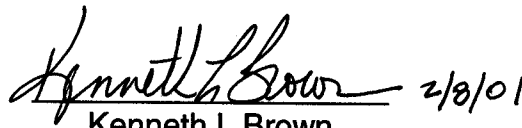
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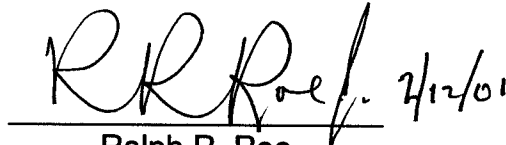
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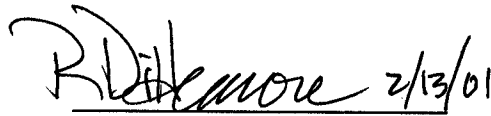
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## INTRODUCTION

The Space Transportation System (STS)-97 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-97 flight was the sixth mission to the International Space Station (ISS) to perform maintenance and logistics tasks.

The STS-97 report also summarizes the activities of the STS-97 mission, and presents 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 first mission of the Space Shuttle Program. STS-97 was the seventy-sixth flight since the return to flight, and the fifteenth flight of the OV-105 (Endeavour) vehicle. This flight delivered the heaviest (over 17 tons) and largest element thus far delivered to the ISS.

The flight vehicle consisted of the OV-105 Orbiter; an ET, which was the ninth Super Lightweight Tank (SLWT), and it was designated ET-105; three Block IIA SSMEs that were designated as S/Ns 2054, 2043, and 2049 in positions 1, 2, and 3, respectively; and two SRBs that were designated BI103. The two RSRMs were designated RSRM-72 with one installed in each SRB. The individual RSRMs were designated as 360L072A for the left SRB and 360L072B for the right SRB.

The primary objective of the STS-97 flight was to deliver and assemble the 4A launch package (LP) to the orbiting ISS Stage 3A. The P6 Integrated Truss Segment (ITS) includes the Photo Voltaic Module (PVM), the Integrated Electronic Assembly (IEA) with full battery complement, and the longer spacer with two Early External Active Thermal Control Systems (EEATCS). Additionally, the S-Band Antenna Structural Assembly (SASA) was relocated from the Z1 Truss to the outboard end of the IEA making the S-Band system operational. As a complex secondary payload, the IMAX cargo bay camera 3D objectives were to be performed in conjunction with the ISS activities.

The STS-97 flight was planned as a 11-day, plus 2-contingency-day flight. The two contingency days were available for bad 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.

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. All times during the flight are given in Greenwich mean time (G.m.t.) and mission elapsed time (MET).

The five-person crew of the STS-97 flight consisted of Brent W. Jett, CDR., U. S. Navy, Commander; Michael J. Bloomfield, Lt Col., U. S. Air Force, Pilot; Joseph R. Tanner, Civilian, Mission Specialist 1; Marc Garneau, M. D, Mission Specialist 2, and Carlos I. Noriega, Lt. Col. U. S. Marine Corp, Mission Specialist 3. STS-97 was the third space flight for the Commander, Mission Specialist 1, and Mission Specialist 2. STS-97 was the second space flight for the Pilot and Mission Specialist 3.

## MISSION SUMMARY

Also during the prelaunch operations, the Commander exercised the push-to-talk button on the rotational hand controller (RHC), but the push-to-talk function would not operate. However, the Commander was able to talk by engaging an alternate push-to-talk button on his suit. Because of the availability of the alternate function, the apparent switch failure did not impact the mission. All other functions of the RHC were tested successfully with the exception of the BFS push-button, which was not tested. This problem was not a constraint to the flight, and troubleshooting was performed during the postflight turnaround operations. The troubleshooting isolated the problem to the push-to-talk switch or the wiring inside the RHC. RHC replacement was scheduled and performed.

The STS-97 mission was launched on 10:03 p.m. e.s.t. on November 30, 2000, as planned with no unscheduled holds during the flawless countdown. The official time of launch was 336:03:06:00.986 G.m.t. The orbital maneuvering subsystem (OMS) assist maneuver was performed at 336:03:08:15.2 G.m.t. (00:00:02:14.2 MET) following Solid Rocket Booster (SRB) separation. The maneuver was 102.2 seconds in duration, and the OMS performed satisfactorily.

A determination of vehicle performance was made using vehicle acceleration and preflight propulsion prediction data. The average flight-derived engine specific impulse ( $I_{sp}$ ) was 453.2 seconds, which was the same as the SSME tag value at the 104.5-percent power level.

The OMS 2 maneuver was performed at 336:03:49:15.81 (00:00:43:15.8 MET) and was 78.2 seconds in duration. The differential velocity ( $\Delta V$ ) was 118.8 ft/sec, and the orbit was 106.2 by 175.1 nautical miles (nmi.) following the maneuver. The OMS performed satisfactorily throughout the maneuver.

The payload bay doors were opened at 336:04:37:56 G.m.t. (00:01:31:55 MET). All voltages were nominal and the motors opened the doors in nominal dual-motor time.

The OMS 3 maneuver for the rendezvous was performed using the right OMS engine. Ignition for the maneuver occurred at 336:06:49:16.2 G.m.t. (00:03:43:25.6 MET). The maneuver was 10.4 seconds in duration, and the  $\Delta V$  was 7.7 ft/sec. The resulting orbit was 110.6 by 175.1 nmi. OMS performance was nominal.

At 336:08:00:13 G.m.t. (00:04:54:12 MET), reaction control subsystem (RCS) thruster L5D was automatically deselected by the RCS redundancy management (RM) when the oxidizer injector temperature transducer output became erratic and fell below the RM fail leak limit of 130 °F. The fuel injector temperature was normal and remained steady; however, the oxidizer transducer continued to perform erratically throughout the mission. Because this condition has been observed on a number of previous missions and based on the fuel injector temperature, it was determined that this was an instrumentation problem and the thruster was operating properly. A preflight approved change to the vernier oxidizer injector temperature limit of 130 °F was up-linked to reduce the limit to 0 °F, and this restored vernier leak detection via the RCS RM. (Note: This action changed the oxidizer limit for all vernier thrusters.) This condition coupled with the failure of the thruster



F5R fuel injector temperature sensor (discussed in a later paragraph) did result in the loss of vernier thrusters later in the mission.

The successful checkout of the extravehicular mobility units (EMUs), the Simplified Aid for EVA Rescue (SAFER) units, the Remote Manipulator System (RMS), the Orbiter Space Vision System (OSVS), and the Orbiter Docking System (ODS) were all completed nominally during the course of Flight Day 2. The ODS centerline camera, which has experienced alignment difficulties during installation on recent flights, was installed with no misalignment noted. A payload bay survey using the RMS cameras was performed beginning at 336:20:21 G.m.t. (00:17:14 MET). Upon completion of the survey, the arm was cradled and powered down at 336:21:30 G.m.t. (00:18:23 MET).

During the detailed review of the motor drive data from ascent, the data showed that AC bus 1 phase A did not provide current to vent door 8 and 9 motor 1 during the prelaunch vent door repositioning at 336:03:05 G.m.t. Later, during the ET Door closing at 336:03:34 G.m.t. (00:00:27 MET), the AC bus 1 motors operated on phases B and C only. In both cases, the motor run time was nominal. During the earlier prelaunch operations of vent door 8 and 9 motor 1, all three phases worked properly. Both of these motors are powered from circuit breaker (4 on panel MA73C:D), which powers the AC1 aft motor control (AMC) 1 bus. This circuit breaker (CB) bus does not power any other motors. Loss of power to a single phase did not impact motor operation. If another phase feeding the same motor is lost, the motor will not operate; however, the redundant motor in the system will continue to drive the mechanism. Oxidation of the phase A contact in this 3-phase breaker is suspected, a condition which could possibly be cleared by cycling the breaker. No efforts to restore AC bus 1 AMC 1 phase A power were planned during the mission; however, the CB were cycled postlanding six times during postlanding operations and the CB operation was nominal following the cycling. The OMRSD allows five cycles to clear the problem; therefore, the decision was made to remove panel MA73C and send it to NASA Shuttle Logistics Depot (NSLD) for circuit breaker replacement.

The RCS NPC + X-axis rendezvous maneuver was performed at 336:18:42:39 G.m.t. (00:15:36:38 MET). The firing duration was 20.34 seconds and the  $\Delta V$  was 4.6 ft/sec.

The OMS 4 maneuver (NC3) for the rendezvous was performed using both OMS engines. Ignition for the maneuver occurred at 337:03:23:45.1 G.m.t. (01:00:17:44 MET). The maneuver was 52.1 seconds in duration, and the  $\Delta V$  was 80.0 ft/sec. The resulting orbit was 126.1 by 204.6 nmi. OMS performance was nominal.

The Orbiter successfully docked with the International Space Station (ISS) at 337:20:10 G.m.t. (01:17:03:59 MET). The docking was nominal. The brakes power-on time was 2 minutes 9 seconds and did not exceed the 5-minute limit. The ring was not extended to the forward position; instead retraction was initiated from the initial position. During retraction, the ring alignment indication remained off for most of the retraction. Petal 2 lagged by approximately 6 percent, but the lag was consistent, and petal 2 caught up at the end of the retraction.

The RMS was then used to remove the P6 truss from the payload bay beginning at 337:22:17 G.m.t. (01:19:10:59 MET) and maneuver the truss into an overnight park position to take advantage of better thermal conditions outside of the payload bay while awaiting truss installation. The hatch between the Orbiter and Pressurized Mating Adapter (PMA) 3 was opened at 338:00:22:01 G.m.t. (01:21:16 MET), and the process of loading

ISS transfer items, including two filled contingency water containers (CWCs) into the PMA was started. The Orbiter/PMA hatch was closed prior to Shuttle crew sleep, and the ISS crew removed the transfer items stowed in it during the following ISS crew day.

The following table shows the rendezvous maneuvers that were performed.

Maneuver	Time, G.m.t./MET	$\Delta V$ , ft/sec	Firing time, sec	Orbit, nmi.
NCC (Multi-axis RCS)	337:16:35:01 001:13:29:00	1.0	4	196.4 x 204.4
TI (Left OMS)	337:17:32:44.4 001:14:26:43	6.0	7.6	199.9 x 204.8
MC-1 (+X RCS)	337:17:52:43 001:14:46:42	1.1	5.0	199.6 x 204.7
Planar Null	337:18:12:52 001:15:06:51	-	1.0	-
MC-2 (Multi-axis RCS)	337:18:29:36 001:15:23:35	2.7	10.3	199.9 x 204.5
MC-3 (+X RCS)	337:18:46:36 001:15:40:35	0.9	4.0	200.5 x 206.0
MC-4 (Multi-axis RCS)	337:18:56:36 001:15:50:35	1.4	6.0	201.3 x 205.5

Some difficulties were experienced when ground controllers attempted to command payload bay camera B and the Laser Dynamic Range Imager (LDRI), which is attached to camera B. The crew was able to successfully command camera B and the LDRI using nominal on-board procedures. Postflight investigation into this condition will determine whether a system problem or procedure caused the behavior.

At 338:02:23:01 G.m.t. (01:23:17 MET), the wastewater tank quantity gage data dropped from 54-percent to as low as zero and was erratic for about 27 seconds. A second dropout occurred at 343:00:25:01 G.m.t. (01:23:17 MET). This problem is believed to be associated with minor contamination of the quantity gage potentiometer and did not impact wastewater tank usage.

The RMS was used to successfully mate the P6 truss to the ISS, beginning with the RMS maneuver from the overnight park position at approximately 338:15:53 G.m.t. (02:12:47 MET) and continuing until the P6 grapple fixture was released at 338:20:17 G.m.t. (02:17:11 MET). Nominal RMS operations continued throughout the extravehicular activity (EVA) that is discussed in a following paragraph. The RMS was powered down after the completion of the EVA support operations.

The supply water tank B quantity transducer data exhibited a quantity dropout at approximately 338:17:59:05 G.m.t. (02:14:53:05 MET). The dropout occurred at a tank quantity of approximately 93 percent and lasted for approximately 5 seconds. The dropout appeared as a 10 percent shift downward and then a return to normal. The initial evaluation of this condition indicates that minor contamination may be present in the quantity gage potentiometer, and this does not impact normal supply water tank usage.

The first STS-97 EVA began at 338:18:34 G.m.t. (02:15:28 MET) when the suits were transferred to internal battery power. The EVA was completed 7 hours and 33 minutes later at 339:02:07 G.m.t. (02:23:00 MET). Minor issues occurring during the EVA included a torn cuff checklist on the EV2 crewmembers' extravehicular mobility unit (EMU), sluggish retract operation of a safety tether reel, inadvertent opening of an EVA equipment tether hook, and a low-torque indication on a pistol grip tool (PGT).

Owing to the incomplete deployment of the solar arrays on the P6 truss on Flight Day 4, while the Orbiter was controlling the mated vehicle stack attitude control was restricted to vernier thruster operations only. Primary thruster attitude control modes that would have been available had the deployment been completed could not be used in this off-nominal configuration. Had the Orbiter lost vernier attitude control for any reason, the ISS would have assumed attitude control of the mated vehicle.

At 339:12:51 G.m.t. (03:09:45 MET), aft power converter unit (APCU) 2 tripped off line. Review of the data indicated that the Orbiter buses were good and that there had been no large load shifts on the Orbiter or the aft power converter (APC) buses. The APCU can trip off due to sensing a low output voltage (less than 115 V for 55 msec) or due to sensing a low input voltage (22 to 24 V instantaneous trip). It is believed that one of these circuits may have caused a false trip. At 339:14:42 G.m.t. (03:11:36 MET), APCU 2 was re-powered with no problems. Approximately 4 hours later, at 339:16:48 G.m.t. (03:13:42 MET), APCU 1 shut down for approximately 10 seconds, then returned to nominal power output levels without any intervention from the crew or the ground controllers. Both APCUs performed nominally after these events occurred.

At 339:18:14 G.m.t. (03:15:08 MET), the crew attempted to reconfigure from temperature controller 1 to the temperature controller 2. Upon removal of the pip pin from the primary controller and linkage, the crew reported the pin would not move within the linkage and control arm. No further attempt to remove the pin was made while on orbit, and operations were continued on controller 1 for the remainder of the flight. During postflight troubleshooting, KSC personnel determined that with the controller in the full-heat exchanger position, a preload is placed on the linkage that makes it difficult to remove the pin. With the controller positioned to the full-cool position, the pin is much easier to remove from the linkage and the controller arm. The flight controllers have been informed of the KSC findings in anticipation of modifying the procedure for future flights. In addition, the training personnel have been contacted to inform the crew the procedure is a two-hand operation. Two hands are required to remove the pin when the cabin temperature control valve is in the full-heat exchanger position.

