

# **STS-92 SPACE SHUTTLE MISSION REPORT**

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January 2001



**National Aeronautics and  
Space Administration**

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

NOTE

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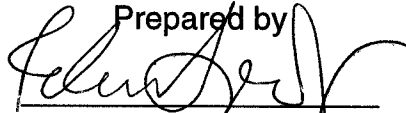
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STS-92

SPACE SHUTTLE

MISSION REPORT

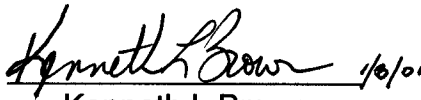
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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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January 2001

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## INTRODUCTION

The Space Transportation System (STS)-92 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-92 flight was the fifth mission to the International Space Station (ISS) to perform maintenance and logistics tasks.

This Space Shuttle Program Mission Report presents a discussion of the Orbiter subsystem operation and the in-flight anomalies that were identified. The report also summarizes the activities of the STS-92 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 mission. STS-92 was the one-hundredth flight of the Space Shuttle Program, the seventy-fifth flight since the return to flight, and the twenty-eighth flight of the OV-103 (Discovery) vehicle.

The flight vehicle consisted of the OV-103 Orbiter; an ET, which was the eighth Super Lightweight Tank (SLWT), and it was designated ET-104; three Block IIA SSMEs that were designated as S/Ns 2045, 2053, and 2048 in positions 1, 2, and 3, respectively; and two SRBs that were designated BI104. The two RSRMs were designated RSRM-76 with one installed in each SRB. The individual RSRMs were designated as 360T076A for the left SRB and 360L076B for the right SRB.

The primary objective of the STS-92 flight was to launch, rendezvous and dock with the orbiting ISS stage and deliver to orbit the 3A launch package (LP). The Z1 Integrated Truss Segment (ITS) was attached to the zenith port of Node 1. In addition, the Pressurized Mating Adapter 3 (PMA 3), which was launched on a Spacelab Logistics Pallet (SLP) carrier, was attached to the nadir port of Node 1. Additionally, two extravehicular activity (EVA) tool stowage devices (ETSDs) that were launched on the SLP, and two DC to DC converter units (DDCUs) that were launched on the Get-Away Special (GAS) Beam carriers, were installed on the Z1 truss on-orbit via EVA. Several other EVA tasks, as well as Node 1 ingress, were accomplished during the flight. As a complex secondary payload, the IMAX cargo bay camera 3D (ICBC3D) objectives were performed in conjunction with the ISS activities.

The STS-92 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 seven-person crew of the STS-92 flight consisted of Brian Duffy, Col., U. S. Air Force, Commander; Pamela A. Melroy, Lt Col., U. S. Air Force, Pilot; Leroy Chiao, Ph. D., Civilian, Mission Specialist 1; William S. McArthur, Col. U. S. Army, Mission Specialist 2, Peter J. K. Wisoff, Ph. D., Civilian, Mission Specialist 3; Michael E. Lopez-Alegria, CDR, U. S. Navy, Mission Specialist 4, and Koichi Wakata, Civilian, Japanese Space Agency (NASDA), Mission Specialist 5. STS-92 was the fourth space flight for

the Commander and Mission Specialist 3, the third space flight for Mission Specialist 1 and Mission Specialist 2, the second space flight for Mission Specialist 4 and Mission Specialist 5, and the first space flight for Pilot.

## MISSION SUMMARY

The STS-92 mission was scheduled for launch on October 5, 2000; however, prior to loading cryogenics into the External Tank (ET), the mission was scrubbed because of a condition that was noted during the photographic review of film from the STS-106 (OV-104) 35-mm ET separation camera. The condition noted was the apparent failure of the right-hand ET attach bolt to fully retract. Following the scrub decision and while backing out of the launch countdown, a failed Orbiter liquid-oxygen (LO<sub>2</sub>) Pogo accumulator recirculation valve 2 was found. The valve did not indicate open when commanded. The decision was made to remove and replace the valve. As a result of these issues, the mission was rescheduled to October 9, 2000. Analysis determined that the ET attach bolt issue was acceptable to fly as-is. The LO<sub>2</sub> Pogo valve was successfully removed, replaced and retested.

The second launch attempt was also scrubbed prior to tanking because the winds were too high to allow tanking of the ET. The launch was rescheduled for October 10, 2000. Approximately 3-hours prior to the planned launch, a ground support equipment (GSE) pip pin with a tether was observed near the ET liquid oxygen feed-line during the Ice Team inspection. The launch was scrubbed prior to picking up the countdown at T-20 minutes because of the uncertainties as to what damage, if any, the pin and tether might cause. Note that there was no significant vehicle issues being worked at the time. The launch was rescheduled for October 11, 2000, at 6:17 p.m. c.d.t.

The STS-92 mission was launched as planned with no unscheduled holds during the flawless countdown. The launch phase was nominal except for the failure to spray by water spray boiler (WSB) 2 as discussed in a later paragraph. The time of launch was 285:23:17:00.011 G.m.t. The orbital maneuvering subsystem (OMS) assist maneuver was performed at 285:23:19:13.2 G.m.t. (00:00:02:13.2 MET) following Solid Rocket Booster (SRB) separation. The maneuver was 41 seconds in duration, and the OMS performed satisfactorily.

WSB 2 failed to provide spray cooling during ascent and auxiliary power unit (APU) 2 was shut down when the lubrication oil outlet temperature reached 317 °F. WSB 2 was launched on the system A controller and was switched to the B controller prior to APU shutdown. The normal temperature of the lubrication oil during cooling is 252 °F. A suspected frozen WSB spray bar is believed to be the cause of the non-spraying condition, a situation that had been seen on previous missions. APU 2 was used during the flight control system (FCS) checkout and proper WSB operation was verified.

STS-92 was the third successful flight of the Space Shuttle Program during which a mixture of Propylene Glycol Monomethyl Ether (PGME) and water was used in WSB 3 to prevent over-cooling conditions. The results were comparable to the results from the previous two flights, and thus far, no over-cooling conditions have occurred with this mixture of PGME and water.

Data review also revealed that the WSB 2 gaseous nitrogen (GN<sub>2</sub>) regulator/relief valve cracking and reseating pressures were not within limits and failed the File IX requirements. Data analysis has shown that the cracking pressure was much higher than the limit of 33.5 psig (cracked at 40.13 psig), and the reseal pressure was lower



than the limit of 28.0 psig (reseated at 27.08 psig). The valve will be removed and replaced.

The OMS 2 maneuver was performed at 286:00:00.32.87 (00:00:41:15.8 MET) and was 53.6 seconds in duration and the differential velocity ( $\Delta V$ ) was 81.6 ft/sec. The orbit was 85.4 by 175.1 nautical miles following the maneuver.

The payload bay doors were opened at 286:00:54:37 G.m.t. (00:01:37:37 MET). All voltages were nominal and the motors opened the doors within the nominal time.

A dual-engine, straight-feed OMS 3 NC-1 rendezvous maneuver was performed at 286:02:35:58 G.m.t. (00:03:18:58 MET). The maneuver was 31.0 seconds in duration and provided a  $\Delta V$  of 47.0 ft/sec. The resultant orbit was 95.6 by 190.5 nmi.

At approximately 286:14:07 G.m.t. (00:14:50 MET), the Ku-band system failed to transmit or receive in the communications mode. Troubleshooting consisted of power cycling the Ku-band system and performing self-tests. The power cycle did not recover the transmit or receive capabilities and the self-tests failed. Circuit analysis suggested that the most probable cause of the failure was the exciter sub-shop replaceable unit (SRU) located within the Deployed Electronics Assembly (DEA). The exciter is the common circuit associated with the forward and return link functions as well as the self-test function.

At approximately 286:15:17 G.m.t. (00:16:00 MET), the crew reported that the primary Orbiter docking system (ODS) centerline (C/L) camera was misaligned. They reported that at 10-degree zoom, the monitor-generated crosshair was just outside the target circle in the lower left. At 39-degree zoom, the monitor-generated crosshair was just inside the target circle at the upper right. The primary camera was removed and the backup camera was installed. The crew reported that the misalignment was much worse and that the crosshair did not appear in the target circle at any zoom setting. The crosshair was below the target circle and slightly to the left with the camera zoomed in. As the camera was zoomed out, the crosshair moved to the right. The crew reinstalled the primary camera.

To assist in future troubleshooting, the crew was requested to take digital photos of the aft flight deck monitor with each camera installed and zoom settings of 10, 22 and 39 degrees. The primary camera was determined to be acceptable for use during the rendezvous and docking.

A reaction control subsystem (RCS) NC-2 rendezvous maneuver was performed at 286:16:39:55 G.m.t. (00:17:22:55 MET). The maneuver lasted 27.0 seconds and provided a  $\Delta V$  of 6.0 ft/sec. The resultant orbit was 94.8 by 189.7 nmi.

A dual-engine, straight-feed OMS 4 NC-3 rendezvous maneuver was performed at 286:23:53:53 G.m.t. (01:00:36:53 MET). The maneuver was 138.8 seconds in duration and provided a  $\Delta V$  of 153.0 ft/sec. The resultant orbit was 164.4 by 205.2 nmi.

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

### RENDEZVOUS MANEUVERS

Maneuver	Time, G.m.t./MET	$\Delta V$ , ft/sec	Firing time, sec	Orbit, nmi.
NC (Dual OMS)	287:12:28:54 001:13:11:54	50.6	32.6	205.1 x 193.7
NCC (Multi-axis RCS)	287:13:11:17 001:13:54:17	1.2	-	204.7 x 193.9
<u>TI</u> (Left OMS)	287:14:09:00 001:14:52:00	13.0	16.4	206.2 x 200.1
MC-1 (+X RCS)	287:14:28:59 001:15:11:59	0.7	2.0	206.0 x 200.1
MC-2 (RCS)	287:15:05:53 001:15:48:53	2.1	9.0	206.0 x 200.5
MC-3 (RCS)	287:15:22:53 001:16:05:53	0.2	1.0	206.0 x 200.5
MC-4 (RCS)	Not Required	-	-	-

Use of the Ku-Band system in the radar mode was attempted during the rendezvous and as expected, the system was failed. The Ku-Band antenna gimbals were locked and the system was powered off. The antenna was stowed following the extravehicular activities (EVAs). The performance of the Trajectory Control Sensor (TCS) in support of the STS-92 docking with the International Space Station (ISS) was nominal.

The Orbiter/ISS capture occurred at 287:17:45:10 G.m.t. (01:18:28:10 MET). The docking ring retraction and hook closure were completed nominally. The ODS performance was nominal with the exception of the X4 connector-mate indication. The indication did not mode to 'on' as expected. The X4 connector contains ISS 1553 data bus signals, and those signals were used to verify a good connector mate. The connector-mate indication also did not toggle to 'on' during undocking. There was no mission impact.

At 288:12:57:18 G.m.t. (02:13:40:18 MET), a 14-ampere current increase was observed on mid main bus B. Approximately 2.5 seconds later, the mid main bus B dropped 20 amperes. During this same time period, the Orbiter interface unit (OIU) 1 and the Orbiter space vision system (OSVS) equipment no longer were operational. A review of the equipment lost indicated that the cabin payload (CABPL) 3 bus was lost. With the loss of the CABPL 3 bus, the keel camera, the remote manipulator system (RMS) side view camera, the ODS C/L camera, the payload timing buffer, and the DC-to-DC converter unit (DDCU) starboard system B heater were also lost.

The CABPL 3 bus is powered by a 15-ampere remote power controller (RPC), which receives its power from the Orbiter mid main bus B when the Cabin Payload power switch is in the main B position. The observed current spike equates to the signature expected when the output of a 15-ampere RPC is shorted (125- to 150-percent of rated load for 2 to 3 seconds, then trips off).

OIU 2 was used for ISS data and the spare OSVS unit was powered from the panel A11 direct-current (DC) utility outlet using a breakout box. To protect the RPC from being reset, the crew placed a switch guard over the Cabin Payload switch.

Data evaluation isolated three components as the potential cause based upon the current-spike signature and their circuit-protection-device characteristics. These components are a 35-ampere diode in the mid power control assembly (MPCA) 2, the OSVS unit and the Orbiter keel camera. Though considered unlikely, a wiring short was also a potential cause. The feasibility of in-flight workarounds was evaluated in the event of additional failures. Postflight troubleshooting determined the cause to be the OSVS unit.

During performance of the top-off charge of the stowed extravehicular 2 (EV2) crewmember's extravehicular mobility unit (EMU) batteries, the crew reported that both green "Ready" light emitting diodes (LEDs) were intermittent during the 3-second lamp check at power up on the primary charger (S/N 1002). During the charge period, both red "On" LEDs were illuminated which indicated flow of charge current. At the end of the charge cycle, only the B channel "Ready" LED was lit and both the red LEDs were extinguished. The crew swapped batteries between channel A and B and reportedly obtained the same set of lights. It is not known if the DC power to the unit was cycled. The crew then connected the same batteries to the backup charger (S/N 1001). The results of this activity were unclear. The crew comments suggested that the same results were obtained with this unit. The crew was instructed to use the B channel of each charger to charge only one battery each. The batteries were checked using the airlock power supply following each charge completion. There was no mission impact. Postflight troubleshooting will be performed to determine the cause of the problem.

At 289:03:27 G.m.t. (03:04:10 MET), the left OMS pod bondline temperature sensor was reading approximately 19 °F and then stepped down to approximately -85 °F. The indication remained erratic in the -75 to -90 °F range through the end of the mission. There was no mission impact from the loss of this measurement.

The first extravehicular activity (EVA) was completed satisfactorily in 6 hours 23 minutes and 53 seconds.

At approximately 290:07:51 G.m.t. (05:08:34 MET), the left-hand inboard main landing gear tire pressure 2 measurement dropped from 322 psia to off-scale low (OSL) (232 psia). The measurement remained OSL through 296:16:14 G.m.t. (010:16:57 MET) when the measurement returned to a normal reading. The redundant measurement remained operable, and there was no mission impact.

The second EVA was completed satisfactorily in 7 hours 6 minutes.

The first ISS reboost maneuver was initiated at 290:21:03:00 G.m.t. (04:21:46:00 MET) when RCS thrusters L1A and R1A were fired. The maneuver lasted 30 minutes and 34 seconds. There were a total of 18 +X primary-RCS-thruster reboost pulses with vernier-RCS-thruster attitude adjustments. The aft down-firing vernier-RCS thrusters (L5D and R5D) had an average duty cycle of 60 seconds on and 40 seconds off. There were no thermal violations during the reboost maneuver, and the propellant usage was as expected. The  $\Delta V$  delivered was 6 ft/sec, and the final orbit was 208 x 202 nmi, an altitude increase of approximately 1.5 nmi.

At the start of EVA 3, the crew reported that the airlock depressurization valve cap drifted out and away from the airlock. The cap was tethered to the body of the depressurization valve and it provided a redundant seal to that valve. The depressurization valve inlet was taped over, and the valve was not used for the remainder of the mission. One of the airlock hatch equalization valves was used for airlock depressurization for EVA 4.

The third EVA was completed satisfactorily in 6 hours 47 minutes.

The second ISS reboost maneuver was initiated at 291:22:45:59 G.m.t. (05:23:28:59 MET) when RCS thrusters L1A and R1A were fired. The maneuver lasted 32 minutes and 20 seconds. There were a total of 19 +X primary-RCS-thruster reboost pulses with vernier-RCS-thruster attitude adjustments. The aft down-firing vernier-RCS thrusters (L5D and R5D) had an average duty cycle of 60 seconds on and 40 seconds off. There were no thermal violations during the reboost maneuver, and the propellant usage was as expected. The  $\Delta V$  delivered was 5.8 ft/sec, and the final orbit was 211 by 202 nmi, an altitude increase of approximately 1.5 nmi.

At 292:14:28 G.m.t. (06:15:11 MET), dedicated signal conditioner (DSC) OM2 card 22 failed causing four measurements to go OSL at -75 °F. The four measurements were three hydraulic system temperatures and one APU temperature. The hydraulic system measurements are the left inboard elevon actuator return line temperature, the left main landing gear brake line temperature B, and the right main landing gear brake line temperature D. The APU measurement is the APU 3 water line temperature sensor.

The left inboard elevon actuator return line temperature is one of several measurements that are in the control logic for hydraulic circulation pump 2 runs, but its loss had no mission impact. The hydraulic brake line temperatures monitor heater operation on those lines and the loss of that insight had no mission impact. Finally, the APU water-line temperature monitors heater operation for the APU injector-cooling system. As expected, there was no impact from the loss of insight into the operation of this heater.

The fourth EVA was completed satisfactorily in 6 hours 56 minutes.

The third ISS reboost maneuver was initiated at 292:22:23:32 G.m.t. (06:23:06:32 MET) when RCS thrusters L1A and R1A were fired. The maneuver lasted 29 minutes and 32 seconds. There were a total of 18 +X primary-RCS-thruster reboost pulses with vernier-RCS-thruster attitude adjustments. The aft down-firing vernier-RCS thrusters (L5D and R5D) had an average duty cycle of 60 seconds on and 40 seconds off. There were no thermal violations during the reboost maneuver, and the propellant usage was as expected. The  $\Delta V$  delivered was 5.6 ft/sec, and the final orbit was 214 by 202 n.mi, an altitude increase of approximately 1.5 n.mi.

Undocking from the ISS was performed satisfactorily at 294:15:08:21 G.m.t. (08:15:51:21 MET). The initial separation from the ISS was initiated at 294:15:08:38 G.m.t. (08:15:51:38 MET) with a low Z-axis pulse of the Orbiter primary RCS. The initial separation from the ISS, an out-of-plane separation maneuver, and the final separation from the ISS were all performed nominally. The final separation maneuver from the ISS was initiated at 294:15:52:59 G.m.t. (08:16:35:59 MET) using primary RCS thrusters L1A and R1A for 15 seconds that resulted in a  $\Delta V$  of 4.0 ft/sec.

The crew reported that the 250 mm lens jammed on the 70 mm Hasselblad 203S. The crew performed a malfunction procedure (Cannot Remove Lens) from the Photo/TV Checklist to remove the lens. The crew also reported the 70 mm Hasselblad 203S Camera was not functioning normally in auto bracketing. The bracketing varied from 1/180 second to 1/1500 second. The crew executed a battery change and the program settings were verified to make sure the bracket was set to 1. The crew reported the bracketing problem was intermittent. As a result, the image quality may be impacted.

The FCS checkout was performed using APU 2, which was started at 295:14:22:27 G.m.t. (09:15:05:27 MET). The data showed that FCS and APU performance was nominal. The APU run time was 14 minutes 40 seconds, and 31 lb of fuel were consumed. The APU ran longer than is normally required so that the operation of WSB 2 could be verified. WSB 2 did not provide cooling to APU 2 during ascent.

Initially, cooling was delayed with the APU 2 lubrication oil return temperature reaching 281 °F during the FCS checkout with WSB 2 configured to the A controller. As is typically the case, this under-cooling condition was followed by an over-cooling condition with the lubrication oil return temperature dropping to 206 °F. Steady-state cooling was subsequently achieved with an oil-return temperature of about 256 °F. The WSB was then reconfigured to the B controller. The APU 2 lubrication-return-oil temperature rose briefly to 267 °F and then stabilized at about 258 °F. The performance of WSB 2 was deemed acceptable for the nominal use of APU 2 during entry and landing.

At approximately 295:14:27 G.m.t. (09:15:10 MET), during the WSB 3 vent heater operation prior to FCS checkout, slightly off-nominal heater cycling was observed while on the B controller. Following the FCS checkout, a bake-out was performed to ensure that there was no ice accumulation in the vent nozzle. An ice signature was not observed during the bake-out. During the pre-entry operation of the WSB 3 vent heater on flight days (FDs) 12 and 13, off-nominal heater cycling was again observed on the B controller. The heater on and off points appeared to be changing with each heater cycle within a band of 140 to 190 °F. During the FD 13 operation, WSB 3 was switched to the A controller, and the heater cycles were normal. The B controller was subsequently reselected and normal heater cycles continued. The B controller was again selected on FD 14 during deorbit preparations and the vent did not come up to temperature, indicating that the heater was not operating. The A controller was selected and the heater performed nominally.

The RCS hot fire was initiated at 295:15:28 G.m.t. (09:16:11 MET). All thrusters were fired at least once and demonstrated nominal performance.

At 296:14:19 G.m.t. (10:15:02 MET), after the radiator bypass and flash evaporator system (FES) checkout, the FES primary B controller shut down in the full-up mode. After the shutdown, the high-load duct heaters were configured to A/B to preclude ice formation in the inboard ducts. An entry pocket checklist procedure for flushing the high-load core was initiated after the shutdown. Following the flush procedure, the high-load core was allowed to run on the secondary controller per the procedures. After that time, a restart on the primary B controller in the full-up mode was attempted. This attempt resulted in a second FES shutdown. The FES was then successfully restarted on the primary A controller. No mission impact is expected. The cause of the shutdowns is under investigation.

The payload bay doors were closed and latched for landing at 296:14:57:36 G.m.t. (10:15:40:36 MET). The landing opportunities for the first landing day were cancelled because of the crosswinds being higher than the established limits. The payload bay doors were reopened at 296:16:37:17 G.m.t. (10:17:18:00 MET).

The payload bay doors were closed and latched for landing at 297:18:17:54 G.m.t. (11:19:00:54 MET) for the second day landing opportunities. Winds were in excess of the limits for a Kennedy Space Center (KSC) landing on the second day, and as a result, all landing opportunities were waived for the day. The second-day landing opportunities at EAFB were also waived because of showers within 30 nmi. of the Edwards Air Force Base (EAFB) runway. The payload bay doors were reopened for the second time at 297:21:43:55 G.m.t. (11:22:26:55 MET).

For the third-day landing opportunities, the payload bay doors were closed and latched for landing at 298:17:01:00 G.m.t. (12:17:44:00 MET). Winds were in excess of the limits for a KSC landing on the third day, and as a result, all KSC landing opportunities were waived for that day. The deorbit maneuver for the third-day EAFB first landing opportunity, a two-engine straight-feed firing, was performed on orbit 202 at 298:19:52:00 G.m.t. (12:20:32:43 MET). The maneuver was 183.2 seconds in duration with a  $\Delta V$  of 341.6 ft/sec.