The RMS was powered up at 339:18:12 G.m.t. (03:10:06 MET) to support viewing of the deployment of the ISS P6 truss 4B solar array wing (SAW). The arm was then maneuvered to the SAW viewing configuration to survey the P6 starboard forward and aft blankets as well as the tensioning mechanisms on the right and left solar array blanket box (SABB). RMS performance was nominal throughout this activity.

The second on-orbit fuel cell purge was performed at 340:13:18 G.m.t. (04:10:12 MET). During the 84-hour purge interval, nominal voltage decays of 0.18 Vdc on fuel cell 1, 0.14 Vdc on fuel cell 2, and 0.11 Vdc on fuel cell 3 were experienced. The fuel cell monitoring system (FCMS) single-cell voltage data were recorded for 12 minutes. No changes from the acceptable data recorded during the prelaunch operations were noted.

The RMS was powered up at 340:16:55 G.m.t. (04:13:49 MET) to support the second EVA. RMS Operations included transfer of the S-band antenna structural assembly (SASA), mating of the P6 quick disconnect, and tasks involving pressurized mating adapter (PMA) 2, as well as viewing of the P6 radiator deployment. The arm performed nominally in support of all of these tasks, and was powered down at 341:02:08 G.m.t. (04:23:02 MET).

EVA 2 began at 340:17:21 G.m.t. (04:14:15 MET) when the EMUs were transferred to internal battery power. No significant EMU or EVA tool anomalies were noted during the EVA. Loss of the EV1 EVA Remote Camera Assembly (ERCA) function did not impact the EVA. Total EVA duration was 6 hours and 37 minutes.

The RMS was powered up and uncradled at 342:13:38 G.m.t. (06:10:32 MET) to support EVA 3 operations. The RMS was used to perform a survey of the PMA 2 connectors, to observe the repair work on the ISS solar array wing (SAW) tensioning mechanism, and to observe the installation of the floating potential probe (FPP). After completion of these tasks, the arm was cradled and powered down at 342:21:22 G.m.t. (06:18:16 MET). This completed all planned RMS operations for this mission.

The EMUs performed nominally in support of the third scheduled EVA. Total EVA duration was 5 hours and 9 minutes. During the EVA, an additional crew safety tether experienced sluggish retraction, a retractable tether cord failed, and the stowage pocket in the tool stowage assembly (TSA) for the needle nose pliers loosened and would no longer hold the tool in by friction. None of these problems with EVA tools had a significant impact on the accomplishment of the EVA tasks. The need for a fourth EVA no longer existed, owing to the success in repairing the ISS SAW tensioning mechanism as well as the completion of all of the nominally scheduled tasks for this EVA.

Orbiter and ISS pressure equalization and repressurization of the mated vehicle stack to 14.7 psia was completed at 343:14:18 G.m.t. (07:11:12 MET). The hatch between the pressurized mating adapter (PMA) and Node 1 was opened for ISS ingress at 343:14:36 G.m.t. (07:11:30 MET).

Data review determined that the vernier RCS thruster F5R fuel-injector temperature was not tracking the F5R oxidizer injector temperature as expected. When this thruster was fired, the fuel injector temperature measurement went off-scale high at a higher rate than the oxidizer injector temperature (Flight Problem STS-97-V-01). Also, during periods of thruster inactivity, the fuel injector temperature lagged behind the oxidizer injector temperature as the temperatures returned to the nominal range. This behavior is indicative of a temperature sensor problem, and thruster operation was not impacted by this condition. However, because the thruster leak detection limit had been disabled for all vernier thrusters as a result of the L5D oxidizer injector temperature sensor failure, this new problem rendered the on-board leak detection capability for F5R questionable.

In preparation for undocking, the ODS hatch was closed and vestibule depressurization was begun at 344:16:05 G.m.t. (08:12:59 MET). Undocking occurred at 344:19:13 G.m.t. (08:16:07 MET), and a fly-around of the ISS was initiated a short time later at 344:19:30 G.m.t. (08:16:24 MET). After completion of the fly-around, a two-thruster +X RCS final separation maneuver was performed at 344:20:16 G.m.t. (08:17:10 MET). The maneuver was 11.4 seconds in duration and the  $\Delta V$  delivered was 3.1 ft/sec. The resulting orbit was 204.5 by 197.5 nmi.

The Orbiter Ku-Band radar system performed nominally for undocking with the crew switching to the radar mode at 344:20:07 G.m.t. (08:17:01 MET). First lock-on occurred at a range of approximately 530 feet, and the system was used to track the ISS out to a range of approximately 1200 feet. The system was then switched back to communications mode at 344:20:23 G.m.t. (08:17:17 MET).

During undocking and separation from the ISS, vernier RCS thruster F5R was used extensively and the fuel and oxidizer injector temperatures remained off-scale high for approximately 90 minutes. When the thruster cooled down following this activity, the fuel-injector temperature, which had been exhibiting problems earlier in the flight but was usable, failed to drop below off-scale high, even after the oxidizer temperature indicated that the thruster had cooled sufficiently for its heater to come on. This behavior rendered automatic on-board leak detection ineffective for this thruster. This failure coupled with the loss of oxidizer leak detection because of the L5D thruster problem, lead to the loss of use of the vernier thrusters for the remainder of the flight, leaving the vehicle operating on primary thrusters. Since the Orbiter was no longer docked to the ISS, where vernier thruster attitude control was preferred, loss of vernier thruster availability had minimal impact.

The OMS 7 orbit adjustment maneuver was performed using both OMS engines. Ignition for the maneuver occurred at 345:01:39:56.6 G.m.t. (08:22:33:55 MET). The maneuver was 12.4 seconds in duration, and the  $\Delta V$  was 21.5 ft/sec. The resulting orbit was 198.1 by 189.7 nmi. OMS performance was nominal.

During the flight day 9 crew-sleep period, the ground discovered that closed circuit television (CCTV) camera C appeared to have a loose blanket on the rear surface of the camera. When the camera was pointed straight up, the camera blanket hung on the pan-tilt-unit bracket. The hang-up was cleared by repeatedly driving the camera through the area of interference. This problem had no impact on camera performance.

The flight control system (FCS) checkout was performed nominally, with no problems identified. Auxiliary power unit (APU) 1 (S/N 405) was used to support the checkout, with a start time of 345:15:42:08 G.m.t. (09:12:36:07 MET) and stop time of 345:15:46:21 G.m.t. (09:12:40:20 MET). The run time was 4 minutes, 13 seconds, and fourteen pounds of fuel were used during the APU operation. All APU parameters, including gas generator valve module (GGVM) and gas generator (GG) performance, as well as the chamber pressure (Pc) signature were nominal throughout the run, and there were no indications of bubbles during start-up. No gearbox repressurizations occurred, and the total run time was too short to require the water spray boiler (WSB) to provide spray cooling. Flight control avionics, instrumentation, and navigational hardware also performed as expected during the checkout.

After transition to OPS 8 for FCS checkout, the air data transducer assembly (ADTA) 4 annunciated a Discrete Input Good built in test equipment (BITE) failure and a ADTA Good fail. ADTA 4 did not respond to the self-test command. The problem was cleared with an onboard computer command. Subsequent high and low self-tests were nominal on ADTA 4. This problem has been seen during power-up on this unit during preflight testing. The BITE reappeared at the power-up of ADTA during entry; however, ADTA performance during entry was nominal.

Following FCS checkout, the RCS hot fire was performed without incident. The hot fire began at 345:16:34 G.m.t. (09:13:28 MET) and ended at 345:16:43 G.m.t. (09:13:37 MET). A review of thruster chamber pressure data confirmed that all firings were good, with each thruster receiving two 320-millisecond duration pulses.

In preparation for landing, Ku-Band communications were terminated, and the antenna was stowed at 346:00:47 G.m.t. (09:21:41 MET).

The right main landing gear outboard tire pressure transducer became erratic at approximately 346:17:29:01 G.m.t. (10:14:23:00 MET) and eventually failed off-scale low. The loss of this measurement did not impact the successful completion of the flight.

The payload bay doors were closed and latched for landing at 346:19:17:09 G.m.t. (10:16:11:08 MET).

The deorbit maneuver for the first KSC landing opportunity at the Shuttle Landing Facility, a two-engine straight-feed firing, was performed on orbit 170 at 346:21:57:31.2 G.m.t. (10:18:51:30 MET). The maneuver was 161.6 seconds in duration with a  $\Delta V$  of 311.6 ft/sec.

The APU 1 exhaust gas temperature (EGT) 1 and 2 measurements were both erratic from 346:23:01:01 G.m.t. (10:19:55:00 MET) to 346:23:06:01 G.m.t. (10:20:00:00 MET). Following this period of erratic operation, the measurements performed satisfactorily for the remainder of entry.

Entry interface (EI) occurred at 346:22:32:01.6 G.m.t. (10:19:26:00.5 MET), and entry was completed satisfactorily. Main landing gear touchdown occurred on KSC concrete runway 15 at 346:23:03:23 G.m.t. (10:19:57:22 MET) on December 11, 2000. The drag chute was deployed at 346:23:03:27 G.m.t. The nose gear touchdown occurred at 346:23:03:35 G.m.t. The drag chute was jettisoned at 346:23:03:53 G.m.t. Wheels stop occurred at 346:23:04:20 G.m.t. The rollout was normal in all respects. The flight duration was 10 days 19 hours 57 minutes 22 seconds. The three APUs were shutdown 18 minutes 57 seconds after landing.

## **PAYLOADS AND EXPERIMENTS**

The STS-97 mission enhanced the capabilities of the International Space Station (ISS) by delivering the first set of U.S.-provided solar arrays and batteries, called the P6 photovoltaic module (PVM) and temporarily installing the P6 integrated truss structure (ITS) on the Z1 truss. The ITS will remain attached to the Z1 truss until a later Shuttle mission relocates to its permanent position on the P5 truss. The P6 Integrated Truss Structure was the primary payload of the STS-97 mission.

A total of 11 major categories of mission priorities were defined for the STS-97 mission:

1. Rendezvous and dock with ISS;
2. P6 truss physical installation to Z1 truss;
3. Activation of P6 truss to ensure minimal survival;
4. Critical logistics transfers;
5. ISS electrical power system (EPS) reconfiguration to provide power to the U. S. and Russian Segment loads;
6. Mating of the Z1 truss to P6 truss early external thermal control system (EETCS) umbilicals and activation of the EETCS;
7. Scheduled tasks for future flights;
8. Completion of logistics transfers;
9. Loads validation Development Test Objectives (DTOs);
10. IMAX cargo bay camera (CBC) 3-dimension Imagery; and
11. Unscheduled get-ahead tasks for future flights.

All pre-mission-planned objectives/requirements were accomplished with the exception of the IMAX camera imagery. The Space Shuttle Program and ISS Program objectives were 100-percent successful in the completion of primary 4A tasks as well as the get-ahead tasks planned for later assembly missions. The accomplished IMAX camera objectives were at the most 21 percent of the planned because of a failure within the camera or film.

### **P6 INTEGRATED TRUSS STRUCTURE**

The P6 Integrated Truss Structure (ITS) was successfully mated to the ISS Z1 truss during the first extravehicular activity (EVA). The solar arrays were deployed; however, a tensioning anomaly occurred during the deployment of the 2B solar assembly that prevented the wing from being fully tensioned at that time. All of the necessary electrical connections were made, and electrical power was being provided to the ISS. During the third EVA, the wing was fully tensioned and operated properly.

Electrical power is the most critical resource for the ISS because it allows the crewmembers to live comfortably, safely operate the ISS, and perform complex scientific experiments. The generation of electrical power from the sunlight on the solar arrays provides the needed electricity. Large numbers of solar cells make up a solar array that produces electricity at high power levels. These cells are made from purified crystal ingots of silicon that directly converts light into electricity through a process call photovoltaics. Since the ISS is not always in sunlight, rechargeable batteries are used to store electricity and provide a continuous source of power.

Each solar array wing is the largest-ever-deployed in space, weighing over 2,400 lb and using nearly 33,000 solar arrays that measure 8-cm square with 4100 diodes. Each wing is capable of generating 31 kW of direct current.

## **CARGO BAY PAYLOAD**

### **IMAX Cargo Bay Camera 3-Dimension**

The IMAX Cargo Bay Camera 3-Dimension (ICBC3D) successfully filmed 3 of the 14 expected sequences. These scenes were the approach to the International Space Station (ISS), unberthing of the P6 Integrated Truss Structure (ITS), and rotation of the P6 ITS on the Shuttle remote manipulator system (RMS). Three seconds into filming the fourth scene, the camera stopped filming. Subsequent attempts to arm the camera for filming were unsuccessful. The crew reported that the video image from the camera could not be seen on the payload and general support computer (PGSC) display. Other camera commands, such as window door open, lens select, and f/stop select continued to work correctly. The initial assessment was that a catastrophic stop, such as a film jam or break, had occurred and further filming operations could not be conducted. A last attempt to recover the filming capability was performed using the Override Run contingency procedure, but all indications confirmed that a film jam or break had occurred. No further camera operations were conducted.

The three scenes filmed are considered to be at serious risk because of the inability to meet the film temperature requirements. The reported ICBC3D temperatures were consistently well above 100 °F during the time when the attitude of the vehicle was X-axis perpendicular to the orbital plane (XPOP). Preflight plans to avoid these predicted excessive temperatures with maneuvers to the local vertical local horizontal (LVLH) attitude were unable to be executed because of power concerns.



## **VEHICLE PERFORMANCE**

### **SOLID ROCKET BOOSTERS**

All Solid Rocket Booster (SRB) systems performed nominally. The prelaunch countdown was normal, and no SRB Launch Commit Criteria (LCC) or Operational Maintenance Requirements and Specifications Document (OMRSD) violations occurred. One in-flight anomaly occurred and it is discussed in the final paragraph of the Solid Rocket Booster section of the report.

Power-up and operation of all igniter and field joint heaters were accomplished routinely. The heated, ground-supplied, aft-skirt purges maintained the case/nozzle joint and flex bearing temperatures within the required LCC ranges. These purges were switched to high flow during the T-3 hour hold.