Entry interface occurred at 298:20:28:16 G.m.t. (12:21:08:59 MET), and entry was completed satisfactorily. Main landing gear touchdown occurred on EAFB concrete runway 22 at 298:20:59:42 G.m.t. (12:21:40:25 MET) on October 24, 2000. The drag chute was deployed at 298:20:59:46 G.m.t. The nose gear touchdown occurred at 298:20:59:54 G.m.t. The drag chute was jettisoned at 298:21:00:21 G.m.t. Wheels stop occurred at 298:21:00:49 G.m.t. The rollout was normal in all respects. The flight duration was 12 days 21 hours 42 minutes 42 seconds. The APUs were shut down 27 minutes 8 seconds after landing.

With the successful completion of the STS-92 mission, all of the planned mission objectives were completed satisfactorily.

## PAYLOADS AND EXPERIMENTS

During the docked operations, four extravehicular activities (EVAs) were performed to facilitate assembly operations on the next two missions. During the docked period, all preflight planned objectives/requirements were successfully completed. The Space Shuttle Program and the International Space Station (ISS) Program rated the mission as 100-percent successful in the execution of the primary 3A tasks and the get-ahead tasks for the later assembly missions.

The six major categories of mission priorities defined for the STS-92 mission were:

- a. Rendezvous and dock with the ISS;
- b. Physical installation of Z1 truss to Node 1 zenith port;
- c. Tasks required to maintain the integrity of the Z1 truss element;
- d. Pressurized mating adapter 3 (PMA 3) physical installation to Node 1 nadir port;
- e. Tasks required to maintain the integrity of the remainder of ISS-3A flight element hardware; and
- f. Tasks for future flights.

In addition to the EVA tasks completed, many intravehicular ISS tasks were performed and are discussed in the following paragraphs.

On flight day 2, the preparations for docking were completed with the activation of the aft power converter unit and the Orbiter interface unit. Because of the failure of the Ku-band antenna downlink capability, the Shuttle-based Wireless Instrumentation System (SWIS) data downlink was not performed.

Following the successful docking with the ISS on flight day 3, the crew ingress PMA 2, Node 1, and performed Node 1 logistic transfer operations. Additionally, the SWIS data downlink was made. Air samples were taken of Node 1 and the Orbiter.

On flight day 4, following the successful checkout of the common berthing mechanism (CBM), the Z1 truss was mated to the ISS. Node 1 was ingressed and part 1 of the Z1 truss outfitting, control moment gyro (CMG) jumper installation was completed. Also, the Micro Wireless Instrumentation System (MIC-WIS) was retrieved from Node 1 and returned to the Orbiter. Another SWIS data downlink was also completed.

Flight days 5 and 6 were devoted to the first two EVAs and the activities of these EVAs are discussed in the Extravehicular Activity section of this report.

In addition to EVA 3, which was conducted on flight day 7, the IMAX3D in-cabin camera was used successfully to film EVA operations, post-EVA activities, and an out-the-window scene during the EVA.

During the flight day 8 activities, the IMAX3D camera was again used to film the remaining scenes of the post-EVA activities.

Intravehicular activities (IVA) during flight day 9 included ingress to the Functional Cargo Block (FCB). This activity was originally scheduled for flight day 4; however, ingress was delayed because of the loss of an Orbiter cabin payload bus. Following ingress, the Node 1 and FCB transfers were successfully completed. The Protein Crystal Growth-Enhanced Gaseous Nitrogen (PCG-EGN) dewar was successfully transferred from the ISS to the Orbiter for return. The Node Y cable was installed in support of the Expedition 1 crew. The Z1 vestibule outfitting was completed. The Node and FCB air sampling and microbiological inspections were performed, although the microbiological treatments were not accomplished. The Node 1 egress was delayed to flight day 10 because of time constraints.

Following Node 1 egress and installation of the PMA 2 centerline berthing camera system target, the Orbiter was successfully undocked from the ISS.

During the docked operations, three reboost maneuvers were performed and the ISS orbit was raised 3.6 nmi., to the desired altitude. These maneuvers preserve ISS propellants in preparation for the STS-97 launch. The ISS altitude at undocking was 214 by 202 nmi.

### **ORBITER SPACE VISION SYSTEM OPERATIONS**

The Orbiter Space Vision System (OSVS) performed well and met all preflight expectations during the Z1 truss and PMA 3 installation. In both cases, the OSVS was used to correct remote manipulator system (RMS) digitals to accomplish the berthing operations. The OSVS was able to calculate an accurate solution during the Z1 truss installation even though some of the OSVS targets were shadowed. During PMA 3 berthing operations, the RMS operator was able to correct the orientation of the PMA 3 with respect to the Node using the OSVS solution. The OSVS solution was well within the CBM capture corridor.

### **CARGO BAY PAYLOADS**

#### **IMAX Cargo Bay 3D Camera**

The IMAX Cargo Bay Camera 3 Dimension (ICBC3D) camera successfully documented 14 of the possible 17 scenes of the Shuttle approach, ISS assembly tasks, EVA crew activities and undocking. The three scenes that were not completed were the Z1 installation scene (3) and the PMA installation scene (10), both of which occurred in darkness. The third scene missed was Z1 installation scene (4) which was caused by a communication problem between the camera and the payload and general support computer (PGSC).



## **VEHICLE PERFORMANCE**

The STS-92 mission was successfully launched from Kennedy Space Center (KSC), launch pad 39A, main launch platform (MLP) 3 on October 11, 2000, at 7:17 p.m. e.d.t. The primary objectives of this mission were to deliver to the International Space Station (ISS) the Zenith-1 truss and the third pressurized mating adapter (PMA-3). STS-92 was the one hundredth flight of the Space Shuttle Program, and the second mission to carry U. S.-built elements to the ISS.

The October 5, 2000, launch was delayed because of questions about the External Tank (ET)/Orbiter aft attachment bolt. The film review of the STS-106 ET/Orbiter separation shows that the LO<sub>2</sub> side ET/Orbiter aft attachment bolt was not fully retracted into the ET bolt catcher. Further analysis showed that this condition existed on 6 of 17 previous flights where photographic coverage was available. Secondly, it was determined that a very small portion of residual impact energy does cause the bolt to "drift" back out of the bolt catcher at low g conditions, as this drift was observable on some previous flights. Thirdly, there was no indication that bolt hang-up ever occurred in the Orbiter fitting. Finally, for a nominal case, general purpose computer (GPC) failure case, or an return to launch site (RTLS) abort case, the ET and Orbiter are too far apart for load transmittal contact by the time the bolt "drifts" back out of the bolt catcher. Based on these findings, the issue was resolved with the result that protrusion of the bolt is not an anomaly.

Following the declaration of the October 5, launch delay, the main propulsion system (MPS) 2 LO<sub>2</sub> POGO recirculation accumulator valve (PV21) open position indicator failed to indicate "ON" when the valve was cycled to the open position. As a result, the valve was removed and replaced.

The launch on October 9, 2000, was delayed because the maximum winds exceeded the limits of 42 knots at KSC.

The launch on October 10, 2000, was scrubbed so that a 4-inch lock-pin, which was discovered on a strut between the ET and the Orbiter during post-tanking inspections, could be removed. The lock-pin, approximately 4-inch in length with a 10- to 12-inch long tether, was discovered during the T-3 hour final-inspection walkdown. After detanking, the rotational service structure (RSS) was rotated back, the +Y platform was extended, and the pin was recovered. During removal of the pin, a small gouge in the ET TPS was documented. This was the only damage noted during the pin-removal process.

The initial data evaluation of the vehicle propulsion performance was made using vehicle acceleration and preflight propulsion prediction data. The average flight-derived engine specific impulse ( $I_{sp}$ ) was 453.1 seconds as compared to an SSME tag value of 451.64 seconds at 104.5 percent power level.

## **SOLID ROCKET BOOSTERS**

All Solid Rocket Booster (SRB) systems performed as expected. The prelaunch countdown was nominal and no Launch Commit Criteria (LCC) or Operational Maintenance Requirements and Specifications Document (OMRSD) violations occurred.

No SRB-related in-flight anomalies were identified from the flight data and postflight inspection.

Both SRBs were successfully separated from the vehicle at approximately T+ 123.043 seconds. Radar tracking indicated a normal descent to the splashdown in the Atlantic Ocean. Both SRBs were recovered and returned to the Port from where both SRBs were transported to Hangar AF for inspection, disassembly and refurbishment.

### **REUSABLE SOLID ROCKET MOTORS**

All Reusable Solid Rocket Motor (RSRM) systems performed as expected. The prelaunch countdown was nominal and no LCC or OMRSD violations occurred, nor were any in-flight anomalies identified.

The prelaunch power up and operation of the field joint heaters were accomplished routinely. The heaters operated for 13 hours 15 minutes during the countdown. Power was applied to the heating elements 39 percent (average) of the time during the LCC time frame. The igniter joint heaters operated for 13 hours 5 minutes during the launch countdown. Power was applied to the heating elements 48 percent (average) of the time to keep the igniter joints in their normal operating range. All RSRM temperatures were maintained within acceptable limits throughout the countdown.

The heated, ground-supplied, aft skirt purges was activated twice during the final launch countdown for a total of 5 hours 18 minutes. The heater operation was necessary to maintain the case/nozzle joint temperatures within the required LCC ranges. These purges were switched to high flow during the T-3 hour hold. The final flex bearing mean bulk temperature (FBMBT) was a nominal 82 °F.

Data indicate that the flight performance of both RSRMs was well within the allowable performance envelopes and were typical of the performance observed on previous flights. The predicted propellant mean bulk temperature (PMBT) was 78 °F. Delivered burn rates were 0.3689 and 0.3695 in/sec for the left and right motors, respectively. The propulsion system performance is shown in the table on the following page.

The maximum trace shape variation of pressure versus time during the 62- to 80-second time frame was nominal and calculated to be -0.462 percent at 71.5 seconds (left motor) and -1.086 percent at 73 seconds (right motor).

The operational flight instrumentation (OFI) performed within established requirements. All available data were recorded, transmitted and analyzed without incident.

### **EXTERNAL TANK**

The STS-92 mission was scheduled for launch on October 5, 2000; however, prior to loading cryogenics into the External Tank (ET), the mission was scrubbed because of a condition that was noted during the photographic review of film from the STS-106 (OV-104) 35-mm ET separation camera. The condition noted was the apparent failure of the right-hand ET attach bolt to fully retract. Analysis determined that the ET attach bolt issue was acceptable to fly as-is.

## RSRM PROPULSION PERFORMANCE

Parameter	Left motor, 78 °F		Right motor, 78 °F	
	Predicted	Actual	Predicted	Actual
Impulse gates				
I-20, 10 <sup>6</sup> lbf-sec	65.96	66.12	66.09	66.25
I-60, 10 <sup>6</sup> lbf-sec	176.37	176.94	176.65	177.05
I-AT, 10 <sup>6</sup> lbf-sec	297.14	297.85	297.02	296.63
Vacuum Isp, lbf-sec/lbm	268.6	269.3	268.6	268.3
Burn rate, in/sec @ 60 °F at 625 psia	0.3689	0.3688	0.3695	0.3705
Event times, seconds <sup>a</sup>				
Ignition interval	0.232	N/A	0.232	N/A
Web time <sup>b</sup>	108.3	108.3	108.1	107.8
50 psia cue time	118.3	118.6	118.0	117.7
Action time <sup>b</sup>	120.5	120.9	120.2	119.8
Separation command	122.7	123.0	122.7	123.0
PMBT, °F	78	78	78	78
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	3.6	3.1	3.0
Tailoff Imbalance Impulse differential, Klbf-sec	Predicted		Actual	
	N/A		977.5	

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

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

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

All objectives and requirements of the ET associated with propellant loading and flight operations were met. 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. No ET LCC and OMRSD violations occurred during the countdown.

All ice conditions were acceptable. The observed thermal protection system (TPS) cracks were acceptable. However, two unusual cracks were noted in the intertank TPS between the bipod ramps. This was the first time cracks have been observed in this area. The cracks were typical of intertank cracks in other areas and were not deemed an issue for concern.

The pressurization systems functioned properly throughout engine start and flight. The minimum LO<sub>2</sub> ullage pressure slump was a nominal 13.6 psid.

ET separation was confirmed. Entry and breakup of the ET was nominal. The predicted impact point was 72 nautical miles uprange from the preflight predicted impact point.

## SPACE SHUTTLE MAIN ENGINES

The Space Shuttle main engines (SSMEs) performed nominally throughout the flight with no anomalies noted. Prelaunch operations went smoothly except that the hydrogen pump oxidizer turbopump (HPOTP) intermediate seal purge pressure indicated possible icing in the gaseous nitrogen (GN<sub>2</sub>) system. This condition was controlled by a preplanned contingency of using the high-flow helium purge. No SSME LCC or OMRSD violations occurred during the countdown.

The preliminary, flight-derived  $I_{sp}$  was 1.5-second higher than predicted. The block IIA engines have typically delivered approximately 0.8-second higher flight  $I_{sp}$  than predicted from ground testing.

Main engine cutoff (MECO) occurred 505.6 seconds after SRB ignition. The commanded maximum dynamic pressure (max  $q\alpha$ ) throttle down was made in one step (72 percent).

## SHUTTLE RANGE SAFETY SYSTEM

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

## ORBITER SUBSYSTEM PERFORMANCE

### Main Propulsion Subsystem

The MPS performed nominally throughout the countdown and flight. There were no prelaunch LCC or OMRSD violations, nor were there any anomalies identified from the review and analysis of the data. Also, there was not any significant hazardous gas concentrations detected prior to liftoff. The maximum hydrogen concentration level in the Orbiter aft compartment, with the normally elevated system backpressure used for fast-fill, was 143 ppm uncorrected. This level compares favorably with previous data from this vehicle.

Following the scrub decision on October 5, 2000, launch attempt, and while backing out of the launch countdown, a failed Orbiter LO<sub>2</sub> POGO accumulator recirculation valve 2 was found. The valve did not indicate open when commanded. The decision was made to remove and replace the valve. As a result of these issues, the mission was rescheduled to October 9, 2000.

Data indicate that the LO<sub>2</sub> and LH<sub>2</sub> pressurization systems performed as planned, and the engine inlet net positive suction pressure (NPSP) requirements were met throughout the flight. The LO<sub>2</sub> residuals at SSME shutdown were approximately 7700 lbm.

The overall gaseous hydrogen (GH<sub>2</sub>) system in-flight performance was nominal. All three flow control valves performed nominally on all three SSMEs with a total of 10 cycles during ascent. 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 ullage pressure measurements. The Helium system performance for the SSMEs and pneumatic Helium systems was nominal. Entry Helium usage was 63.87 lbm, which is within the limits of the requirements. All other parameters were nominal.

### Reaction Control Subsystem

The reaction control subsystem (RCS) performed satisfactorily 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. The following table lists pertinent data concerning the RCS maneuvers.

#### RCS TRANSLATIONAL MANEUVERS

Maneuver	Time, G.m.t./MET	$\Delta V$ , ft/sec	Firing time, sec	Orbit, nmi.
NC-2	286:16:39:55 00:17:22:55	6.0	27	94.8 by 189.7
NCC (Multi-axis RCS)	287:13:11:17 01:13:54:17	1.2	-	204.7 by 193.9
MC-1 (+X RCS)	287:14:28:59 01:15:11:59	0.7	2.0	206.0 by 200.1
MC-2 (RCS)	287:15:05:53 01:15:48:53	2.1	9.0	206.0 by 200.5
MC-3 (RCS)	287:15:22:53 01:16:05:53	0.2	1.0	206.0 by 200.5
Reboost 1	290:21:03:00 04:21:46:00	6.0	18 PRCS pulses with verniers on 60 seconds/off 40 seconds	208 by 202
Reboost 2	291:22:45:59 05:23:28:59	5.8	19 PRCS pulses with verniers on 60 seconds/off 40 seconds	211 by 202
Reboost 3	292:21:54:00 06:22:37:00	5.6	18 PRCS pulses with verniers on 60 seconds/off 40 seconds	214 by 202
ISS undocking	294:15:08:38 08:15:51:38	N/A	2	5.6
Out of plane separation	294:15:31 08:16:14	2	6.1	N/A
Final separation	294:15:52:59 08:16:35:59	4.0	15	-

A total of 4014.2 lbm propellants (2139.9 - oxidizer, 1874.3 - fuel) were used from the RCS during the rendezvous mission with the International Space Station. In addition, a total of 4463 lbm of the orbital maneuvering subsystem (OMS) propellants were used by the RCS during interconnect operations. The primary RCS thrusters had 9110 firings and a total firing time of approximately 6453.9 seconds. The vernier RCS thrusters had 19064 firings and a total firing time of 49521.36 seconds.

The first ISS reboost maneuver was initiated at 290:21:03:00 G.m.t. (04:21:46:00 MET) when RCS thrusters L1A and R1A were fired. The maneuver lasted 30 minutes and 34 seconds. There were a total of 18 +X primary-RCS-thruster reboost pulses with vernier-RCS-thruster attitude adjustments. The aft down-firing vernier-RCS thrusters (L5D and R5D) had an average duty cycle of 60 seconds on and 40 seconds off. There were no thermal violations during the reboost maneuver, and the propellant usage was as expected.

The second ISS reboost maneuver was initiated at 291:22:45:59 G.m.t. (05:23:28:59 MET) when RCS thrusters L1A and R1A were fired. The maneuver lasted 32 minutes and 20 seconds. There were a total of 19 +X primary-RCS-thruster reboost pulses with vernier-RCS-thruster attitude adjustments. The aft down-firing vernier-RCS thrusters (L5D and R5D) had an average duty cycle of 60 seconds on and 40 seconds off. There were no thermal violations during the reboost maneuver, and the propellant usage was as expected.

The third ISS reboost maneuver was initiated at 292:22:23:32 G.m.t. (06:23:06:32 MET) when RCS thrusters L1A and R1A were fired. The maneuver lasted 29 minutes and 32 seconds. There were a total of 18 +X primary-RCS-thruster reboost pulses with vernier-RCS-thruster attitude adjustments. The aft down-firing vernier-RCS thrusters (L5D and R5D) had an average duty cycle of 60 seconds on and 40 seconds off. There were no thermal violations during the reboost maneuver, and the propellant usage was as expected.

Undocking from the ISS was performed satisfactorily at 294:15:08:38 G.m.t. (08:15:51:38 MET). The initial separation from the ISS was initiated at 294:15:08:38 G.m.t. (08:15:51:38 MET) with a low Z-axis pulse of the Orbiter primary RCS. The initial separation from the ISS, an out-of-plane separation maneuver, and the final separation from the ISS were all performed nominally.

The RCS hot fire was performed at 263:03:06:00 G.m.t. (10:14:20:13 MET) and ended at 263:03:12:00 G.m.t. (10:14:26:13 MET). All of the thrusters were fired at least twice for at least 0.480-second and each one demonstrated nominal performance. Prior to the hot fire, 23 of the 38 thrusters had been fired during the mission.

### **Orbital Maneuvering Subsystem**

The OMS performed satisfactorily throughout the mission. No LCC or OMRSD violations were noted during the prelaunch countdown nor during the three launch scrubs. Likewise, no OMS in-flight anomalies were recorded during the mission. 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.

A total of 22029 lbm (13581 – oxidizer and 8448 lbm – fuel) of OMS propellants were consumed during the mission. Of this total, the OMS provided 4463 lbm of propellants to the RCS during interconnect operations.

At 289:03:27 G.m.t. (03:04:10 MET), the left OMS pod bondline temperature sensor was reading approximately 19 °F and then stepped down to approximately –85 °F. The indication remained erratic in the –75 to –90 °F range through the end of the mission. There was no mission impact from the loss of this measurement.

The deorbit maneuver for the first Edwards Air Force Base (EAFB) landing opportunity on the second extension day was a two-engine straight feed firing that was performed on orbit 202.

The OMS 1 maneuver was not required because of the nominal ascent trajectory. The OMS maneuvers performed in support of the rendezvous are shown in the following table.

**OMS RENDEZVOUS MANEUVERS**

<b>Maneuver</b>	<b>Time, G.m.t./MET</b>	<b>ΔV, ft/sec</b>	<b>Firing time, seconds</b>	<b>Orbit, nmi.</b>
Assist (Dual OMS)	285:23:19:13 00:00:02:13.2	-	41.2	-
OMS-2 (Dual OMS)	286:00:00:32.8 00:00:43:32.8	81.6	53.8	85.4 x 175.1
OMS-3 (NC-1) (Dual OMS)	286:02:35:58 00:03:18:58	47	31	95.6 x 190.5
OMS-4 (NC-3) (Dual OMS)	286:23:53:53 01:00:36:53	153	98.8	164.4 x 205.2
OMS-5 (NC) (Dual OMS)	287:12:28:54 01:13:11:54	50.6	32.6	205.1 x 193.7
OMS-6 (TI) (Left OMS)	287:14:09:00 01:14:52:00	13.0	16.4	206.2 x 200.1
Deorbit Maneuver (Dual OMS)	298:19:52:00 12:20:35:00	341.4	183	

**Power Reactant Storage and Distribution Subsystem**

The power reactant storage and distribution (PRSD) subsystem performance was nominal during the STS-92 mission. No anomalies were found during the flight and postflight analysis of the data.

A total of 2942 lbm of oxygen and 370 lbm of hydrogen was furnished to the fuel cells for power generation and potable water production. In addition, the PRSD supplied 197 lbm of oxygen to the environmental control and life support system (ECLSS) for pressurization and crew breathing. At wheels stop after landing, 751 lbm of oxygen and 77 lbm of hydrogen remained in the PRSD system. A 49-hour mission extension was possible at the STS-92 average power level of 13.9 kW with the reactants remaining at landing. At extension-day power levels of 12.5 kW, a 55-hour mission extension was available.