Both SRBs were successfully separated from the vehicle approximately 123.924 seconds after liftoff. Radar tracking indicated a normal descent to splash down. Both SRBs floated and were retrieved and returned to KSC for inspection, disassembly, and refurbishment.

On this flight, four of the 48 sea-water activated release (SWAR) links on the main parachute risers failed to release upon contact with the ocean. The remaining 44 SWAR links released properly. A subsequent inspection showed that on the failed SWAR links had functioned but had not released. The failure mode of the remaining three SWAR links is being investigated.

The postflight inspection of the SRBs showed them to be generally in good condition. However, the postflight inspection revealed broaching on the holddown stud bores of holddown post 1. This broaching is consistent with the stud hang-up observed in the postlaunch film reviews. The broached areas are generally on the +Z side of the bore.

Additional damage was found on the right SRB antenna in the form of missing material to one corner. The cause of the damage could not be determined.

The disassembly of the left SRB revealed an unexpended pyrotechnic cartridge in one of the left aft lower strut (Flight Problem STS-97-B-001). The primary cartridge had not fired but the secondary cartridge had fired and caused a nominal separation to occur. Since this is a criticality 1R failure, an anomaly resolution team was formed to investigate this anomaly. This team found an open circuit on both conductors and the shield of the reusable ordnance cable caused the failure. The team further determined that the cause of the cable failure was handling damage. A final report of this team will be available from the Marshall Space Flight Center (MSFC).

### **REUSABLE SOLID ROCKET MOTOR**

The Reusable Solid Rocket Motors (RSRMs) performed as designed with no LCC or OMRSD violations during prelaunch operations. In addition, no in-flight anomalies were identified from the inspection and data review. Data indicate that the flight performance of both RSRMs was well within the allowable performance envelopes, and was typical of the performance observed on previous flights. The motor performance parameters for this

flight were within contract end item (CEI) specification limits. The propulsion performance is shown in the following table. The calculated propellant mean bulk temperature (PMBT) was 68 °F. The maximum trace shape variation of pressure versus time nominal during the 62 to 80 second time frame and was calculated as 0.77 percent at 68 seconds on the left motor, and 0.78 percent at 80 seconds on the right motor. The delivered burn rates of the RSRMs were nominal at 0.3696 in/sec for the left motor and 0.3700 in/sec for the right motor.

All RSRM temperatures were maintained within acceptable limits throughout the countdown.

The field joint heaters operated for 13 hours 40 minutes during the final launch countdown. Power was applied to the heating elements and average of 50 percent of the time during the LCC time frame. All field joint heaters operated as expected.

The igniter joint heaters operated for 18 hours 29 minutes during the final launch countdown. The igniter heaters were activated at L-18 hours because the ambient temperature at that time was less than 55 °F. Power was applied to the heating elements 66 percent of the time to keep the igniter joints in their normal operating range.

### RSRM PROPULSION PERFORMANCE

Parameter	Left motor, 68 °F		Right motor, 68 °F	
	Predicted	Actual	Predicted	Actual
Impulse gates				
I-20, 10 <sup>6</sup> lbf-sec	65.75	65.59	65.80	65.58
I-60, 10 <sup>6</sup> lbf-sec	175.90	174.78	176.03	175.51
I-AT, 10 <sup>6</sup> lbf-sec	297.15	296.64	297.30	297.64
Vacuum Isp, lbf-sec/lbm	268.5	268.0	268.5	268.8
Burn rate, in/sec @ 60 °F at 625 psia	0.3706	0.3696	0.3706	0.3700
Event times, seconds <sup>a</sup>				
Ignition interval	0.232	N/A	0.232	N/A
Web time <sup>b</sup>	108.7	109.1	108.6	109.1
50 psia cue time	118.7	119.3	118.7	118.9
Action time <sup>b</sup>	120.9	121.5	120.9	121.4
Separation command	123.1	123.7	123.1	123.3
PMBT, °F	68	68	68	69
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	3.0	3.1	3.6
Tailoff Imbalance Impulse	Predicted		Actual	
differential, Klbf-sec	N/A		513.4	

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).

The aft skirt purge was activated six times during the 72 hours of recorded data for a total of 25 hours 24 minutes. The last activation occurred during the final countdown with a duration of 11 hours 34 minutes. It was necessary to activate the aft skirt purge to maintain the nozzle/case joint temperatures above the minimum LCC temperature. During the LCC time frame, nozzle/case joint sensor temperatures ranged from 77 to 85 °F and 77 to 82 °F on the left and right motors, respectively. The final flex bearing mean bulk temperature (FBMBT) was determined to be 80 °F.

### **EXTERNAL TANK**

All External Tank (ET) objectives and requirements associated with propellant loading and flight operations were met. The ET performance was nominal with no in-flight anomalies identified from the data.

Initiation of tanking of the External Tank (ET) was delayed approximately 1.5 hours so that a loose bracket could be retrieved from the Orbiter Access Arm. The bracket is used to secure a fire-suppression water line mounted on the arm. The concern was that the bracket could come loose as a result of launch vibrations, and the bracket could impact the Orbiter wing.

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 monitored and performed properly, except a concern existed with the primary controller for the heated nose cone purge. As a result, control was switched to the secondary controller. No ET LCC or OMRSD violations occurred.

All ice conditions were acceptable. The observed cracks in the thermal protection system (TPS) were acceptable for flight with no repair required.

The no. 2 liquid hydrogen (LH<sub>2</sub>) 98-percent level sensor transducer indicated wet for 10 minutes during pressurization for the LH<sub>2</sub> slow-fill operations. The transducer recovered prior to the start of fast fill and read normally through the transition to the topping mode.

The pressurizations systems functioned properly throughout engine start and flight. ET separation was performed and since it occurred within expected tolerances, entry and break-up occurred within the expected footprint approximately 67 miles downrange from the preflight predicted impact point.

### **SPACE SHUTTLE MAIN ENGINE**

The Space Shuttle main engines (SSMEs) performed nominally throughout the flight with no anomalies noted. Prelaunch operations went smoothly with no SSME LCC or OMRSD violations occurring during the countdown. No in-flight anomalies were identified during the data evaluation process.

The flight derived  $I_{sp}$  was 453.2 seconds, which was the same as predicted prior to the flight. Main engine cutoff (MECO) occurred 511.73 seconds after main engine 1 ignition. Maximum dynamic pressure (Max q) throttle down was in one-step to 72 percent. Controller and software performance was nominal with no problems noted. A number of minor conditions were noted during the flight; however, none were significant in nature.

## SHUTTLE RANGE SAFETY SYSTEM

Shuttle Range Safety System (SRSS) closed loop testing was completed as scheduled during the launch countdown. All SRSS safe and arm (S&A) devices were armed and system inhibits turned off at the appropriate times. The system operated as expected throughout the countdown and the flight. As planned, the SRB S&A devices were safed and the SRB system power was turned off prior to SRB separation.

## ORBITER SUBSYSTEM PERFORMANCE

### Main Propulsion Subsystem

The main propulsion subsystem (MPS) performed satisfactorily throughout their operational portion of the mission. There were no LCC violations; however, one OMRSD occurred during the prelaunch period and it is discussed in the following paragraph. There were no MPS in-flight anomalies.

During prelaunch operations, the ET liquid hydrogen (LH<sub>2</sub>) 98-percent no. 2 sensor failed to the wet state for approximately 10 minutes before returning to the dry condition that was normal for that time frame and operated properly for the remainder of loading and closely tracked the 98-percent no. 2 sensor. The failure was an OMRSD violation only and had no LCC impacts. No other ET sensors associated with multiplexer/demultiplexer (MDM) OA1 card 07 channel 00 displayed anomalous performance that was concurrent with the ET point sensor failure. The MPS point sensor electronics package shares both power and checkout circuits with other sensor and ullage pressure circuits. A failure in the main propulsion subsystem (MPS) circuitry would normally propagate to other ET sensors or affect the ET ullage pressure circuits. No other ET instrumentation displayed any anomalous indications concurrent with the ET sensor failure. The most likely cause of the problem is a failure of the ET sensor itself. The LH<sub>2</sub> ET sensor had been pressurized for LH<sub>2</sub> loading and had undergone both a pressure and temperature cycle prior to failure. This type of failure is not uncommon to the ET point sensors as both a short or an open will cause the sensor to fail wet. The point sensor was bypassed in the LH<sub>2</sub> loading software. The software ignored this failed sensor and automatic transition to topping occurred based on indications from the LH<sub>2</sub> 99-percent sensor (1) and the LH<sub>2</sub> 100-percent minus sensor. However, to ensure that the problem is not in the Orbiter circuitry, postflight testing of the related Orbiter circuits will be required. This condition did not affect the launch or ascent performance.

Data from the prelaunch, main engine cutoff (MECO), post-MECO and entry/landing events revealed no anomalous valve movement. All timings were within the required specification and within the historical database.

The maximum hydrogen concentration level in the Orbiter aft compartment was 145 ppm. These data compare favorably with previous data for this vehicle.

Data show that the LO<sub>2</sub> and LH<sub>2</sub> pressurization systems performed as planned, and that engine inlet net positive suction pressure (NPSP) requirements were met throughout the flight. The gaseous oxygen (GO<sub>2</sub>) fixed orifice pressurization system performed as predicted. Reconstructed data from the engine and MPS parameters closely matched the actual ET ullage pressure measurements. Helium system performance was nominal.

### Reaction Control Subsystem

The reaction control subsystem (RCS) performed nominally throughout the mission. No LCC or OMRSD violations were noted prior to launch, and no failures of problems were noted during the countdown. No in-flight anomalies were noted during the data review and analysis. Two thruster problems, which are discussed in following paragraphs, occurred during the mission, but neither of these significantly impacted the mission.

At 336:08:00:13 G.m.t. (00:04:54:12 MET), RCS thruster L5D was automatically deselected by the redundancy management (RM) when the oxidizer injector temperature transducer output became erratic and fell below the RM fail leak limit of 130 °F. The fuel injector temperature was normal and remained steady; however, the oxidizer transducer continued to perform erratically throughout the mission. Because this condition has been observed on a number of previous missions and based on the fuel injector temperature, it was determined that this was an instrumentation problem and the thruster was operating properly. A preflight approved change to the vernier oxidizer injector temperature limit of 130 °F was up-linked to reduce the limit to 0 °F, and this restored vernier leak detection via the RCS RM. (Note: This action changed the oxidizer limit for all vernier thrusters.) This condition coupled with the failure of the thruster F5R fuel injector temperature sensor (discussed in a later paragraph) did result in the loss of vernier thrusters later in the mission. The L5D problem first occurred on STS-68 and has repeated itself four times in the last nine flights. The thruster was removed and replaced after STS-68. Troubleshooting has not been able to duplicate this anomaly since it first occurred.

The following table lists pertinent data concerning the RCS maneuvers.

Maneuver	Time, G.m.t./MET	$\Delta V$ , ft/sec	Firing time, sec	Orbit, nmi.
NC-1/NPC	336:18:42:39 00:15:36:39	4.6	20.34	--
NCC (Multi-axis RCS)	337:16:35:01 01:13:29:00	1.0	4	196.4 x 204.4
MC-1 (+X RCS)	337:17:52:43 01:14:46:42	1.1	5.0	199.6 x 204.7
Planar Null	337:18:12:52 01:15:06:51	-	1.0	--
MC-2 (Multi-axis RCS)	337:18:29:36 01:15:23:35	2.7	10.3	199.9 x 204.5
MC-3 (+X RCS)	337:18:46:36 01:15:40:35	0.9	4.0	200.5 x 206.0
MC-4 (Multi-axis RCS)	337:18:56:36 01:15:50:35	1.4	6.0	201.3 x 205.5
ISS Separation	345:16:34 09:13:28	3.1	11.4	--

Data review determined that during docked operations, the vernier RCS thruster F5R fuel-injector temperature was not tracking the F5R oxidizer injector temperature as expected. When this thruster was fired, the fuel injector temperature measurement went off-scale high at a higher rate than the oxidizer injector temperature (Flight Problem STS-97-V-01). Also, during periods of thruster inactivity, the fuel injector temperature lagged behind the

oxidizer injector temperature as the temperatures returned to the nominal range. This behavior is indicative of a temperature sensor problem, and thruster operation was not impacted by this condition.

During undocking and separation from the ISS, vernier RCS thruster F5R was used extensively and the fuel and oxidizer injector temperatures remained off-scale high for approximately 90 minutes. When the thruster cooled down following this activity, the fuel-injector temperature, which had been exhibiting problems earlier in the flight but was usable, failed to drop below off-scale high, even after the oxidizer temperature indicated that the thruster had cooled sufficiently for its heater to come on. This behavior rendered automatic on-board leak detection ineffective for this thruster. This failure coupled with the loss of oxidizer leak detection because of the L5D thruster problem, lead to the loss of use of the vernier thrusters for the remainder of the flight, leaving the vehicle operating on primary thrusters. Since the Orbiter was no longer docked to the ISS, where vernier thruster attitude control was preferred, loss of vernier thruster availability had minimal impact. Troubleshooting will be performed during the turnaround operations to isolate the cause of this anomaly.

Following FCS checkout, the RCS hot fire was performed without incident. The hot fire began at 345:16:34 G.m.t. (09:13:28 MET) and ended at 345:16:43 G.m.t. (09:13:37 MET). A review of thruster chamber pressure data confirmed that all firings were good, with each thruster receiving two 320-millisecond duration pulses.

A total of 4658.6 lbm propellants (2846.8 - oxidizer, 1811.8 - fuel) were used from the RCS during the rendezvous mission with the International Space Station. In addition, a total of 937.6 lbm of the orbital maneuvering subsystem (OMS) propellants were used by the RCS during interconnect operations. The primary RCS thrusters had 5212 firings and a total firing time of approximately 943.76 seconds. The vernier RCS thrusters had 12767 firings and a total firing time of 28723.66 seconds.

### **Orbital Maneuvering Subsystem**

The orbital maneuvering subsystem (OMS) performed satisfactorily throughout the mission. No LCC or OMRSD violations occurred, and no in-flight anomalies were identified. The OMS inlet pressures, chamber pressures and regeneration jacket temperatures for both engines were as predicted, verifying nominal engine performance. All OMS maneuvers were performed accurately and OMS operation was nominal during all the maneuvers. The table on the following page lists the pertinent data concerning all OMS maneuvers.