### **Fuel Cell Powerplant Subsystem**

The overall performance of the fuel cell powerplant (FCP) subsystem was nominal during the STS-92 mission, and there were no in-flight anomalies noted in the data. The average electrical power level and load was 14.8 kW and 483 amperes. The fuel cells produced 3312 lbm of potable water and 4313 kWh of electrical energy while using 2942 lbm of oxygen and 370 lbm of hydrogen. The Orbiter electrical power level averaged 13.8 kW and the total Orbiter load averaged 451 amperes. The fuel cells were started twice for this mission. The first start-up was for the October 5 launch attempt, and the second was on October 9 in preparation for the launch.

Six purges of the fuel cells were performed during the mission. The 24 hours between the last two purges resulted from the landing wave-offs. The actual fuel cell voltages at the end of the mission were 0.15 V above predicted for fuel cell 1, 0.20 V above predicted for fuel cell 2, and same as predicted for fuel cell 3. The voltage margin above the minimum performance curve at 200 amperes at the end of the mission was 1.2 V for all three fuel cells.

The overall thermal performance of the fuel cell water relief, water line, and reactant purge heater systems was nominal. All of the water system heaters cycled to satisfy the in-flight checkout requirements. The fuel cell 3 alternate water line temperature was high and erratic during the entire on-orbit phase of the mission, indicating a slight leakage past the check valve. This leakage had no impact on the successful completion of the planned mission.

The fuel cell monitoring system (FCMS) was used to monitor the individual cell voltages during prelaunch operations, at various times during the mission and postlanding. Full-rate data were recorded for a 16-minute period early in the mission. These data showed that all cell voltages were nominal.

The fuel cell 1 hydrogen flow meter output was high and erratic during the last half of the mission, but it returned to normal during entry. The flow-rate did not respond to the increased purge flow rate during the last three purges. This flow meter has flown on this fuel cell for the last nine flights. The meter has a history of erratic behavior on several flights, in particular STS-69 and STS-72 in which the signature was very similar to this mission.

### **Auxiliary Power Unit Subsystem**

The APU performed satisfactorily throughout the mission. There were no in-flight anomalies recorded during the operation of the APUs. The table on the following page shows the run times and fuel consumption for the three APUs during the mission.

WSB 2 failed to provide spray cooling during ascent, and APU 2 was shut down when the lubrication-oil outlet temperature reached 317 °F. As a result, the flight control subsystem (FCS) checkout was performed using APU 2, which was started at 295:14:22:27 G.m.t. (09:15:05:27 MET). The data showed that APU performance was nominal. The APU run time was 14 minutes 40 seconds, and 31 lb of fuel were consumed. The APU ran longer than is normally required so that the operation of WSB 2 could be verified.



### APU RUN TIMES AND FUEL CONSUMPTION

Flight phase	APU 1 (S/N 208) (a) (b)		APU 2 (S/N 204) (a)		APU 3 (S/N 404) (a)	
	Time, Min:sec	Fuel consumption, lb	Time, Min:sec	Fuel consumption, lb	Time, min:sec	Fuel consumption, lb
Ascent	20:18	50	18:54	50	20:30	55
FCS checkout			14:40	31		
Entry <sup>a</sup>	99:16	176	70:42	149	70:45	161
Total	119:34	226	104:16	231	91:15	216

<sup>a</sup> APUs were shut down 27 minutes 8 seconds after landing.

The APU 1 exhaust gas temperature 2 (EGT 2) was erratic during entry and went off-scale low shortly before shutdown. After shutdown, the sensor did recover but only to a value of approximately 800 °F, which was approximately 150 °F lower than the backup sensor (EGT 1). The sensor will be removed and replaced during turnaround operations for the next flight of the vehicle.

The APU 1 EGT 1 temperature sensor was erratic for about one minute after the initial start-up for launch, then went open for about two minutes after the FCS checkout shutdown, then went erratic twice for three and 13 minutes during entry. Although there is a redundant measurement, this sensor will be replaced prior to the next flight of the vehicle.

The APU 3 water line temperature went off-scale low along with three other measurements on the same dedicated signal conditioner (DSC) card indicating that there was a problem with that DSC card. Line operations were verified by the tank temperature measurement having a small perturbation impressed on the tank heater thermal cycle data plots.

### Hydraulics/Water Spray Boiler Subsystem

The overall hydraulics and water spray boiler (WSB) system performance was nominal during the mission, except for the points of interest discussed in the following paragraphs.

During ascent, WSB 2 failed to provide spray cooling and, as a result, APU 2 was shut down when the lubrication oil outlet temperature reached 317 °F (Flight Problem STS-92-V-01). WSB 2 was launched on the system A controller and was switched to the B controller prior to APU shutdown. The normal temperature of the lubrication oil during cooling is 252 °F. A suspected frozen WSB spray bar was believed to be the cause of the non-spraying condition, a situation that had been seen on previous missions.

Data review also revealed that the WSB 2 GN<sub>2</sub> regulator/relief valve cracking and reseating pressures were not within limits and failed the File IX requirements. Data analysis has shown that the cracking pressure was much higher than the limit of 33.5 psig (cracked at 40.13 psig), and the reseal pressure was lower than the limit of 28.0 psig (reseated at 27.08 psig). The valve will be removed and replaced.

APU 2 was used during the FCS checkout to verify proper WSB operation. Initially, cooling was delayed with the APU 2 lubrication oil return temperature reaching 281 °F during the FCS checkout with WSB 2 configured to the A controller. As is typically the case, this under-cooling condition was followed by an over-cooling condition with the lubrication oil return temperature dropping to 206 °F. Steady-state cooling was subsequently achieved with an oil-return temperature of about 256 °F. The WSB was then reconfigured to the B controller. The APU 2 lubrication return oil temperature rose briefly to 267 °F and then stabilized at about 258 °F. The performance of WSB 2 was deemed acceptable for the nominal use of APU 2 during entry and landing.

STS-92 was the third successful flight of the Space Shuttle Program during which a mixture of Propylene Glycol Monomethyl Ether (PGME) and water was used in WSB 3 to prevent over-cooling conditions. The results were comparable to the results from the previous two flights, and thus far, no over-cooling conditions have occurred with this mixture of PGME and water. The original plan for use of PGME in one WSB in each of eight flights will be shortened to five flights, with the next flight of OV-103 being the first flight in which the PGME additive will be flown in all three WSBs.

At approximately 295:14:27 G.m.t. (09:15:10 MET), during the WSB 3 vent heater operation prior to FCS checkout, slight off-nominal heater cycling was observed while operating of the B controller (Flight Problem STS-92-V-04). Following FCS checkout, a bakeout was performed to ensure that there was no ice accumulation in the vent nozzle. An ice signature was not observed during the bakeout.

During the mission, a decision was made to lower all three hydraulic system thermal circulation pump turn-on temperature limits from 0 °F or -10 °F to -30 °F and -35 °F and the turn-off temperature limits from 20 °F to -10 °F. This action was taken to minimize circulation pump run times to reduce cryogenic consumables usage and increase mission cryogenics margins for the cryogenic-critical ISS missions. As a result, this flight had considerably fewer circulation-pump runs (9) than previous flights. The longest circulation pump run-time was approximately 30 minutes and this was caused by the failure of a DSC card (Flight Problem STS-92-V-07). This card failure caused four temperature measurements, three of which were hydraulic temperature measurements, to fail off-scale low at -75 °F. The card failure was determined to not be mission critical.

During the pre-entry operation of the WSB 3 vent heater on flight days 12 and 13, off-nominal heater cycling was again observed while operating on the B controller. The heater on and off points appeared to be changing with each heater cycle within the band from 140 to 190 °F. During the flight day 13 operation, WSB 3 was switched to the A controller, and the heater cycles were normal. The B controller was subsequently reselected and normal heater cycles continued. The B controller was again selected on flight day 14 during deorbit preparations, and the vent did not come up to temperature. The A controller was selected and the heater performed nominally. Removal of the B controller will be performed during the postflight turnaround activities.

Prior to entry, the WSB 2 vent nozzle temperature dropped off prior to APU 2/hydraulic system 2 was started for entry (Flight Problem STS-92-V-05). Normally, the vent temperature decreases after spray cooling is observed on the corresponding WSB. The drop in temperature was also slower than what is typically observed during spray cooling operations. Hardware replacement is planned during the postflight turnaround activities.

A hydraulic loads test was performed after landing. Systems 1 and 3 were alternately operated at low pressure and the aerosurfaces were exercised in each configuration with satisfactory results. All components of the hydraulics systems performed nominally during the loads test.

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

The electrical power distribution and control (EPDC) subsystem performance was nominal during the mission. One related in-flight anomaly was identified and it is discussed in the following paragraph.

At 288:12:57:18 G.m.t. (02:13:40:18 MET), a 14-ampere current increase was observed on mid main bus B. Approximately 2.5 seconds later, the mid main bus B dropped 20 amperes. During this same time period, the Orbiter interface unit (OIU) 1 and the Orbiter space vision system (OSVS) equipment no longer were operational (Flight Problem STS-92-V-03). A review indicated that the cabin payload (CABPL) 3 bus was lost. With the loss of the CABPL 3 bus, the function of the keel camera, the remote manipulator system (RMS) side view camera, the ODS C/L camera, the payload timing buffer, and the DC-to-DC converter unit (DDCU) starboard system B heater were also lost.

The CABPL 3 bus is powered by a 15-ampere remote power controller (RPC), which receives its power from the Orbiter mid main bus B when the Cabin Payload power switch is in the main B position. The observed current spike equates to the signature expected when the output of a 15-ampere RPC is shorted (125- to 150-percent of rated load for 2 to 3 seconds, then trips off).

OIU 2 was used for ISS data and the spare OSVS unit was powered from the panel A11 direct-current (DC) utility outlet using a breakout box. To protect the RPC from being reset, the crew placed a switch guard over the Cabin Payload switch.

Data evaluation isolated three components as the potential cause based upon the current-spike signature and their circuit-protection-device characteristics. These components are a 35-ampere diode in the mid power control assembly (MPCA) 2, the OSVS unit and the Orbiter keel camera. A wiring short is also a potential cause. The feasibility of in-flight workarounds was evaluated in the event of additional failures.

Postflight testing at Johnson Space Center (JSC) determined that the OSVS unit failed the pin-to-pin test in both directions indicating a short, but passed the pin-to-chassis test for both pins. The unit was sent to the Canadian vendor for further testing, which identified the +12 power supply as the cause of the short circuit condition. Repairs of this unit will be made. Troubleshooting of the vehicle will also be performed during the postflight turnaround activities to determine if the vehicle contributed to the shorted condition.

### **Orbiter Docking System**

The Orbiter Docking System (ODS) performed the required functions for docking and undocking in a satisfactory manner. One in-flight anomaly was identified and is discussed in a following paragraph.

At approximately 286:15:17 G.m.t. (00:16:00 MET), the crew reported that the primary ODS centerline camera was misaligned (Flight Problem STS-92-V-02). The crew reported that at the 10-degree zoom setting, the monitor-generated crosshair was just outside the target circle on the lower left. At the 39-degree zoom setting, the monitor-generated crosshair was just inside the target circle on the upper right. The primary camera was removed and the backup camera was installed. The crew reported that the misalignment was much worse and that the crosshair did not appear in the target circle at any zoom setting. The crosshair was below the target circle and slightly to the left with the camera zoomed in. As the camera was zoomed out, the crosshair moved to the right. The crew reinstalled the primary camera and noticed some raised paint around the mounting holes.

The crew used a digital camera to photograph the aft flight deck monitor with each ODS camera installed and the three zoom settings of 10, 22, and 39 degrees. The primary camera was determined to be acceptable for the rendezvous and docking. KSC will perform normal alignment checks during the postflight turnaround activities.

The Orbiter/ISS capture occurred at 254:05:51:16.1 G.m.t. (01:17:05:29.1 MET). Docking ring retraction started at 254:05:57:37 G.m.t. (01:17:11:50 MET) and was completed 4 minutes 39 seconds later. Hook closure was activated at 254:06:02:03 G.m.t. (01:17:16:16 MET) and was completed approximately 2 minutes 22 seconds later. The docking ring retraction and hook closure were completed nominally. The ODS performance was nominal with the exception of the X4 connector-mate indication. The indication did not mode to 'on' as expected. The X4 connector contains ISS 1553 data-bus signals, and those signals were used to verify a good connector mate. The connector-mate indication also did not toggle to 'on' during undocking. There was no mission impact. The docking ring extension was completed satisfactorily at 253:10:40:45 G.m.t. (00:21:54:58 MET) in preparation of the docking with the ISS.

Undocking from the ISS was performed satisfactorily at 294:15:08:21 G.m.t. (08:15:51:21 MET).

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

The atmospheric revitalization pressure control subsystem (ARPCS) performed normally throughout the duration of the flight. The active system monitor parameters indicated normal outputs throughout the duration of the mission.

After orbital insertion, the cabin pressure regulator inlet valves were closed and the cabin was allowed to bleed down to save consumables. After docking, repressurization of the vestibule and PMA 2 was performed by cycling the equalization valve to prevent Androgynous Peripheral Attachment System (APAS) hatch seal damage. This procedure has been used for previous ISS missions. Orbiter pressure was then equalized with Node 1 pressure, and the two were repressurized to 14.7 psia. The airlock hatch was closed and depressurization to 10.2 psia was initiated in preparation for the four extravehicular activities (EVAs). Following the completion of the fourth EVA, the normal pressure equalization and hatch openings were performed for ingressing the ISS modules. Before undocking, the entire Orbiter/ISS stack was repressurized to 14.7 psia, and later the pressure for the stack was increased to 14.96 psia using oxygen.

The crew egressed the ISS using the ISS egress procedure to ensure that the ISS modules were left at the required pressures.

### **Atmospheric Revitalization Subsystem**

The atmospheric revitalization subsystem (ARS) performed nominally during the STS-92 mission. The flight rule concerning cabin temperature control and management was modified prior to the flight to allow the cabin temperature to go to 85 °F during the 10.3-psia operations. The previous temperature limit of 80 °F had been exceeded several times on prior missions. The highest cabin temperature recorded on this flight during 10.2 psia operations was 81 °F. The highest cabin temperature recorded during normal pressure operations (above 14 psia) was 82.4 °F during the cabin airlock repressurization to 14.65 psia.

As a result of the stagnant air in the ISS that was noted by the STS-96 crew, air ducting 106-inches long by 4-inch diameter was manifested so that the Shuttle-supplied air to the ISS could be relocated to a more favorable location for the ISS. On the first flight of this ducting change, the STS-101 crew stated that the air quality in the ISS was improved.

After the completion of the first EVA and during the power up cycle of the airlock booster fan, the fan operated on two phases (A and C). The three-phase fan continued to operate on two phases for approximately 16 hours and 20 minutes. The crew was asked to verify that all three circuit breakers were pushed in and to cycle the phase B circuit breaker. The fan was powered up after this check and began operating on all three phases for the remainder of the flight. The fan vendor reported that this fan could operate for 165 hours on two phases without permanently damaging the fan.

At 289:38:51 G.m.t. (03:15:32 MET), the partial pressure of carbon dioxide (ppCO<sub>2</sub>) peaked at 5.15 mmHg while cabin pressure was at 10.2 psia. During 14.7-psia cabin pressure operations, the ppCO<sub>2</sub> peaked at 7.6 mmHg for a short duration. This high level occurred during the first wave off for landing. The ppCO<sub>2</sub> averaged 5 mmHg after the cabin depressurization period and 2.5 mmHg during the 10.2-psia cabin operations.

### **Active Thermal Control Subsystem**

The active thermal control subsystem (ATCS) performed nominally throughout the flight with one in-flight anomaly identified. The anomaly is discussed in a later paragraph.

Ascent and on-orbit operations were nominal with radiator flow initiated 1 hour 20 minutes into the mission.

The flash evaporator system (FES) primary B controller had two shutdowns with the first occurring shortly after radiator bypass/FES checkout was completed on the nominal end-of-mission (EOM) day at 296:14:19 G.m.t. (10:15:02 MET) (Flight Problem STS-92-V-06). The FES was operating in the full-up mode when the primary B controller shutdown the FES. About two minutes after the shutdown, the high load duct heaters were switched from string B to A/B to preclude ice formation. Initial indications were that the high load core may have had ice or excess carryover because evaporator outlet temperatures were unstable during the secondary high-load mode of the FES checkout. A high-load core flush procedure was initiated at 296:14:30 G.m.t. (10:15:11 MET) and

completed 12 minutes later. The temperatures of the high-load ducts did not show any evidence of ice or slush during the flush procedure. A restart of the primary B controller in full-up mode was attempted at 296:14:31 G.m.t. (10:15:24 MET) and this resulted in a second shutdown of the FES. The FES was successfully started on the Primary A controller.

A second deorbit attempt was made one day after the nominal EOM. On this day, a modified radiator bypass/FES checkout was performed during which the high-load core was run on the secondary controller using the B valve. The B valve was used rather than the A valve that is normally used during checkout of the secondary high-load mode of operation. This modified checkout was performed because the possible anomalous condition of the high-load B valve may have caused the shutdowns. The checkout resulted in oscillations of the evaporator outlet temperatures, but the control band of  $62 \pm 2$  °F was maintained successfully. As a result, a decision was made that the primary B controller would not be used again during the mission. The FES performed nominally for the rest of the mission while operating on the primary A controller.

The radiator bypass/FES checkout in preparation for entry and landing was performed using the primary A controller at 298:16:50 G.m.t. (12:17:31 MET). Radiator flow was initiated about 11 minutes prior to landing. The radiator flow control assembly was commanded to the high set point approximately 11 minutes after landing in preparation for the use of the ammonia boiler system (ABS). The ABS was commanded on using the primary B GPC three minutes later and it was deactivated 46 minutes later in preparation for ground support equipment (GSE) cooling.

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

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

Water tanks B and D were ganged together early in the mission with the supply crossover valve open. Tank C was isolated for post-EVA EMU recharging. Following the EVAs, tank C was no longer isolated so that it could refill and be used for de-orbit preparations.

Supply water was managed through the use of the FES and the overboard dump system. Six FES water dumps were performed during the mission. Four of the five supply water dumps were simultaneous water dumps with the waste water. The average dump rate was 1.6 percent/minute (2.64 lb/min). The supply water dump line temperature was maintained between 65 and 95 °F throughout the mission with the operation of the line heater.

Five wastewater dumps were performed at an average rate of 1.85 percent/minute (3.05 lb/min). The wastewater dump line temperature was maintained between 60 and 95 °F throughout the mission. The vacuum vent line temperature was maintained between 60 and 83.5 °F.

### **Waste Collection Subsystem**

The waste collection subsystem performed satisfactorily throughout the flight. The crew did not report any anomalies or problems.

### **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.

The airlock depressurization valve was used to depressurize the cabin and external airlock to 10.2 psia and to depressurize the airlock for the first three EVAs. The depressurization valve cap was lost during crew egress for the third EVA. A depressurization valve leak contingency plan was prepared, should the depressurization valve leak during airlock depressurization following the third EVA. The valve did not leak and the contingency plan was not implemented; however, a decision was made to not use the depressurization valve for the remaining depressurizations of the mission. In addition, the crew was requested to tape the depressurization valve inlet and use the aft hatch equalization valve for upcoming depressurizations. The aft hatch equalization valve was used for the fourth EVA and final egress from the ISS. The depressurization valve inspection and valve cap replacement will be performed at Kennedy Space Center (KSC).

Because of the hot thermal attitude of this mission, a canopy was flown to protect the external airlock water lines and oxygen line from overheating. Additionally, the female half of a quick disconnect (QD) was flown so that the oxygen line that supplies the extravehicular mobility units (EMUs) during recharging could be used to bleed if the temperature exceeded 90 °F. The oxygen line remained below 90 °F, and the purge disconnect was not used.

A leak was detected during the airlock depressurization for the second EVA and the depressurization was stopped. The crew was requested to perform a check and the equalization valve on the hatch between the cabin and airlock was found open with a cap installed. The valve was closed and the airlock depressurization was completed nominally.

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

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

### **Flight Data Subsystem**

The flight data subsystem performed nominally during the mission with the exception of the -Z star tracker anomaly discussed in the following paragraphs. The anomaly did not impact the successful completion of the planned mission.

## **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.

Higher than normal lateral accelerometer readings were noted at liftoff. Data analysis showed that the SRB hold-down stud hang-up was the cause of the high readings.

Descent navigation performed nominally. The external sensors [drag, Tactical Air Navigation (TACAN), air data transducer assembly (ADTA), and Microwave Scanning Beam Landing System (MSBLS)] data were incorporated into the onboard navigation state vector at their expected region of operations. The residuals and residual ratio values from the external sensors were nominal and no navigation editing was required.

Overall, the Global Positioning System (GPS) miniature air-to-ground receiver for Shuttle (MAGR-S) performed well throughout the mission. A more complete discussion of the MAGR-S operation is found in the DTO 700-14 discussion in the Development Test Objective section of this report.

The inertial measurement units (IMUs) were calibrated prior to the flight with nominal results. IMU performance throughout the flight was also nominal. Only one adjustment of the IMU accelerometer compensation values was performed during the mission.

Rendezvous and docking with the ISS was completed in accordance with the timeline. The guidance navigation and control (GN&C) subsystems performed nominally with the exception of the failed Ku-Band antenna, which is discussed in the Communications and Tracking section of this report.

The star trackers performed nominally throughout the mission, and the star tracker was used in place of the rendezvous radar during the final rendezvous operations. Star tracker marks to update the navigation were terminated once the ISS had maneuvered to the docking attitude.

Undocking and separation was completed satisfactorily. No flyaround of the ISS was performed because of the extra amount of propellant used by the RCS during the rendezvous because of the loss of the Ku-Band radar capability. At a range of approximately 150 feet from the ISS, a nominal +X maneuver was initiated to provide the final separation from the ISS.



## **Displays and Control Subsystem**

The displays and control subsystem performed nominally throughout the STS-92 mission. No in-flight anomalies or problems were identified from the review and analysis of the data.

## **Communications and Tracking Subsystem**

The communications and tracking subsystem performed nominally in meeting all requirements of the mission. One in-flight anomaly was identified and it is discussed in a following paragraph.