The deorbit maneuver for the first KSC landing opportunity was performed on orbits 170 at 346:21:57:31.2 G.m.t. (10:18:51:30 MET).

A total of 17584 lbm (10981 - oxidizer and 6603 lbm - fuel) of OMS propellants were consumed during the mission. Of this total, the OMS provided 937.5 lbm of propellants to the RCS during interconnect operations.

Maneuver	Time, G.m.t./MET	$\Delta V$ , ft/sec	Firing time, sec	Orbit, nmi.
Assist (Dual OME)	336:03:08:15 00:00:02:15	-	102.3	-
OMS 2 (Dual OME)	336:03:49:15 00:00:43:15	118.8	78.2	106.2 by 175.1
OMS 3 (NC-1) (Right OME)	336:06:49:16 00:03:43:16	7.7	10.4	110.6 by 175.1
OMS 4 (NC-3) Dual OME)	337:03:23:45 00:00:17:45	79.9	52.2	126.1 by 204.6
OMS 5 (NC 4) (Dual OME)	337:16:00:09 01:12:54:09	123.9	79.8	--
TI (OMS 6) (Left OMS)	337:17:32:44.4 01:14:26:43	6.0	7.6	199.9 by 204.8
OMS 7 (Orbit Adjust) (Dual OME)	345:01:39:56 08:22:33:56	21.5	12.4	--
Deorbit Maneuver (Dual OME)	346:21:57:31 10:18:51:31	311.5	161.5	--

#### **Power Reactant Storage and Distribution Subsystem**

The power reactant storage and distribution (PRSD) subsystem performance was nominal throughout the STS-97 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. The PRSD subsystem supplied the fuel cells with 2387 lbm of oxygen and 301 lbm of hydrogen for the production of 3464 kWh of electrical energy. In addition, the environmental control and life support system (ECLSS) was supplied 164 lbm of oxygen for life support.

One set of the oxygen/hydrogen manifold isolation valves were cycled each day to support the crew sleep periods, and this procedure satisfied the OMRSD File IX in-flight checkout requirements.

The Orbiter landed with 1370 lbm of oxygen and 155 lbm of hydrogen remaining in the PRSD subsystem. A 113-hour mission extension capability existed at landing, based on the PRSD oxygen (limiting reactant) tank landing quantities and the average flight power level of 13.3 kW. At an extension-day power level of 12.5 kW, a 123-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 13.3 kW and 436 amperes. The fuel cells produced 2688 lbm of potable water and 3464 kWh of electrical energy while using 2387 lbm of oxygen and 301 lbm of hydrogen.

Four purges of the fuel cells were performed, all of which achieved nominal results. The actual fuel cell voltages at the end of the mission were 0.15 V above the predicted for fuel cell 1, as predicted for fuel cell 2, and 0.10 V above the predicted for fuel cell 3. The voltage margin above the minimum performance curve at the end of the mission was 1.1 V for fuel cell 1, 0.4 V for fuel cell 2, and 0.9 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 3.6 days of the mission. The B system was selected at that time and it operated for the remainder of the mission.

The fuel cell monitoring system (FCMS) was used to monitor individual cell voltages during the prelaunch period as well as during the mission and after landing. Full-rate on-orbit data were recorded for 12 minutes during the mission. No problems were identified from the analysis of the data. All of the cell performance monitor (CPM) values remained stable throughout the mission.

### Auxiliary Power Unit Subsystem

The auxiliary power unit (APU) subsystem performance was nominal throughout the STS-97 mission. No in-flight anomalies were identified during the review of the data. The following table presents the APU run times and fuel consumption for the mission.

**APU RUN TIMES AND FUEL CONSUMPTION**

Flight phase	APU 1 (S/N 405)		APU 2 (S/N 303)		APU 3 (S/N 409)	
	(a) (b) Time, Min:sec	Fuel consumption, lb	(a) Time, Min:sec	Fuel consumption, lb	(a) Time, min:sec	Fuel consumption, lb
Ascent	19:29	45	19:46	50	19:58	50
FCS checkout	04:13	14				
Entry <sup>a</sup>	62:52	115	89:40	189	63:03	130
Total	86:34	174	109:26	239	83:01	180

<sup>a</sup> APUs were shut down 18 minutes 57 seconds after landing.

The flight control system (FCS) checkout was performed nominally, with no problems identified. APU 1 was used to support the checkout, with a start time of 345:15:42:08 G.m.t. (09:12:36:07 MET) and stop time of 345:15:46:21 G.m.t. (09:12:40:20 MET). All APU parameters, including gas generator valve module (GGVM) and gas generator (GG) performance, as well as the chamber pressure (Pc) signature were nominal throughout the run, and there were no indications of bubbles during start-up. No gearbox repressurizations occurred, and the total run time was too short to require the water spray boiler (WSB) to provide spray cooling.

The APU 1 exhaust gas temperature (EGT) 1 and 2 measurements were both erratic from 346:23:01:01 G.m.t (10:19:55:00 MET) to 346:23:06:01 G.m.t. (10:20:00:00 MET). Following this period of erratic operation, the measurements performed satisfactorily for the remainder of entry.



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

The overall performance of the hydraulics/water spray boiler (WSB) subsystem was nominal with no in-flight anomalies identified in the analysis of the data. STS-97 was the fourth successful flight in which the WSB water additive [Propylene Glycol Monomethyl Ether (PGME)] was used. The additive mixture of 53-percent water and 47-percent PGME was placed in WSB 2 core and no freeze-ups of that WSB occurred. WSB 1 and 3 had

An APU confidence run was performed on all three hydraulic/WSB subsystems to verify APU operation, since it exceeded the nine-month requirement prior to STS-97. The hydraulic/WSB subsystem performance was nominal on all systems, except on system 3 which had a drop in pressure during the low-pressure start-up, prior to going to normal pressure. The pressure dropped from approximately 711 psia to 88 psia for about 2 seconds, then recovering back to 539 psia before going to the normal pressure of 3000 psia. The pressure decay was most likely caused by a momentary hang-up of the stroking piston, resulting in the cam hanger going over center. As a result, a second modified confidence run was performed on system 3 for troubleshooting purposes. The run had a normal start and the pressure was cycled from normal to low for 20 seconds three times and then left in normal for 90 seconds before going to low pressure for an additional two minutes. The hydraulic system responded appropriately with no indication of a pressure anomaly.

The hydraulic system thermal circulation pump turn-on limit procedures were changed from 0 °F or -10 °F to -30 °F or -35 °F and the turn-off limits were changed for 20 °F to -10 °F. This was done to successfully minimize circulation pump run-times and increase mission cryogenic margins for cryogenic critical ISS missions. As a result, there was only one pump run, which was to place the elevons in the park position. This flight had no circulation pump runs for thermal conditioning because the XPOP attitude with respect to the Sun.

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

The electrical power distribution and control (EPD&C) subsystem performed nominally throughout the STS-97 mission. No EPD&C subsystem in-flight anomalies were identified during the analysis of the data.

During the detailed review of the motor drive data from ascent, the data showed that AC bus 1 phase A did not provide current to vent door 8 and 9 motor 1 during the prelaunch vent door repositioning at 336:03:05 G.m.t. Later, during the ET Door closing at 336:03:34 G.m.t. (00:00:27 MET), the AC bus 1 motors operated on phases B and C only. In both cases, the motor run time was nominal. During the earlier prelaunch operations of vent door 8 and 9 motor 1, all three phases worked properly. Both of these motors are powered from circuit breaker (4 on panel MA73C:D), which powers the AC1 aft motor control (AMC) 1 bus. This circuit breaker (CB) bus does not power any other motors. Loss of power to a single phase did not impact motor operation. If another phase feeding the same motor is lost, the motor will not operate; however, the redundant motor in the system will continue to drive the mechanism. Oxidation of the phase A contact in this 3-phase breaker is suspected, a condition which could possibly be cleared by cycling the breaker. No efforts to restore AC bus 1 AMC 1 phase A power were planned during the mission. Postlanding during the ET door reconfiguration, the CB was cycled six times and

the problem cleared. The OMRSD requirement allows five cycles to clear the problem, therefore, the decision has been made to remove the panel containing this CB and send it to the NASA Shuttle Logistics Depot (NSLD) for replacement of the CB.

At 339:12:51 G.m.t. (03:09:45 MET), aft power converter unit (APCU) 2 tripped off line. Review of the data indicated that the Orbiter buses were good and that there had been no large load shifts on the Orbiter or the aft power converter (APC) buses. The APCU can trip off due to sensing a low output voltage (less than 115 V for 55 msec) or due to sensing a low input voltage (22 to 24 V instantaneous trip). It is believed that one of these circuits may have caused a false trip. At 339:14:42 G.m.t. (03:11:36 MET), APCU 2 was re-powered with no problems. Approximately 4 hours later, at 339:16:48 G.m.t. (03:13:42 MET), APCU 1 shut down for approximately 11 seconds, then returned to nominal power output levels. Both APCUs performed nominally after these events occurred.

### **Orbiter Docking System**

The Orbiter Docking System (ODS) performed satisfactorily throughout the mission. No in-flight anomalies were found in the review and analysis of the data.

The Orbiter successfully docked with the International Space Station (ISS) at 337:20:10 G.m.t. (01:17:03:59 MET). The docking was nominal. The brakes power-on time was 2 minutes 9 seconds and did not exceed the 5-minute limit. The ring was not extended to the forward position; instead retraction was initiated from the initial position. During retraction, the ring alignment indication remained off for most of the retraction. Petal 2 lagged by approximately 6 percent, but the lag was consistent, and petal 2 caught up at the end of the retraction.

The ODS valves were used during the docked operation and for EVA. After docking, the vestibule/PMA 3 pressurization and leak check was performed. One equalization valve was configured to normal to pressurize the vestibule and PMA 3. The equalization valve was cycled on and off to prevent the Vestibule-to-PMA 3 hatch from burping during the pressurization.

The PMA 3 hatch was leak checked by depressurizing the vestibule while PMA 3 was pressurized. PMA 3 was then used for stowing transfer items. In preparation for undocking, the ODS hatch was closed and vestibule depressurization was begun at 344:16:05 G.m.t. (08:12:59 MET). Undocking occurred at 344:19:13 G.m.t. (08:16:07 MET).

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

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

The atmospheric revitalization pressure control subsystem (ARPCS) performed normally throughout the duration of the flight. To save Orbiter consumables, the cabin pressure regulator inlet valves were closed, and the cabin was allowed to bleed down before the cabin was depressurized to 10.2 psia for the extravehicular activities (EVAs). The cabin depressurization to 10.2 psia was initiated at 337:00:49 G.m.t. (00:21:43 MET) and completed satisfactorily. In anticipation of ingressing the pressurized mating adapter 3

(PMA 3) for transfer operations, the cabin pressure was further reduced to 9.41 psia at 337:20:56 G.m.t. (01:17:50 MET). Following the transfer operations to PMA 3, the cabin was repressurized to 10.2 psia. At 342:22:06 G.m.t. (06:19:00 MET), following the third EVA, the Orbiter cabin repressurization to 14.7 psia was initiated. At 342:22:21 G.m.t. (06:19:15 MET), the cabin repressurization was halted at 14.12 psia to allow the proper differential pressure ( $\Delta p$ ) to exist across the hatches during ISS ingress.

At 343:14:10 G.m.t. (07:11:04 MET), the Orbiter cabin pressure was equalized with the entire ISS volume. Following this, the interior pressure of the entire structure was raised to 14.68 psia, and the pressure control system (PCS) was configured to system 1 to maintain both the Orbiter and ISS at 14.7 psia. At 344:00:16 G.m.t. (07:21:10 MET), an additional pressurization was performed, using oxygen, to raise the overall Orbiter and ISS pressure to 14.92 psia and thereby minimize the use of ISS consumables.

At 344:15:52 G.m.t. (08:12:46 MET), the hatches to the ISS were closed and normal Orbiter operations were resumed for the remainder of the mission. The PCS was reconfigured to system 1, and switchover from oxygen flow to nitrogen flow on PCS 1 was observed.

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

### **Atmospheric Revitalization Subsystem**

The atmospheric revitalization subsystem (ARS) performed satisfactorily throughout the mission. No in-flight anomalies were noted in the review and analysis of the data.

During the preflight period, the second HALO bypass duct was manifested because this was the initial flight for the Orbiter to dock at PMA 3, which requires the HALO ducting to supply the ISS with Orbiter conditioned air. On flight day 3, at 338:00:22 G.m.t. (01:21:16 MET), the crew opened the hatch for ingress into PMA 3. The HALO bypass duct was used to provide the conditioned air to the Orbiter Docking System (ODS) and PMA 3 while the crew was working in that area. Prior to closing the hatch, the crew deployed a desiccant bag for continued removal of condensate after the hatch was closed.

The modification to improve ISS air for the crew was again manifested on this flight. The modification provided an air duct (106 inches in length by 4-inches in diameter) that relocated the Orbiter conditioned air that was supplied to the ISS. The middeck air intake was relocated from near the 576 bulkhead hatch location to 51 inches forward into the middeck. The STS-96 crew had commented on the stagnant air in the Node portion of the ISS. The STS-97 crew response was positive in stating the air quality in the ISS was improved. As a result, this ducting will be flown on all future ISS flights through STS-98, the initial flight of the under-the-floor ducting.

At 339:18:14 G.m.t. (03:15:08 MET), the crew attempted to reconfigure from temperature controller 1 to the temperature controller 2. Upon removal of the pip pin from the primary controller and linkage, the crew reported the pin would not move within the linkage and control arm. No further attempt to remove the pin was made while on orbit, and operations were continued on controller 1 for the remainder of the flight. During postflight troubleshooting, KSC personnel determined that with the controller in the full-heat exchanger

position, a preload is placed on the linkage that makes it difficult to remove the pin. With the controller positioned to the full-cool position, the pin is much easier to remove from the linkage and the controller arm. The flight controllers have been informed of the KSC findings in anticipation of modifying the procedure for future flights. In addition, the training personnel have been contacted to inform the crew the procedure is a two-hand operation. Two hands are required to remove the pin when the cabin temperature control valve is in the full-heat exchanger position.