At approximately 286:14:07 G.m.t. (00:14:50 MET), the Ku-band system failed to transmit or receive in the communications mode (Flight Problem STS-92-V-01). Troubleshooting consisted of power cycling the Ku-band system and performing self-tests. The power cycle did not recover the transmit or receive capability and the self-tests failed. Circuit analysis suggests that the most probable cause of the failure is the exciter sub-shop replaceable unit (SRU) located within the Deployed Electronics Assembly (DEA). The exciter is a common circuit associated with the forward and return link functions as well as the self-test function.

Use of the Ku-Band system in the radar mode was attempted during the rendezvous and as expected, the system was failed. The Ku-Band antenna gimbals were locked and the system was powered off. The antenna was stowed following the extravehicular activities (EVAs). The performance of the Trajectory Control Sensor (TCS) in support of the STS-92 docking with the ISS was nominal.

The antenna was successfully stowed following the EVAs.

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

The operational instrumentation (OI) subsystem and Modular Auxiliary Data Subsystem (MADS) performance was nominal in meeting all mission requirements.

At 292:14:28 G.m.t. (06:15:11 MET), dedicated signal conditioner (DSC) OM2 card 22 failed causing four measurements to go off-scale low at -75 °F (Flight Problem STS-92-V-07). The four measurements were three hydraulic system temperatures and one APU temperature. The hydraulic system measurements are the left inboard elevon actuator return line temperature, the left main landing gear brake line temperature B, and the right main landing gear brake line temperature D. The APU measurement was the APU 3 water line temperature sensor.

The left inboard elevon actuator return line temperature is one of several measurements that are in the control logic for hydraulic circulation pump 2 runs, but its loss had no mission impact. The hydraulic brake line temperatures monitor heater operation on those lines and the loss of that insight had no mission impact. Finally, the APU water-line temperature monitors heater operation for the APU injector-cooling system. As expected, there was no impact from the loss of insight into the operation of this heater. Postflight troubleshooting will be performed during the turnaround activities.

### Structures and Mechanical Subsystems

The structures and mechanical subsystems performed nominally with no anomalies noted.

The payload bay doors were opened at 296:00:54:37 G.m.t. (00:01:37:37 MET). All voltages were nominal and the motors opened the doors within the nominal time. The payload bay doors were closed and latched for landing at 264:04:14:41 G.m.t. (11:15:28:54 MET).

### LANDING AND BRAKING PARAMETERS

Parameter	From Threshold, Ft	Speed, Keas	Sink rate, ft/sec	Pitch rate, deg/sec
Main gear touchdown	2771.2	200.6	-2.82	N/A
Nose gear touchdown	6509.4	152.2	N/A	-5.81
Brake initiation speed		76.4 knots		
Brake-on time		33.06 seconds		
Rollout distance		9086.6 feet		
Rollout time		67.64 seconds		
Runway		22 (Concrete) EAFB		
Orbiter weight at landing		205,123 lb		
Brake sensor Location	Peak Pressure, Psia	Brake assembly	Gross energy, million ft-lb	
Left-hand inboard 1	712.9	Left-hand inboard	8.02	
Left-hand inboard 3	712.9			
Left-hand outboard 2	607.4	Left-hand outboard	5.73	
Left-hand outboard 4	607.4			
Right-hand inboard 1	530.7	Right-hand inboard	7.96	
Right-hand inboard 3	530.7			
Right-hand outboard 2	543.5	Right-hand outboard	6.52	
Right-hand outboard 4	543.5			

The drag chute was deployed at 298:20:59:46.2 G.m.t. The nose gear touchdown occurred at 298:20:59:53.9 G.m.t. The drag chute was jettisoned at 298:21:00:21.04 G.m.t. All components of the drag chute were recovered and appeared to have functioned normally. Both reefing line cutter pyrotechnic devices were expended. During the postlanding walkdown of the runway, no flight hardware was found with the exception of an unidentified orange rubber electrical D-connector (1/2-inch long by 1/16-inch bushing) found in the vicinity of the drogue chute. The source of this item has not been identified.

The landing gear tires were in good condition. There was no evidence of ply undercutting on the main landing gears tires. A 0.375-inch diameter by 0.1-inch long bushing was found on the runway underneath the nose gear doors. The source of this item has not be identified.

## **Integrated Vehicle Heating and Thermal Interfaces**

The prelaunch thermal interface purges were normal with no problems noted. Likewise, the ascent aerodynamic heating and plume heating was nominal with no problems noted. The entry aerodynamic heating on the SSME nozzles was also normal with no bluing of the closure metal noted.

### **Thermal Control Subsystem**

There were no passive thermal control subsystem (TCS) issues during the mission. All heater systems operated nominally, and all subsystem temperatures were maintained within acceptable limits.

The docked phase consisted of mostly the X-axis perpendicular to orbital plane (XPOP) attitude. STS-92 was the first mission where the XPOP0 (Sun from the tail) attitude was necessary to help the ISS use more passive thermal warming. The external airlock canopy, specifically designed for this mission, protected the water and oxygen line temperature from exceeding the limits throughout the EVA timeframe. The main landing gear (MLG) temperature of  $-36^{\circ}\text{F}$  matched the lowest ever recorded in the Space Shuttle Program for these measurements, and this temperature was present at the end of the docked phase. The tires were well above the  $-31^{\circ}\text{F}$  limit when the Orbiter landed at EAFB after two weather-extension days.

Four EVAs were performed on four consecutive days during the docked phase. The external airlock canopy discussed in the previous paragraph allowed the four EVAs to be completed without any further thermal constraints upon the attitudes. Because of the satisfactory control of temperatures by the canopy, the crew was not required to perform any of the oxygen purge procedures. The oxygen line reached a maximum of  $-81^{\circ}\text{F}$  and never threatened to violate the  $90^{\circ}\text{F}$  upper limit.

The hydraulic circulation pumps were managed in the same manner as STS-106. The control sensor limits during the docked phase were changed by the ground controllers to reduce the total pump run-time thereby reducing cryogenics usage. While the management plan did result in reduced pump run-times, the attitudes were also much warmer on STS-92 than any previous ISS mission.

### **Aerothermodynamics**

Data indicate that a limited asymmetrical transition occurred. Aileron data showed an asymmetric transition. The fuselage centerline transition was symmetrical as discussed in the following paragraph. One AMES gap-filler was protruding a few feet in front of the right-hand forward outboard corner of the ET door cavity. No local over-temperature conditions were noted in the data. Entry acreage heating as well as local heating was normal.

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

The thermal protection subsystem (TPS) performed satisfactorily. Entry heating was as expected based on lower-surface structural temperature response data. Data showed that boundary layer transition from laminar flow to turbulent flow was a limited asymmetric transition. A deviation from the aileron command at Mach 16.4 indicates

asymmetric transition. However, fuselage centerline transition is normal, occurring at 1237 seconds after entry interface (EI) on the right side and 1239 seconds after EI on the left side. The bondline temperature data indicate a higher-than-usual temperature rise, which may indicate the occurrence of early transition.

The TPS and windows performed nominally with no in-flight anomalies identified. Entry heating was normal based on structural temperature rise data. MADS data showed asymmetric transition from turbulent to laminar flow occurred at Mach 6.4, which was 1290 seconds after entry interface and was symmetric.

The postlanding inspection of the Orbiter TPS identified a total of 127 impacts of which 24 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.

A comparison of the number of damage sites with statistics from previous missions indicates that both the total number and the number of damage sites that were 1-inch or larger were somewhat greater than the fleet averages. The fleet averages were 102.6 damage sites on the vehicle with 16.1 damage sites larger than 1-inch.

The Orbiter lower surface sustained 86 hits (damage sites), of which 14 had a major dimension of 1-inch or larger. Approximately 33 damage sites (with three larger than 1-inch) were located in the area from the nose landing gear to the main landing gear wheel well on both the left and right chines. The majority of this damage occurred on the right-hand side of the vehicle, though some of these hits may be attributed to impacts from ice in the LO<sub>2</sub> feedline bellows. ET 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	14	86
Upper Surface	1	7
Window Area	6	16
Right Side	0	0
Left Side	0	0
Right OMS Pod	3	11
Left OMS Pod	0	7
<b>Total</b>	<b>27</b>	<b>113</b>

The largest lower surface tile damage site, located on the right wing immediately outboard of the LO<sub>2</sub> umbilical door, measured 2-inches long by 1-inch wide by 0.75-inch deep. The cause of this damage site is believed to be ice from the ET LO<sub>2</sub> feedline.

Numerous tile damage sites around the LH<sub>2</sub> ET/Orbiter umbilical were most likely caused by pieces of the umbilical purge barrier material flailing in the airstream and contacting tiles before pulling loose and falling aft.

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

Parameter	STS -90	STS -91	STS -95	STS -88	STS -96	STS -93	STS -103	STS -101	STS -106	STS -92
Lower surface total hits	76	145	139	80	160	161	84	70	73	86
Lower surface hits > 1 in.	11	45	42	21	66	42	13	19	17	14
Longest damage site, in.	3.0	3.0	4.0	4.5	4.0	6.0	1.5	8	6	2.0
Deepest damage site, in.	0.25	0.5	0.4	0.5	0.5	0.5	0.25	0.75	0.50	0.75

Less than the usual amounts of tile damage occurred on the base heat shield. The

The postlanding walkdown of runway 22 was performed immediately after landing. No flight hardware was found with the exception of an unidentified orange rubber electrical D-connector (1/2-inch long by 1/16-inch bushing) found in the vicinity of the drogue chute, and a 0.375-inch diameter of 0.1-inch long bushing found on the runway underneath the nose gear doors. The source of these items is undetermined. All components of the drag chute were recovered and appeared to have functioned normally. Both reefing line cutter pyrotechnic devices were expended.

The potential identification of debris damage sources for this mission will be based on laboratory analysis of Orbiter postlanding microchemical samples, inspection of the recovered SRB components, film analysis and aerodynamic debris particle trajectory analysis. The results will be documented in a KSC publication.

**Gas Sample Analysis**

STS-92 was an acceptable flight in that only four of the six gas-sample bottles provided data within the nominal range on this thirty-second flight of the redesigned hardware. The data obtained on the four acceptable bottles during ascent were nominal. Four of the six bottle-pressures were in the expected range. The hydrogen concentration was within the database for all Space Shuttle vehicles. The oxygen data were within the bands of error as is determined by the argon measurement, and the amount detected can be attributed to air. The no.1 bottles on the left and right side leaked air into the sample, rendering the samples unusable. The preliminary finding from the failure investigation identified an inadequate cleaning process of the pyrotechnic valve manufacturer. As a result, metal debris could have been left in the valve, causing a leak path after the sample was taken.

## EXTRAVEHICULAR ACTIVITY

All preparations for the extravehicular activities (EVAs) were completed on flight day 2 with the satisfactory checkout of the extravehicular mobility Units (EMUs) and the remote manipulator system (RMS).

The first EVA was completed satisfactorily in 6 hours 23 minutes and 53 seconds. Tasks completed during the first EVA included connecting of the Z1 truss power and data umbilicals, deployment of the Space ground antenna (SGANT), and the port EVA tool storage device (ETSD) was installed on the Z1 truss. In addition, the Z1 truss string 1 and string 2 umbilicals were connected. The S-band antenna structural assembly (SASA) was relocated to the on-orbit stowage location, and the SGANT dish was installed on the boom and the boom was deployed.