At 334:01:00 G.m.t. (02:02:06 MET), the ppCO<sub>2</sub> peaked to 5.62 mmHg while cabin pressure was at 10.2 psia. At 346:02:01 G.m.t. (09:22:55 MET) during 14.7-psia cabin-pressure operations, the ppCO<sub>2</sub> peaked to 7.6 mmHg for a short duration. The ppCO<sub>2</sub> averaged 4-mmHg after the cabin depressurization and for the period while the cabin was below 14.7 psia. The average ppCO<sub>2</sub> while the cabin was at 14.7 psia was approximately 4.5 mmHg.

Cabin humidity averaged 37.3 percent for the flight, with a peak of 47.6 percent during flight day 1 operations.

During the launch-ascent phase of the flight, the heat exchanger outlet temperature peaked to 69.36 °F approximately 4 minutes into the flight, with the cabin air temperature peaking to 77.37 °F about 1 hour 44 minutes after launch. The cabin humidity peaked near 47.6 percent approximately 4 minutes after launch.

During the landing phase of the flight, the heat exchanger outlet temperature peaked at 58.61 °F at 6 minutes and 16 seconds after wheel stop, with the cabin air temperature peaking to 75.5 °F at 39 minutes 50 seconds after wheel stop. The cabin humidity peaked near 49.6 percent approximately 8 minutes 2 seconds after wheel stop.

### **Active Thermal Control Subsystem**

The Active Thermal Control Subsystem (ATCS) performed nominally for the STS-97 mission. A small amount of pre-evaporative cooling was observed in the first few minutes of the flight. A drop of 2 °F was observed on the flash evaporator system (FES) outlet temperature before the general purpose computers (GPCs) activated the FES for ascent. The relatively small amount of pre-evaporative cooling indicates that a very small amount of condensate had collected in the FES cores during prelaunch operations.

At approximately 336:04:26 G.m.t. (00:01:20 MET), the FES controller was switched from primary-A command to primary-B command to support the storage of potable water in tanks A and B for eventual water transfer to the ISS. The use of the primary B command enables the withdrawal of water from tanks C and D as the two tanks were ganged together. During the mission, nine FES water dumps were performed.

Eight of the FES water dumps were performed using the primary-B command controller and the ninth or last FES water dump was performed using the primary-A command controller. The ninth FES water dump was performed after the water transfers to the ISS were completed.

The radiator coldsoak for entry was begun at 346:18:01 G.m.t. (10:14:55 MET) and the radiator bypass/FES checkout was performed at 346:19:07 G.m.t. (10:16:01 MET). Radiator flow was initiated at 346:22:52 G.m.t. (10:19:46 MET), which was approximately

12 minutes before wheel stop. The radiators were configured to the high set point at 346:23:07 G.m.t., and the ammonia boiler system (ABS) secondary A controller was powered on about 1 minute later. At 346:23:44 G.m.t., the ammonia tank A ammonia supply was exhausted and the system was switched from the secondary A controller to primary B controller. The ammonia system was powered off at 347:00:02 G.m.t., and the radiators were placed in normal set point configuration in preparation for ground cooling, which was initiated at 347:00:04 G.m.t.

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

The Supply Water and Waste Management Systems performed nominally throughout the mission. By the completion of the mission, 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 dump system. Nine FES water dumps were performed during the mission. One supply-water nozzle dump was performed at a nominal dump rate of 1.56 percent (2.57 lb/min). The line heater maintained the supply water dump line temperature between 75.3 °F and 98.8 °F throughout the mission.

Seven contingency water containers (CWCs) were filled and transferred to the ISS, for a total of 679.14 lb. Four of the CWC's transferred were potable water and three were technical water.

At 338:17:59:05 G.m.t. (02:14:53:04 MET), the water tank B quantity sensor experienced a quantity dropout at a tank quantity of 93 percent. The quantity drop was 10 percent for 5 seconds. The wastewater tank quantity transducer also exhibited a quantity dropout prior to the first wastewater dump at approximately 338:02:23 G.m.t. (01:23:17 MET). The dropout occurred at a tank quantity of approximately 54 percent and lasted for about 27 seconds. Such dropouts have been experienced in previous flights, and the problem was probably caused by minor contamination that intermittently interrupts the output signal of the potentiometer. Such dropouts are understood problems and deferred for repair at Orbiter Maintenance Down Period (OMDP). The overboard dump vacuum vent line temperature was maintained between 57.9 °F and 81.2 °F.

Two wastewater dumps were performed at an average rate of 1.88 percent per minute (3.10 lb/min). The wastewater dump line temperature was maintained between 54.1 °F and 77.6 °F throughout the mission.

At 338:02:23:01 G.m.t. (01:23:17 MET), the wastewater tank quantity gage data dropped from 54-percent to as low as zero and was erratic for about 27 seconds. A second dropout occurred at 343:00:25:01 G.m.t. (01:23:17 MET). This problem is believed to be associated with minor contamination of the quantity gage potentiometer and did not impact wastewater tank usage.

A crewmember detected that the EMU 2 wastewater valve talkback was indicating an open position when the valve was supposed to be closed. The crew switched the valve to a closed position several times and the open indication did not go away. The crew then switched the valve to open position and then to close, and was able to get the proper indication.

### **Waste Collection Subsystem**

The Waste Collection Subsystem (WCS) performed properly throughout the mission. No in-flight anomalies were reported by the crew following the flight.

The Shuttle Urine Pretreat Assembly (SUPA) was flown for the first time on this mission. In an effort to preclude any wastewater dumps during the period while the Orbiter was docked to the ISS, cabin air condensate was separated and collected in a CWC. Condensate separation was terminated prior to undocking and the condensate CWC was stowed and returned.

### **Airlock Support System**

The airlock support system performed satisfactorily in the support of the EVAs. The remaining active system monitor parameters indicated normal outputs throughout the remainder of the flight.

### **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 System**

The flight data system performed nominally throughout the STS-97 mission, and no in-flight anomalies were identified during the analysis of the data.

After the transition of the operations (OPS) 8 mode for the flight control system checkout, the advanced air data transducer (ADTA) 4 annunciated a discrete input good built in test equipment (BITE) failure and the ADTA Good fail. ADTA 4 did not respond to the self-test command. The problem was cleared through computer commands, and subsequent self-tests results were nominal. This same problem occurred also during the turnaround flow, and the unit was power-cycled three times with no repeat of the problem. Subsequently, the problem repeated several more times. Additional troubleshooting and power cycling of the unit 30 times resulted in no recurrence of the problem. The BITE reappeared during the power-up of the ADTA for entry; however, the ADTA performance during entry was nominal.

The discrete input bit BITE failure occurred previously on the unit installed on OV-104 when preparing for the STS-106 mission. That unit is being repaired at the vendor. This BITE failure has no affect on the primary avionics software system (PASS) or the backup flight system (BFS) software operation. This BITE failure will only result in loss of the self-test capability. Other means are available to assess the ADTA health.

The crew reported at 344:19:01 G.m.t. (08:15:55 MET) prior to undocking from the ISS, that data were not flowing out of the windecom payload and general support computer (PGSC) communications ports 2 and 4. Troubleshooting will be performed postflight to determine the cause of the data problem.

The inertial measurement unit (IMU) performance was nominal throughout the STS-97 mission. While on-orbit, only one adjustment to the onboard IMU accelerometer and one

adjustment of the drift compensations was required for the three IMUs. The performance of the IMUs during entry was also satisfactory and this ship-set has been deemed acceptable for the next flight of this vehicle.

Entry guidance navigation and control (GN&C) performance was nominal. The soft landing did prevent the main gear proximity sensors from indicating weight on wheel until derotation. As a result of the disagreement with the wheel speed sensors, RM failed both main gear proximity sensors.

Descent navigation performed nominally on STS-97. External navigation sensors (drag, TACAN, ADTA, and MLS) data were incorporated into the onboard navigation state vectors at their expected region of operation. All external sensor measurement residuals and residual ratios were nominal and no navigation edit was observed.

The miniature air-to-ground receiver (MAGR) – Shuttle GPS receiver's performance during entry was below expectation. The receiver's figure of merit (FOM) was greater than 8 as it came out of the plasma region and remained so until approximately 150K ft altitude. Per the GPS Navigation system design, a GPS state vector corresponding to a FOM > 5 is not considered as valid for selection. While MAGR performance did not violate any system requirements, data from previous flights have shown that the receiver's typically produce FOM's of less than or equal to 3 for this region of flight. Post flight data review (including the receiver vendor) determined that the receiver's poor performance during entry was the result of a known firmware glitch. The firmware deficiency condition is one of the items being addressed in the upcoming firmware review.

### **Flight Software**

The flight software performed satisfactorily throughout the mission. No problems or in-flight anomalies were noted. The navigation and control software performed as planned during the rendezvous and docking portion of the mission. The undocking and separation software also performed satisfactorily. The software performed satisfactorily during entry.

### **Flight Control Subsystem**

The flight control subsystem (FCS) performed satisfactorily throughout the mission. No in-flight anomalies were noted in any sensor, controller or hydraulic actuator during the review and analysis of the flight data.

At the moment of main gear touchdown, the redundant weight-on-wheels (wheel speed) sensors indicated weight on wheels approximately 7 seconds before the primary weight-on-wheels (squat switch) sensors – a long enough period to cause a failure indication. No failure actually occurred; the landing was exceedingly smooth. The wheels contacted the ground and spun up, turning on the redundant indications; however, the vehicle retained enough lift to prevent the oleo struts from compressing sufficiently to activate the primary sensors before the redundancy management (RM) software declared them failed.

### **Displays and Controls Subsystem**

The displays and control subsystem performed nominally. No in-flight anomalies or problems were identified from the review and analysis of the data.

## Communications and Tracking Subsystems

The communications and tracking subsystems performed nominally throughout the mission. No in-flight anomalies were identified in the analysis of the flight data.

Also during the prelaunch operations, the Commander exercised the push-to-talk button on the rotational hand controller (RHC), but the push-to-talk function would not operate. However, the Commander was able to talk by engaging an alternate push-to-talk button on his suit. Because of the availability of the alternate function, the apparent switch failure did not impact the mission. All other functions of the RHC were tested successfully with the exception of the BFS push-button, which was not tested. This problem was not a constraint to the flight, and troubleshooting was performed during the postflight turnaround operations. The troubleshooting isolated the problem to the push-to-talk switch or the wiring inside the RHC. RHC replacement was scheduled and performed.

The crew attempted to transmit with the primary onboard VHF transceiver. The transceiver display annunciated an error message, which indicated a problem with the transmitter section of the transceiver. The crew configured the backup VHF receiver and restored the VHF Orbiter-to-ISS communication system. The hardware was shipped back to JSC for troubleshooting to recreate the problem. Following the isolation of the problem, the hardware will be shipped to the vendor for repair. This problem did not impact mission operations because the backup capability existed.

During the flight day 9 crew-sleep period, the ground controller discovered that the closed circuit television (CCTV) camera C appeared to have a loose thermal blanket on the rear surface of the camera. When the camera was pointed straight up, the camera blanket hung on the pan-tilt unit bracket. The camera was recovered through repeated attempts to pass through the interference point. The initial evaluation from the downlinked video indicated that the most likely cause of the interference involved the installation of the camera onto the pan-tilt unit, as the blankets appeared to be installed properly. Postflight troubleshooting of this problem revealed that an interference problem existed between the CCTV and the pan-tilt unit (PTU) blankets. This interference caused the reported problem. The problem resulted from a slight misalignment of the CCTV camera-mounting guides.

On several occasions, after commanding the camera B iris closed, a faint image was seen on the downlink video and this indicates that the iris was not closing completely. The evaluation of the downlink video confirmed the viewable image. The camera was removed from the vehicle and sent to the laboratory at KSC for troubleshooting. During the postflight evaluation, the condition was duplicated using an external light source to increase the lighting intensity as was seen during the mission. Five additional intensified television cameras (ITVCs) were evaluated and all exhibited the same characteristic. In addition to a mechanical stop, an iris end-of-travel adjustment potentiometer controls the precise iris closure. This fine-tuning adjustment was performed when the ITVCs were originally manufactured. If the adjustment is off by just one gear tooth, it results in the reported condition in a brightly illuminated environment.

At 344:18:45 G.m.t. (08:15:38 MET), the crew selected the sequential still video (SSV) output rate of 4 (25 Kbps). The proper configuration for undocking was loaded into the onboard system and the system was locked. The SSV ground processor in the Mission Control Center (MCC) failed to lock. After the SSV ground system software was reloaded in an attempt to correct system operation was unsuccessful, the crew was asked to select



## **Integrated Aerodynamics, 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 closure metal noted.

### **Thermal Control Subsystem**

Performance of all thermal control systems was nominal and all temperatures were maintained within acceptable limits.

The L5D thruster oxidizer injector and the F5R thruster fuel injector sensors failed, and as a result, vernier RCS attitude control was lost after undocking. Since the software update for the L5D thruster failure eliminated monitoring of all vernier RCS oxidizer injector temperature sensors, loss of the fuel injector sensor on the F5R thruster resulted in the loss of leak detection monitoring of thruster F5R. For the remainder of the mission, primary attitude control was used.

Loss of the starboard outboard pressure transducer 2 did not impact the mission.

The X-axis perpendicular to the orbital plane (XPOP) attitudes were shaded by the ISS and therefore, there were no extravehicular mobility unit (EMU) limit issues related to the external airlock fluid lines. Several periods of free drift during the extravehicular activities (EVAs) did not result in any limit issues for the oxygen line. The bottom to earth with the tail on velocity vector attitudes also did not result in any EMU limit issues. Despite the biased top to sun XPOP attitudes, the forward primary RCS thruster heaters cycled due to ISS shading.

Reduction of the hydraulic circulation pump on/off set points that has become standard for ISS missions to save cryogenics was used on this mission. The savings were minimal since the environments for the elevons and rudder speedbrake (RSB) were warm. The elevons would have had little or no cycling, and the RSB power drive unit (PDU) would have had a very low duty cycle if the limits had not been readjusted.

### **Aerothermodynamics**

Aileron data and yaw thruster firings both show indications of asymmetric drag starting at 1141 seconds after entry interface (EI). Surface temperature data recorded the wing transition onset to turbulent flow as early as Mach 8.9 (1182 seconds from EI) on the right wing to as late as Mach 8.0 on the left wing. Along the lower centerline of the Orbiter, transition was recorded at Mach 8.0 or 1227 seconds after EI. One protruding AMES-gap-filler was reported on the left-hand main landing gear door.

The acreage heating was normal. The entry was with a light vehicle entering from a high inclination orbit.

Local heating was characterized by a localized hot spot on the right-hand ET door. Flow got around the thermal barrier, between the fingers and into the area between the thermal barrier and the environmental seal. Other than minor thermal barrier damage, no other

damage was identified in that area. The environmental seal was not reported as damaged.

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

The TPS performed satisfactorily. Entry heating was normal based on lower-surface structural temperature response data. Boundary layer transition from laminar flow to turbulent flow occurred 1192 seconds after entry interface (EI).

The postlanding inspection of the Orbiter TPS identified a total of 84 impacts of which 10 had a major dimension of 1-inch or larger. The distribution of these impacts on the vehicle is shown in the following table. 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 Orbiter lower surface sustained 78 hits of which 10 had a major dimension of 1-inch or larger. Approximately 43 damage sites (three larger than 1-inch) were located in the area from the nose landing gear to the main landing gear wheel wells. More damage occurred on the right-hand side of the vehicle than on the left-hand in a typical pattern. ET thermal protection system (TPS) venting modifications continue to have a reducing effect on the quantity and size of the damage sites.

#### **TPS DAMAGE SITES**

<b>Orbiter Surfaces</b>	<b>Hits &gt; 1 Inch</b>	<b>Total Hits</b>
Lower Surface	10	78
Upper Surface	0	0
Window Area	0	4
Right Side	0	0
Left Side	0	0
Right OMS Pod	0	0
Left OMS Pod	0	2
Total	10	84

The largest damage site on the lower surface was located on the Orbiter center-line immediately forward of the main landing gear and it measured 3-inches long by 1-inch wide by 0.5 inch deep. The damage site spanned two tiles, and the cause of the damage has not been determined.

Some of the damage sites around the LO<sub>2</sub> 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.

Less than the usual amounts of tile damage occurred on the base heat shield. All SSME dome heat shield closeout blankets were in excellent condition. No unusual tile damage occurred on the leading edge of the OMS pods. Only two small hits were noted on the leading edge of the left OMS pod. There were no debris hits on the right OMS pod. No tile damage was evident on the vertical stabilizer leading edge.

A comparison of the number of damage sites with statistics from previous missions indicates that both the total number of hits and the number of hits 1-inch or larger were much lower than the fleet averages, which were 124 hits with 20 larger than 1-inch.

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

<b>Parameter</b>	<b>STS -90</b>	<b>STS -91</b>	<b>STS -95</b>	<b>STS -88</b>	<b>STS -96</b>	<b>STS -93</b>	<b>STS -103</b>	<b>STS -101</b>	<b>STS 92</b>	<b>STS 97</b>
Lower surface total hits	76	145	139	80	160	161	84	70	86	78
Lower surface Hits > 1 in.	11	45	42	21	66	42	13	19	14	10
Longest damage Site, in.	3.0	3.0	4.0	4.5	4.0	6.0	1.5	8	2	3
Deepest damage Site, in.	0.25	0.5	0.4	0.5	0.5	0.5	0.25	0.75	0.75	0.5

Damage sites on the window-perimeter tiles were less than usual in quantity and size. Hazing and streaking of the forward-facing Orbiter windows was moderate.

**Gas Sample Analysis**

The STS-97 mission was a successful flight for the gas sample bottles. The hardware provided six excellent gas samples. The data obtained during ascent in the gas sample bottle system was nominal. All six bottle-pressures were in the expected range. The hydrogen concentration was within the database for all Space Shuttle flights. The oxygen data was within the bands of error as determined by the argon measurement, and the amount detected can be attributed to air.

STS-97 was the third flight for these reprocessed bottles. New pyrotechnic valves were installed on all bottles after the bottles were thoroughly cleaned by the vendor. The bottles were submitted to the same cleaning and vacuum processing cycle as when the bottles were new.

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#### TPS DAMAGE SITES

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Left OMS Pod	0	2
Total	10	84

The largest damage site on the lower surface was located on the Orbiter center-line immediately forward of the main landing gear and it measured 3-inches long by 1-inch wide by 0.5 inch deep. The damage site spanned two tiles, and the cause of the damage has not been determined.

Some of the damage sites around the LO<sub>2</sub> 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.

Less than the usual amounts of tile damage occurred on the base heat shield. All SSME dome heat shield closeout blankets were in excellent condition. No unusual tile damage occurred on the leading edge of the OMS pods. Only two small hits were noted on the leading edge of the left OMS pod. There were no debris hits on the right OMS pod. No tile damage was evident on the vertical stabilizer leading edge.

A comparison of the number of damage sites with statistics from previous missions indicates that both the total number of hits and the number of hits 1-inch or larger were much lower than the fleet averages, which were 124 hits with 20 larger than 1-inch.

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

<b>Parameter</b>	<b>STS -90</b>	<b>STS -91</b>	<b>STS -95</b>	<b>STS -88</b>	<b>STS -96</b>	<b>STS -93</b>	<b>STS -103</b>	<b>STS -101</b>	<b>STS 92</b>	<b>STS 97</b>
Lower surface total hits	76	145	139	80	160	161	84	70	86	78
Lower surface Hits > 1 in.	11	45	42	21	66	42	13	19	14	10
Longest damage Site, in.	3.0	3.0	4.0	4.5	4.0	6.0	1.5	8	2	3
Deepest damage Site, in.	0.25	0.5	0.4	0.5	0.5	0.5	0.25	0.75	0.75	0.5

Damage sites on the window-perimeter tiles were less than usual in quantity and size. Hazing and streaking of the forward-facing Orbiter windows was moderate.

**Gas Sample Analysis**

The STS-97 mission was a successful flight for the gas sample bottles. The hardware provided six excellent gas samples. The data obtained during ascent in the gas sample bottle system was nominal. All six bottle-pressures were in the expected range. The hydrogen concentration was within the database for all Space Shuttle flights. The oxygen data was within the bands of error as determined by the argon measurement, and the amount detected can be attributed to air.

STS-97 was the third flight for these reprocessed bottles. New pyrotechnic valves were installed on all bottles after the bottles were thoroughly cleaned by the vendor. The bottles were submitted to the same cleaning and vacuum processing cycle as when the bottles were new.

## EXTRAVEHICULAR ACTIVITY OPERATIONS

All EVA scheduled as well as the unscheduled get-ahead tasks were successfully completed during the three extravehicular activities (EVAs). The total EVA time was 19 hours and 2 minutes.

The first STS-97 EVA began at 338:18:34 G.m.t. (02:15:28 MET) when the suits were transferred to internal battery power. The EVA was completed 7 hours and 17 minutes later at 339:02:07 G.m.t. (02:23:00 MET). Accomplishments during the EVA were mating the P6 truss to the Z1 truss, and deployment of the solar arrays. The 2B solar array could not be tensioned at that time because the tension cables came off of the spools. As a result, the deployment of the 4B solar arrays was deferred until an analysis of the 2B solar wing anomaly could be completed.

Minor issues occurring during the EVA included a torn cuff checklist on the EV2 crewmembers' extravehicular mobility unit (EMU), sluggish retract operation of a safety tether reel, inadvertent opening of an EVA equipment tether hook, and a low-torque indication on a pistol grip tool (PGT).

EVA 2 began at 340:17:21 G.m.t. (04:14:15 MET) when the EMUs were transferred to internal battery power. No significant EMU or EVA tool anomalies were noted during the EVA. Loss of the EV1 EVA Remote Camera Assembly (ERCA) function did not impact the EVA. Total EVA duration was 6 hours and 35 minutes.

The Z1 and Node patch panel reconfigurations were completed, providing power to the ISS segment loads. The S-band Antenna Support Assembly (SASA) relocation from the Z1 truss to the P6 truss brought the ISS low-rate S-band on line. The crew surveyed the 2B Solar Array Wing (SAW) tensioning reels in preparation for the EVA 3 task to correct the tension cable anomaly. The Z1-to-P6 ammonia quick-disconnects (QDs) were mated. The aft early external thermal control system (EETCS) radiator cinches and winches were released and the radiator was deployed. The scheduled 5A get-ahead tasks to prepare the PMA2 for relocation and the relocation of the articulated portable foot restraint were successful. The unscheduled 5A get-ahead task to relocate the Z1 Wireless Instrumentation System (WIS) antenna pool handle and remove the Integrated Electronic Assembly (IEA) MMOD shield were successfully accomplished.

The EMUs performed nominally in support of the third scheduled EVA. Total EVA duration was 5 hours and 10 minutes. The task of tensioning the 2B SAW was completed successfully when the tension cables respooled on both the inboard and outboard tension reels on the first attempt, thus placing the 2B SAW in the nominal configuration and properly tensioned. The EVA installation of the common berthing mechanism (CBM) CBCS cable and floating potential probe were also completed. Additionally, two unscheduled get-ahead tasks were also completed.

During the EVA, an additional crew safety tether experienced sluggish retraction, a retractable tether cord failed, and the stowage pocket in the tool stowage assembly (TSA) for the needle nose pliers loosened and would no longer hold the tool in by friction. None of these problems with EVA tools had a significant impact on the accomplishment of the EVA tasks. The need for a fourth EVA no longer existed, owing to the success in repairing

the ISS SAW tensioning mechanism as well as the completion of all of the nominally scheduled tasks for this EVA.

At the end of the third extravehicular activity (EVA), when returning tools to the tool stowage assembly (TSA), the EV2 crewmember reported that the needle-nose pliers caddy and the 3-inch latch tool bag were tending to float out of their positions in the TSA. The crewmember pushed the tools back into position and closed the TSA. The tools in the TSA are held in place by friction fit. The TSA will be examined during the postflight period and possible design enhancements will be evaluated.

## **REMOTE MANIPULATOR SYSTEM**

The Remote Manipulator System (RMS) performed satisfactorily throughout the STS-97 mission, the fifty-eighth flight of the RMS during the Space Shuttle Program. The primary tasks of the RMS were to aid in the installation of the world's largest solar arrays on to the International Space Station (ISS), and to support three extravehicular activities.

The RMS checkout was completed nominally during the course of Flight Day 2. A payload bay survey using the RMS cameras was performed beginning at 336:20:21 G.m.t. (00:17:14 MET). Upon completion of the survey, the arm was cradled and powered down at 336:21:30 G.m.t. (00:18:23 MET).

The RMS was then used to remove the P6 truss from the payload bay beginning at 337:22:17 G.m.t. (01:19:10:59 MET) and maneuver the truss into an overnight park position to take advantage of better thermal conditions outside of the payload bay while awaiting truss installation. The RMS was used to successfully mate the P6 truss to the ISS, beginning with the RMS maneuver from the overnight park position at approximately 338:15:53 G.m.t. (02:12:47 MET) and continuing until the P6 grapple fixture was released at 338:20:17 G.m.t. (02:17:11 MET). Nominal RMS operations continued throughout the extravehicular activity (EVA) that is discussed in a following paragraph. The RMS was powered down after the completion of the EVA support operations.

The RMS was powered up at 340:16:55 G.m.t. (04:13:49 MET) to support the second EVA. RMS Operations included transfer of the S-band antenna structural assembly (SASA), mating of the P6 quick disconnect, and tasks involving pressurized mating adapter (PMA) 2, as well as viewing of the P6 radiator deployment. The arm performed nominally in support of all of these tasks, and was powered down at 341:02:08 G.m.t. (04:23:02 MET).

The RMS was powered up and uncradled at 342:13:38 G.m.t. (06:10:32 MET) to support EVA 3 operations. The RMS was used to perform a survey of the PMA 2 connectors, to observe the repair work on the ISS solar array wing (SAW) tensioning mechanism, and to observe the installation of the floating potential probe (FPP). After completion of these tasks, the arm was cradled and powered down at 342:21:22 G.m.t. (06:18:16 MET). This completed all planned RMS operations for this mission.



## GOVERNMENT FURNISHED EQUIPMENT/FLIGHT CREW EQUIPMENT

The Government Furnished Equipment (GFE)/Flight Crew Equipment (FCE) performed nominally during the mission. A number of minor problems surfaced, but none of them affected the successful completion of the mission.

Orbiter Condensate Separation hardware was manifest. This was the initial flight of the hardware as GFE and is the preliminary installation. The hardware consists of two piece part configuration, adapter hose assembly P/N # SED 46106871 and Water Dispenser Valve Assembly (WDVA) P/N SDD46106872. Hose installation per SJD32101474, installed on vehicle and pressure check for leakage during OPF turnaround flow. Hose was pressure checked per Chit J5368. The on orbit installation of the WDVA to the adapter hose and CWC performed smoothly to collect the condensate. Post flight weighing of the CWC containing condensate weighed 106.31 lbs.

The intravehicular crewmembers reported that only static was on the wireless video system (WVS) video camera signal from the extravehicular (EV) 1 extravehicular mobility unit (EMU) RF camera assembly (ERCA). The WVS troubleshooting procedures on the cue card were performed but the video signal was not recovered. The EV crewmembers removed the ERCA and inspected the connections to the camera. No mis-configuration of the wiring was found. Additional troubleshooting was performed and satisfactory camera operation could not be attained. The WVS hardware was shipped to JSC for troubleshooting and repair.

During the flight day 9 crew-sleep period, the ground controller discovered that the closed circuit television (CCTV) camera C appeared to have a loose thermal blanket on the rear surface of the camera. When the camera was pointed straight up, the camera blanket hung on the pan-tilt unit bracket. The camera was recovered through repeated attempts to pass through the interference point. The initial evaluation from the downlinked video indicated that the most likely cause of the interference involved the installation of the camera onto the pan-tilt unit, as the blankets appeared to be installed properly. Postflight troubleshooting of this problem revealed that an interference problem existed between the CCTV and the pan-tilt unit (PTU) blankets. This interference caused the reported problem. The problem resulted from a slight misalignment of the CCTV camera-mounting guides.

On several occasions, after commanding the camera B iris closed, a faint image was seen on the downlink video and this indicates that the iris was not closing completely. The evaluation of the downlink video confirmed the viewable image. During the postflight evaluation, the condition was duplicated using an external light source to increase the lighting intensity as was seen during the mission. Five additional intensified television cameras (ITVCs) were evaluated and all exhibited the same characteristic. In addition to a mechanical stop, an iris end-of-travel adjustment potentiometer controls the precise iris closure. This fine-tuning adjustment was performed when the ITVCs were originally manufactured. If the adjustment is off by just one gear tooth, it results in the reported condition in a brightly illuminated environment.

At 344:18:45 G.m.t. (08:15:38 MET), the crew selected the sequential still video (SSV) output rate of 4 (25 Kbps). The proper configuration for undocking was loaded into the onboard system and the system was locked. The SSV ground processor in the Mission Control Center (MCC) failed to lock. After the SSV ground system software was reloaded

in an attempt to correct system operation was unsuccessful, the crew was asked to select the output rate of 3 (16 Kbps). This change in mode did not establish nominal operations, and the onboard system was power cycled but that also did not achieve nominal operations. The ground processor central processing unit (CPU) was replaced and activated, and nominal system performance was recovered. About 30 minutes later, the SSV stopped. The ground processor had the same indications as seen on the primary unit, and five minutes later, a power cycle of the SSV ground processor CPU recovered the system. A CPU power cycle was required many times to recover the SSV capabilities. The same error indications were seen before each power cycle of the system. The ground was not able to isolate the problem to onboard or MCC hardware. The problem became first evident when the crew changed the output rate from 4 to 2, and the failure signature was seen using both ground processors. Postflight troubleshooting revealed two problems that account for the reported condition. The Mission Control Center (MCC) consolidated data select switch (CDSS) output port that provides the signal to the SSV ground equipment was defective. The SSV compression encoder unit was placed into a stowage container while it was operating. This container limited the air-flow around the unit, which is designed to operate in open air, and this condition resulted in the unit overheating.

## **CARGO INTEGRATION**

Integration hardware performance was nominal throughout the mission.

## POSTLAUNCH PAD INSPECTION

The postlaunch inspection of the mobile launch platform (MLP) 1, Pad B fixed service structure (FSS), and rotational service structure (RSS) was conducted between two and four hours after the launch. No flight hardware was found during the inspection.

The Orbiter liftoff lateral acceleration data indicated that a stud hang-up had occurred. No signs of stud hang-ups were detected in the visual inspection of the four south posts. Erosion was typical for the north posts. The north holddown post blast covers and T-0 umbilical exhibited typical exhaust plume damage. Both SRB aft skirt gaseous nitrogen (GN<sub>2</sub>) purge lines were intact, but the protective tape layering was partially eroded.

The liquid oxygen (LO<sub>2</sub>) and liquid hydrogen (LH<sub>2</sub>) tail service masts (TSMs) appeared undamaged and the bonnets were closed properly. The MLP deck was in generally good shape.

The Orbiter access arm appeared to be intact with no evidence of plume impingement. A thorough inspection of the firex pipe and attachment showed no evidence of anomalous operation or damage, especially in the area of the removed loose support that was accomplished during prelaunch countdown activities.

All slide wire baskets were secured with no evidence of damage.

Overall, damage to the pad appeared to be minimal. Minimal debris was noted on the pad apron and FSS.

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

### **DEVELOPMENT TEST OBJECTIVES**

**DTO 257 Structural Dynamics Model Validation** - DTO 257 was successfully performed within 2 hours after the Orbiter docked with the International Space Station (ISS). All requested reaction control subsystem (RCS) thruster firings were performed for the requested duration and spacing to create structural dynamics in the joined vehicles. The resulting structural dynamics data were reduced to structural natural frequencies, modal amplitudes and damping. These data were compared to preflight predictions that were used to tune the control system. The measured frequency and modal characteristics were within the uncertainties used for the preflight design, thus no Orbiter control system tuning was required to avoid overloading the structure. The primary pitch-mode damping was somewhat lower than estimated preflight (1 percent versus 2 percent); consequently, no action was required because of the close match of this modes frequency to the predicted frequency, which enabled reliable avoidance of this mode by the control system.

**DTO 261 International Space Station On-Orbit Validation** - Test 1 and 2 of DTO 261 were accomplished with photogrammetry and Laser Dynamic Range Imager (LDRI), but without ISS Wireless Instrumentation System (IWIS) measurements of the strain and acceleration in Node 1. The IWIS was not available because of the lack of time for installation of the hardware. The initial results show that the solar array and P6 ITS deflections are consistent with model predictions. Inertial measurement unit (IMU) data as well as Russian data, if available, will be used to support the analyses. The set-up, activation and checkout of the IWIS is being request to occur prior to the impending Progress docking to gain the IWIS data for ISS 4A global modes and Node/Z1 interface loads not acquired during STS-97.

**DTO 700-14 Single String Global Positioning System** - All objectives of DTO 700-14 were performed satisfactorily and the DTO was 100-percent successful. The objectives included:

1. Operations (OPS) 2 short and long power cycles;
2. GPS 2 conditioning where the Miniature Air-to-Ground Receiver (MAGR) was powered off overnight to provide data for start-up performance evaluation;
3. Commanded Self-Test during flight control subsystem (FCS) checkout; and Entry/Landing performance evaluation.

The results of each DTO objectives were monitored in real time via downlist during the test, in addition to the data downlisted for storage and further detailed review.

There were two known anomalies observed during the mission. These were: Following the FCS checkout MAGR self-test, a "warning" indication, which has been observed during previous missions and on the ground, was noted. The MAGR team has documented these occurrences and an investigation into the cause is being made. MAGR performance does not appear to be affected by this indication.

During entry, the figure of merit (FOM) remained poor for unexpectedly longer than usual following the entry plasma (blackout) region. Furthermore, the downlisted MAGR channel

status indicators did not appear to be responding to the environment as expected. This anomaly will be fully examined by the team using all available downlisted data.

**DTO 805 Crosswind Landing Performance** - The crosswinds were not sufficient to accomplish this DTO of Opportunity.

### DETAILED SUPPLEMENTARY OBJECTIVES

**DSO 493 - Monitoring Latent Virus Reactivation and Shedding in Astronauts** - The planned data take occurred during the preflight operations as well as the postlanding operations. The data are being analyzed, and the report of the results will be published in other documentation.

**DSO 498 - Spaceflight and Immune Function** - The planned data take occurred during the preflight operations as well as the postlanding operations. The data are being analyzed, and the report of the results will be published in other documentation.

**DSO 802 - Educational Activities** - Tomato seeds were passively flown for postflight use by Canadian school children.

### HUMAN EXPLORATION AND DEVELOPMENT OF SPACE TECHNOLOGY DEMONSTRATIONS

**HDT 1403 - Micro-Wireless Instrumentation System** - The Micro-Wireless Instrumentation System (MICRO-WIS) sensors/recorders passively collected thermal data that will be used for postflight evaluation to characterize the thermal environment for the forward RCS interconnect system.

**HDT 1404 - Laser Dynamic Range Imager** - The Laser Dynamic Range Imager (LDRI) performed well during the STS-97 mission. Checkout was excellent in all modes. The LDRI did not receive good measurements during DTO 261 Test 1 (in daylight). This condition was expected prior to the flight. However, during the night pass of DTO 261 and operating in mode 5, observations of test 2 from the ground indicated that P6 ITS dynamics were measurable with the LDRI and that the peak deflections were approximately 0.5 inch, as expected.

Various temperature measurements in mode 6 showed LDRI cooling at predicted rates in darkness while in the standby mode. Checkout of the Orbiter Space Vision System (OSVS) with the LDRI in mode 2 were performed successfully; however, since the entire P6 ITS berthing occurred in daylight, the LDRI was not needed.

In addition to the planned objectives, the LDRI was used to assess the ISS untensioned starboard solar array blanket and to take data for plume-loads assessment during the undocking sequence.

Two minor problems initially developed but were resolved so that the instrument could be successfully used. These problems are discussed in the following paragraph.

During the first several attempts to command the LDRI from the ground, the issued commands were not received by the LDRI. All commanding was normal from the cabin. It was determined that the LDRI would only receive commands from the ground when the A7

panel was configured for middeck-to-multiplexer (MUX) 1. Further troubleshooting identified that the LDRI would respond to the ground commands anytime the A7 panel had MD-to-MUX1 L, regardless of which camera was being commanded. This condition resulted in the loss of 15 percent of the HDT objectives. All camera automatic light control (ALC) and GAMMA commands go to the LDRI when in the A7 configuration mentioned previously and the LDRI is not asleep. Additionally, there were at least two occurrences where the LDRI was noted to be in Mode 6 with no definitive crew or ground command action to cause Mode 6 to be selected.

## **PHOTOGRAPHY AND TELEVISION ANALYSIS**

### **LAUNCH PHOTOGRAPHY AND VIDEO DATA ANALYSIS**

A total of 65 high-speed 16mm films, large format 35mm tracking films and videos were reviewed. The review of the launch photography has isolated three significant items, which are as follows:

Solid Rocket Booster (SRB) holddown post (HDP) stud hang-up was observed on post no. 1. The stud appeared to be fully extended before it was released, then oscillated back and forth (twang) before falling back into the HDP well. Using the 3.5-inch diameter of the bolt, the extended visual length was estimated to be 9.3 inches. No frangible nut debris was seen during liftoff. A piece of shave aluminum fell from the aft skirt stud hole. Broaching was identified at the SRB postflight assessment held after the return of the SRBs for inspection and disassembly. Instrumentation showed a 0.22g lateral acceleration at liftoff, and this level is indicative of a stud hang-up.

Pulsating flames were visible from the Orbiter +Z auxiliary power unit (APU) vent (forward of the base of the vertical stabilizer) from before SSME ignition through liftoff. The length of the flame was estimated to be 5 to 7 feet. The length of time the flame was periodically visible was 12.27 seconds. The time period between pulses was 0.66 seconds. JSC re-screened the imagery from night launches of STS-92, STS-106, STS-101, SS-103, STS-93 and STS-96, and no indication of flames was seen from the APU vent.

Body flap motion was very apparent during ascent. A comparison with other missions has shown similar motion in amplitude and frequency and this has been confirmed by analytical measurements.

### **ON-ORBIT PHOTOGRAPHY AND VIDEO DATA ANALYSIS**

Twelve hand-held photographs of the External Tank (ET) were acquired using the 35mm camera with a 400mm lens. The lighting was adequate on the first five frames of photography; however, the remaining seven frames showed a large portion of the ET in the dark because of backlighting from the Sun. The photography was acquired during the early orbital maneuvering subsystem (OMS) 2 maneuver preparations with the first frame taken 28 minutes 56 seconds after liftoff. The areas of the vehicle viewed showed no problems or in-flight anomalies.

Views of the nose, the aft dome, and the -Y side of the ET were obtained. Views of the remaining sides of the ET were unusable because of the aforementioned backlighting. The level of detail on the ET that could be seen was limited because of the long distance between the camera and the ET. As a result, the minimum resolvable object size was estimated to be 12 inches.

The normal -Y SRB separation burn scar and aero heating marks were noted on the intertank and nose thermal protection subsystem (TPS) of the ET. The visible portion of the -Y liquid oxygen tank/Ojive TPS appeared to be in satisfactory condition. The -Y thrust panel appeared to be in satisfactory condition.



## **LANDING PHOTOGRAPHY AND VIDEO DATA ANALYSIS**

Ten videos and seven films of landing were received and screened. No significant findings or anomalies were noted in the approach, landing, and roll-out video and film views screened. All observations were nominal.

**TABLE I.- STS-97 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	336:03:01:10.744 336:03:01:13.152 336:03:01:13.214
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	336:03:05:33.966 336:03:05:33.096 336:03:05:33.216 336:03:05:33.376
Main Propulsion System Start <sup>a</sup>	ME-3 Start command accepted ME-2 Start command accepted ME-1 Start command accepted	336:03:06:54.433 336:03:05:54.552 336:03:05:54.664
SRB Ignition Command (Liftoff)	Calculated SRB ignition command	336:03:06:00.986
Throttle up to 104.5 Percent Thrust <sup>a</sup>	ME-2 Command accepted ME-3 Command accepted ME-1 Command accepted	336:03:06:04.972 336:03:06:04.993 336:03:06:05.003
Throttle down to 72 Percent Thrust <sup>a</sup>	ME-2 Command accepted ME-3 Command accepted ME-1 Command accepted	336:03:06:30.892 336:03:06:30.914 336:03:06:30.924
Throttle up to 104.5 Percent Thrust <sup>a</sup>	ME-2 Command accepted ME-3 Command accepted ME-1 Command accepted	336:03:06:49.133 336:03:06:49.154 336:03:06:49.164
Maximum Dynamic Pressure (q)	Derived ascent dynamic pressure	336:03:07:01
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	336:03:07:59.55 336:03:08:00.15
End RSRM <sup>a</sup> Action <sup>a</sup> Time	RH SRM chamber pressure mid-range select LH SRM chamber pressure mid-range select	336:03:08:02.67 336:03:08:02:72
SRB Physical Separation <sup>a</sup>	LH rate APU turbine speed - LOS	336:03:08:04.91
SRB Separation Command	SRB separation command flag	336:03:08:06
OMS Assist Ignition	Right engine bi-prop valve position Left engine bi-prop valve position	336:03:08:15.1 336:03:08:15.2
OMS Assist Cutoff	Right engine bi-prop valve position Left engine bi-prop valve position	336:03:09:57.5 336:03:09:57.6
Throttle Down for 3g Acceleration <sup>a</sup>	ME-1 command accepted ME-2 command accepted ME-3 command accepted	336:03:13:25.772 336:03:13:25.781 336:03:13:25.802
3g Acceleration	Total load factor	336:03:14:11.9
Throttle Down to 67 Percent Thrust <sup>a</sup>	ME-1 command accepted ME-2 command accepted ME-3 command accepted	336:03:14:20.173 336:03:14:20.182 336:03:14:20.203
SSME Shutdown <sup>a</sup>	ME-1 command accepted ME-2 command accepted ME-3 command accepted	336:03:14:26.373 336:03:14:26.382 336:03:14:26.403

<sup>a</sup>MSFC supplied data

**TABLE I.- STS-97 SEQUENCE OF EVENTS  
(Continued)**

<b>Event</b>	<b>Description</b>	<b>Actual time, G.m.t.</b>
MECO	MECO command flag MECO confirm flag	336:03:14:27 336:03:14:27
ET Separation	ET separation command flag	336:03:14:46
APU Deactivation	APU-1 GG chamber pressure APU 2 GG chamber pressure APU 3 GG chamber pressure	336:03:20:36.296 336:03:20:56.821 336:03:21:10.663
OMS-1 Ignition	Left engine bi-prop valve position Right engine bi-prop valve position	Not performed - direct insertion trajectory flown
OMS-1 Cutoff	Left engine bi-prop valve position Right engine bi-prop valve position	
OMS-2 Ignition	Left engine bi-prop valve position Right engine bi-prop valve position	336:03:49:15.8 336:03:49:15.9
OMS-2 Cutoff	Right engine bi-prop valve position Left engine bi-prop valve position	336:03:50:34.3 336:03:50:34.4
Payload Bay Doors (PLBDs) Open	PLBD right open 1 PLBD left open 1	336:04:36:38 336:04:37:58
OMS-3 Ignition	Left engine bi-prop valve position Right engine bi-prop valve position	N/A 336:06:49:17.2
OMS-3 Cutoff	Left engine bi-prop valve position Right engine bi-prop valve position	N/A 336:06:49:27.8
OMS-4 Ignition	Left engine bi-prop valve position Right engine bi-prop valve position	337:03:23:45.0 337:03:23:45.0
OMS-4 Cutoff	Left engine bi-prop valve position Right engine bi-prop valve position	337:03:24:37.4 337:03:24:37.4
OMS-5 Ignition	Left engine bi-prop valve position Right engine bi-prop valve position	337:16:00:09.2 337:16:00:09.2
OMS-5 Cutoff	Left engine bi-prop valve position Right engine bi-prop valve position	337:16:01:29.2 337:16:01:29.2
OMS-6 Ignition	Left engine bi-prop valve position Right engine bi-prop valve position	337:17:32:44.4 Left engine only
OMS-6 Cutoff	Left engine bi-prop valve position Right engine bi-prop valve position	337:17:32:52.2 Left engine only
Docking with ISS	Docking ring final position	337:20:11:51
Begin First Extravehicular Activity	Airlock differential pressure no. 1	143:01:52:51
End First Extravehicular Activity	Airlock differential pressure no. 1	143:08:31:58
Begin Second Extravehicular Activity	Airlock differential pressure no. 1	143:01:52:51
End Second Extravehicular Activity	Airlock differential pressure no. 1	143:08:31:58
Begin Third Extravehicular Activity	Airlock differential pressure no. 1	143:01:52:51
End Third Extravehicular Activity	Airlock differential pressure no. 1	143:08:31:58
Cabin Repressurization to 14.7 psia	Cabin pressure	143:07:49
Undocking from ISS	Undock complete	344:19:13:00

**TABLE I.- STS-97 SEQUENCE OF EVENTS  
(Concluded)**

<b>Event</b>	<b>Description</b>	<b>Actual time, G.m.t.</b>
OMS-7 Ignition	Left engine bi-prop valve position Right engine bi-prop valve position	345:01:39:56.6 345:01:39:56.6
OMS-7 Cutoff	Left engine bi-prop valve position Right engine bi-prop valve position	345:01:40:09.0 345:01:40:09.2
Flight Control System Checkout APU Start APU Stop	APU 1 GG chamber pressure APU 1 GG chamber pressure	345:15:42:07.735 345:15:46:17.575
Payload Bay Doors Close	PLBD left close 1 PLBD right close 1	346:19:14:29 346:19:16:08
APU Activation for Entry	APU-2 GG chamber pressure APU-1 GG chamber pressure APU-3 GG chamber pressure	346:21:52:41.923 346:22:19:22.411 346:22:19:27.573
Deorbit Burn Ignition	Left engine bi-prop valve position Right engine bi-prop valve position	346:21:57:31.2 346:21:57:31.3
Deorbit Burn Cutoff	Left engine bi-prop valve position Right engine bi-prop valve position	346:22:00:12.8 346:22:00:12.9
Entry Interface (400K feet)	Current orbital altitude above	346:22:32:02
Blackout end	Data locked (high sample rate)	No blackout
Terminal Area Energy Management	Major mode change (305)	346:22:56:56
Main Landing Gear Contact	LH main landing gear tire pressure 1 RH main landing gear tire pressure 2	346:23:03:23 346:23:03:23
Drag Chute Deployment	Drag chute deploy 1 CP volts	346:23:03:26.9
Main Landing Gear Weight on Wheels	LH MLG weight on wheels RH MLG weight on wheels	346:23:03:31 346:23:03:31
Nose Landing Gear Contact	NLG LH tire pressure 1	346:23:03:35
Nose Landing Gear Weight On Wheels	NLG weight on wheels 1	346:23:03:35
Drag Chute Jettison	Drag chute jettison 1 CP Volts	346:23:03:52.6
Wheel Stop	Velocity with respect to runway	346:23:04:20
APU Deactivation	APU-1 GG chamber pressure APU-2 GG chamber pressure APU-3 GG chamber pressure	346:23:22:12.928 346:23:22:21.789 346:23:22:28.405

TABLE II- STS-92 SPACE SHUTTLE VEHICLE ENGINEERING OFFICE IN-FLIGHT ANOMALY LIST

No.	Title	Reference	Comments
STS-97-V-01	Vernier Thruster F5R Fuel Injector Temperature Sensor Failed Off-Scale High	338:17:00 G.m.t. 02:13:54 MET CAR 97RF02	<p>While docked to the ISS, the vernier reaction control subsystem (RCS) thruster F5R fuel-injector temperature stopped tracking the oxidizer injector temperature as expected. When this thruster was fired, the fuel injector temperature measurement went off-scale high at a higher rate than the oxidizer temperature. Also, during periods of thruster inactivity, the fuel injector temperature lagged behind the oxidizer injector temperature as the temperatures returned to the nominal range. This behavior was indicative of a temperature sensor problem, and thruster operation was not impacted by this condition. Following undocking from the ISS, the F5R fuel-injector temperature failed off-scale high. Owing to the general purpose computer memory update implemented earlier in the flight because of the vernier thruster L5D oxidizer-injector temperature sensor problem, this left thruster F5R without leak detection. As a result, the vernier thrusters were not used for attitude control for the remainder of the mission. The mission impact was minimal. An MDM FF3 BITE 4 test was performed and did not indicate a problem with the MDM.</p> <p>KSC: Postflight troubleshooting of the forward module electronics will be performed prior to removal of the module for thruster replacement.</p>

**TABLE III.-STS-97 MSFC PROBLEM TRACKING LIST**

No.	Title	Time	Comments
STS-97-B-001	System A NSI Pressure Cartridge in Left Aft Lower SRB Strut Did Not Fire	SRB Cutoff 336:03:08:04 G.m.t. 00:00:02:03 MET	<p>At SRB separation, the system A NSI pyrotechnic pressure cartridge in the left aft lower SRB strut did not fire. A team was organized to investigate this criticality 1R anomaly. The investigation and testing showed an open circuit on both conductors and the shield of the reusable ordnance cables caused the failure. The team determined that the cause of the cable failure was handling damage.</p> <p>The watertight reusable ordnance cables on all three struts and the forward separation bolt of both SRBs on STS-98 were X-rayed to identify similar cable damage. This cable was abandoned in place after its ends were removed, and a new cable was installed. The right SRB had one suspect cable shield on the forward separation bolt. The cable was removed and replaced. The failure analysis confirmed that both cables would have been safe to fly.</p> <p>Electrical checks of all watertight reusable ordnance cables for all three struts on both STS-97 struts were performed. These checks revealed a suspect shield on the left SRB lower strut firing line for system B. The cable failed the continuity check of the shield during a wiggle test at the strut end. The connector was replaced and the cable was successfully retested.</p> <p>For supporting testing, 37 uninstalled reusable strut cables were X-rayed and electrically tested. The mission count of these cables ranged from 0 to 11 missions with 9 cables having 6 or more missions. All cables passed the continuity and wiggle test. The results along with the results of destructive testing led the team to conclude that all of the tested cables were safe to fly.</p> <p>X-rays were taken of 100 cables from the cable inventory. A break in a conductor wire of a forward systems tunnel cable was located. An investigation is in process to determine the cause of the failure and to formulate a corrective action.</p>

**TABLE III.-STS-97 MSFC PROBLEM TRACKING LIST**

No.	Title	Time	Comments
STS-97-B-001 (Continued)	System A NSI Pressure Cartridge in Left Aft Lower SRB Strut Did Not Fire	SRB Cutoff 336:03:08:04 G.m.t. 00:00:02:03 MET	<p>The cable consisted of six wires and had passed electrical bench tests on 12-07-00. The cable passed the initial continuity test but failed continuity during flex testing. The cable had no visible shield damage. The destructive analysis concludes that the failure was tensile in nature and no materials, environmental or corrosion issues were noted. The appearance of the failure surfaces and insulation indicate that the failure was not recent.</p> <p>An additional 100 watertight reusable cables are being subjected to X-ray and electrical evaluation. A demonstrated cable reliability analysis is being calculated.</p> <p>A partial rationale for flight has been formulated. Investigation shows that shield damage on watertight reusable cables occurs prior to damage of the conductors when the damage is caused by handling. The installed watertight reusable ordnance strut cables have been X-rayed with anomalies noted and repaired or replaced. These cables were also successfully tested electrically. These critical functions are redundant (1R) by design.</p> <p>The final rationale for flight is pending successful completion of radiographic inspection, electrical and flex testing of additional reusable cables, and completion of the demonstrated reliability analysis.</p>





## DOCUMENT SOURCES

In an attempt to define the official as well as the unofficial sources of data for the STS-97 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-97 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.

ABS	ammonia boiler system
AC or ac	alternating current
ADTA	air data transducer assembly
ALC	automatic light control
AMC	aft motor controller
APC	aft power controller
APCU	aft power controller unit
APU	auxiliary power unit
ARPCS	atmospheric revitalization pressure control system
ARS	atmospheric revitalization system
ATCS	active thermal control system
BFS	backup flight system
BITE	built in test equipment
bps	bits per second
CABPL	cabin payload
CB	circuit breaker
CBM	common berthing mechanism
CCTV	closed-circuit television
CID	circuit isolation device
C/L	centerline
CMG	control moment gyro
CPM	cell performance monitor
CPU	central processing unit
CWC	contingency water container
DC/dc	direct current
DSO	Detailed Supplementary Objective
DTO	Developmental Test Objective
$\Delta V$	differential velocity
ECLSS	environmental control and life support system
EETCS	Early External Thermal Control System
EGT	exhaust gas temperature
EI	entry interface
EMU	extravehicular mobility unit
EO	ET/Orbiter
EPDC	electrical power distribution and control
EPS	Electrical Power System
ERCA	EVA Remote Camera Assembly
e.s.t.	eastern standard time
ET	External Tank
EVA	extravehicular activity
FBMBT	flexible bearing mean bulk temperature
FCE	flight crew equipment
FCMS	fuel cell monitoring system
FCP	fuel cell powerplant

FCS	flight control system/subsystem
FES	flash evaporator system
FOM	figure of merit
FPP	Floating Potential Probe
FSS	Fixed Service Structure
ft/sec	feet per second
GFE	Government furnished equipment
GG	gas generator
GGVM	gas generator valve module
G.m.t.	Greenwich mean time
GN&C	guidance navigation and control
GN <sub>2</sub>	gaseous nitrogen
GO <sub>2</sub>	gaseous oxygen
GPC	general purpose computer
GPS	Global Positioning System
GSE	ground support equipment
HDP	holddown post
HDT	Human Development Technology
ICBC3D	IMAX Cargo Bay Camera 3 Dimension
IEA	integrated electronics assembly
IMAX	Camera system
IMU	inertial measurement unit
In/sec	inch per second
$I_{sp}$	specific impulse
ISS	International Space Station
ITS	Integrated Truss Structure
IWIS	ISS Wireless Instrumentation System
JSC	Johnson Space Center
keas	knots estimated air speed
KSC	Kennedy Space Center
kW	kilowatt
kWh	kilowatt/hour
lbm	pound mass
lb/min	pound per minute
LCC	Launch Commit Criteria
LDRI	Laser Dynamic Range Imager
LH <sub>2</sub>	liquid hydrogen
LMSO	Lockheed Martin Space Operations
LO <sub>2</sub>	liquid oxygen
LP	Launch Package
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
MLP	Mobile Launch Platform
mmHg	millimeter mercury
MPS	main propulsion system

MLS	microwave landing system
MSFC	Marshall Space Flight Center
MUX	multiplexer
NASA	National Aeronautics and Space Administration
NCC	circularization maneuver (rendezvous maneuver)
NC3	circularization maneuver (rendezvous maneuver)
nmi.	nautical mile
NPC	plane change maneuver (rendezvous maneuver)
NPSP	net positive suction pressure
NSLD	NASA Shuttle Logistics Depot
NSTS	National Space Transportation System (i.e., Space Shuttle Program)
ODS	Orbiter Docking System
OMRSD	Operations and Maintenance Requirements and Specifications Document
OMS	orbital maneuvering subsystem
OPS	Operations
OSH	off-scale high
OSVS	Orbiter Space Vision System
OV	Orbiter Vehicle
PAL	protuberance air load
PASS	primary avionics software system
PCS	pressure control system
PDU	power drive unit
PGME	Propylene Glycol Monomethyl Ether
PGSC	payload and ground support computer
PGT	pistol grip tool
PIP	push in place
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
psi	pound per square inch
psia	pound per square inch absolute
psid	pound per square inch differential
psig	pound per square inch gravity
PVM	Photo Voltaic Module
RCS	reaction control subsystem
RHC	rotational hand controller
RM	redundancy management
RMS	Remote Manipulator System
RSB	rudder speedbrake
RSRM	Reusable Solid Rocket Motor
RSS	rotating service structure
RTV	room temperature vulcanizing (material)
S&A	safe and arm
SABB	solar array blanket box
SAFER	simplified aid for EVA Rescue
SASA	S-band antenna structural assembly
SAW	Solar Array Wing
SLF	Shuttle Landing Facility

SLWT	super lightweight tank
S/N	serial number
SRB	Solid Rocket Booster
SRSS	Shuttle range safety system
SSME	Space Shuttle main engine
SSV	sequential still video
SSVEO	Space Shuttle Vehicle Engineering Office
STS	Space Transportation System
SUPA	Shuttle Urine Pretreat Assembly
SWAR	Sea water activated release
WIS	Wireless Instrumentation System
TACAN	tactical air navigation
TCS	trajectory control sensor/thermal control system
TI	transfer initiation (rendezvous maneuver)
TPS	thermal protection system/subsystem
TSA	tool storage assembly
TSM	tail service mast
V	Volts
WCS	waste collection system
WDVA	water dispenser valve assembly
WSB	water spray boiler
WVS	Wireless Video System
XPOP	X axis perpendicular to orbital plane