During performance of the top-off charge of the stowed extravehicular 2 (EV2) extravehicular mobility unit (EMU) batteries, the crew reported that both green "Ready" light emitting diodes (LEDs) were intermittent during the 3-second lamp check at power up on the primary charger (S/N 1002). During the charge period, both red "On" LEDs were illuminated which indicated flow of charge current. At the end of the charge cycle, only the B channel "Ready" LED was lit and both the red LEDs were extinguished. The crew swapped batteries between channel A and B and reportedly obtained the same set of lights. It is not known if the DC power to the unit was cycled. The crew then connected the same batteries to the backup charger (S/N 1001). The results of this activity were unclear. The crew comments suggested that the same results were obtained with this unit. The crew was instructed to use the B channel of each charger to charge only one battery each. The batteries were checked using the airlock power supply following each charge completion. There was no mission impact. Postflight troubleshooting will be performed to determine the cause of the problem.

The second EVA was completed satisfactorily in 7 hours 6 minutes. During EVA 3, the pressurized mating adapter (PMA) 3 was berthed to the Node 1 nadir port and the PMA3 power and data umbilicals were connected and followed by a successful checkout of the PMA3 umbilicals and heaters. The Rocketdyne Truss Attachment System (RTAS) launch locks were released. The circuit isolation devices (CIDs) were transferred from the Orbiter tool stowage assembly to their temporary stowage location on the Z1 truss.

At the start of EVA 3, the crew reported that the airlock depressurization valve cap drifted out and away from the airlock. The cap was tethered to the body of the depressurization valve and it provided a redundant seal to that valve. The depressurization valve inlet was taped over, and the valve was not used for the remainder of the mission. One of the airlock hatch equalization valves was used for airlock depressurization for EVA 4.

The third EVA was completed satisfactorily in 6 hours 47 minutes. During EVA 3, two dc-to-dc converter units (DDCUs) were installed on the Z1 truss and a successful checkout of the units was completed. The Z1 and PMA 3 power and data umbilicals were reconfigured to support the STS-97 (ISS 4A) docking to PMA3. The starboard ETSD was installed on the Z1 truss. The Z1 truss keel pin and node 1 EVA stowage bag were relocated in preparation for the STS-97 (ISS 4A) mission.

The fourth EVA was completed satisfactorily in 6 hours 56 minutes. During EVA 4, the Z1 flight releasable grapple fixture (FRGF) and the articulating portable foot restraints (APFRs) were relocated. The RTAS and manual berthing mechanism (MBM) latched were successfully cycled. The Z1 tray was deployed and the fluid lines were prepared for the ISS flight 5A. With the completion of EVA 4, the Z1 truss was fully configured to support the next two Shuttle flights to the ISS. A total of 26 hours 38 minutes 40 seconds were spent performing EVAs. Total man-hours in EVA operations were increased by 53 hours, 17 minutes, 20 seconds.

## REMOTE MANIPULATOR SYSTEM

The Remote Manipulator System (RMS) performed satisfactorily throughout the STS-92 mission. STS-92 was the fifty-seventh flight of an RMS and the nineteenth flight of this arm (S/N 301). The primary task of the RMS was to install the Z1 truss structure on the Zenith port of the Unity connecting node, and install pressurized mating adapter 3 (PMA 3) on the nadir port of the node. In addition, the RMS was used during the four extravehicular activities (EVAs) to complete the Z1 truss and PMA 3 installation while the Orbiter was docked to the International Space Station (ISS).

The RMS checkout was performed on flight day 2, and all RMS hardware performed nominally. Following the checkout, the arm was used to perform two payload bay surveys, the second of which was completed after the Orbiter was docked with the ISS on flight day 3.

During flight day 6 activities, an elbow pitch joint brake slip error was detected. This error occurs if joint motion is observed when none is expected. It is triggered when motion greater than 0.5 degree is detected on any joint while the brakes are on. This occurred while an EVA crewmember was ingressing the foot restraint, which is mounted to the wrist-roll striker bar at the tip of the arm. Data showed that the joint movement was only slightly above the 0.5-degree threshold.

Joint brake slip is not uncommon when significant external forces and moments are applied at the tip of the arm, such as occurred on this occasion as well as on a number of previous flights where EVAs occurred. The brakes on the arm are designed such that the brakes will slip before any loads that could cause damage occur.



## GOVERNMENT FURNISHED EQUIPMENT/FLIGHT CREW EQUIPMENT

The overall performance of the government furnished equipment (GFE) and flight crew equipment (FCE) was nominal. One in-flight anomaly was identified and it is discussed in the following paragraph.

At approximately 286:15:17 G.m.t. (00:16:00 MET), the crew reported that the primary Orbiter docking system (ODS) centerline (C/L) camera was misaligned. They reported that at 10-degree zoom, the monitor-generated crosshair was just outside the target circle in the lower left. At 39-degree zoom, the monitor-generated crosshair was just inside the target circle at the upper right. The primary camera was removed and the backup camera was installed. The crew reported that the misalignment was much worse and that the crosshair did not appear in the target circle at any zoom setting. The crosshair was below the target circle and slightly to the left with the camera zoomed in. As the camera was zoomed out, the crosshair moved to the right. The crew reinstalled the primary camera.

To assist in future troubleshooting, the crew was requested to take digital photos of the aft flight deck monitor with each camera installed and zoom settings of 10, 22 and 39 degrees. The primary camera was determined to be acceptable for use during the rendezvous and docking.

The crew reported that the 250 mm lens jammed on the 70 mm Hasselblad 203S. The crew performed the malfunction procedure (Cannot Remove Lens) from the Photo/TV Checklist to remove the lens. The crew also reported the 70 mm Hasselblad 203S Camera was not functioning normally in auto bracketing. The bracketing varied from 1/180 second to 1/1500 second. The crew executed a battery change and the program settings were verified to make sure the bracket was set to 1. The crew reported the bracketing problem was intermittent. As a result, the image quality may be impacted.

## **CARGO INTEGRATION**

Integration hardware performance was nominal throughout the mission.

## **POSTLAUNCH PAD INSPECTION**

The postlaunch inspection of the launch pad and surrounding area did not reveal any flight hardware, and damage to the pad and surrounding area was minimal.

## **DEVELOPMENT TEST OBJECTIVES/DETAILED SCIENCE OBJECTIVES**

### **DEVELOPMENT TEST OBJECTIVES**

#### **DTO 257 – Structural Dynamics Model Verification**

The Development Test Objective (DTO) was scheduled to be performed on flight day 9, but was not accomplished because of the delays in the International Space Station (ISS) ingress activities. The DTO objective for this mission was to collect mated Shuttle/ISS structural dynamics data to allow better tuning of the Shuttle control system on STS-97, the ISS-4A mission. These data would have allowed the effect of the addition of the Service Module (SM) and Progress to the ISS to be updated from the DTO 257 data collected on the STS-88, the ISS-2A mission. The dynamic data anticipated involved a pitch bending mode, a lateral bending mode and a torsional bending mode of the ISS relative to the Shuttle. The most critical part of these data is the pitch-bending mode, and it was recovered during the Shuttle reboost maneuver of the ISS on STS-92, the ISS-3A mission. The loss of the other two objectives will be recovered during the performance of DTO 257 on STS-97, the ISS-4A mission. On STS-97, the ISS-4A mission, the Shuttle will dock to the new pressurized mating adapter 3 (PMA 3), which was installed during the STS-92 (ISS-3A) mission, and these DTO objectives will now recover the PMA 3 induced changes to the dynamics along with the SM and Progress effects on two of the bending modes. The interpretation of the STS-97 (ISS-4A) dynamics data will be more complex because of the DTO 257 data loss on this mission. However, interpretation of the data is to be completed within the 4-hour period to clear the Shuttle primary control system for use, if required.

#### **DTO 675 – Incapacitated EVA Crewmember Translation**

Time constraints during the fourth EVA precluded this DTO of opportunity from being completed.

#### **DTO 689 – USA SAFER Flight Demonstration**

Both crewmembers completed successfully all DTO 689 objectives during EVA 4. Both simplified aid for EVA Rescue (SAFER) units performed nominally.

#### **DTO 700-14 – Single String Global Positioning System**

The Single String Global Positioning System (GPS) performed nominally throughout the mission, which was the eleventh flight of this Development Test Objective (DTO). The miniature air-to-ground receiver (MAGR) ascent performance was poor, but this condition was not unexpected because of External Tank (ET) blockage. Ascent performance improved to nominal following the roll to the heads-up attitude and later ET separation.

The unstowing and on-orbit setup procedures were performed on flight day 2. The crew reported that the number of recorded files during ascent (122) was approximately the number expected. The data indicated that the MAGR had performed satisfactorily. Almost daily checks of the MAGR payload and general support computer (PGSC) recording status were performed with all reports indicating the PGSC was recording

properly. Several "figure of merit (FOM) chimney" outages were reported where the MAGR performance was degraded. These outages were probably due to temporary Orbiter or ISS structural blockage of certain Global Positioning System (GPS) satellite signals. This type of behavior is expected when docked to the ISS. All but the last reported blockage occurred while docked.

One day prior to the planned end of the mission, the crew performed the operations (OPS) 2 MAGR tests and the flight control system (FCS) checkout self-test with nominal results. The crew performed the MAGR entry set-up procedure to configure the MAGR PGSC to automatically record data during OPS 3 (entry). Following this procedure, the MAGR was powered off with plans to power up the receiver just prior to entry to test the MAGRs capability to rapidly recover from a power cycle in dynamic situations.

Entry data were recorded to the electronic flash card media installed in the PGSC. There was no hard-drive activity during entry to ensure that vibrations encountered during entry would not cause damage to the hard drive.

Following the deorbit maneuver, and about 25 minutes prior to entry interface (EI), the MAGR was powered up for the first time in three days caused by two days of wave-offs because of unacceptable weather conditions. The extended power-down time was designed to "stress" the MAGR slightly during entry. The MAGR performance was nominal throughout entry and landing with no degradation in performance noted in the data review.

#### **DTO 805 – Crosswind Landing Performance**

Crosswind conditions during landing did not exist; therefore, this DTO of opportunity was not performed.

#### **DTO 847 – Solid State Star Tracker Size Limitations**

This DTO was not performed.

### **DETAILED SCIENCE OBJECTIVES**

#### **DSO 206 – Effects of Spaceflight on Bone, Muscle 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 496 – Individual Susceptibility to Post-Spaceflight Orthostatic Intolerance**

It is well known that space flight alters cardiovascular function significantly. One of the most important changes negatively affecting flight operations and crew safety is the postflight loss of orthostatic tolerance, which causes astronauts to have difficulty walking independently as well as inducing lightheadedness or fainting.

Data were collected during the preflight and postflight periods. The analysis is being performed, and the results will be reported in other documentation.

### **DSO 498 – Space Flight and Immune Functions**

Astronauts face an increasing risk of contracting infectious diseases as they work and live for longer periods in the crowded conditions and closed environments of the spacecraft such as the ISS. The affect of space flight on the human immune system, which plays a pivotal role in warding off infections, is not fully understood.

Understanding the changes in immune function caused by exposure to microgravity will allow researchers to develop countermeasures to minimize the risk of infection.

Samples were collected from the designated crewmembers during the preflight and postflight periods. The data are being evaluated, and the results will be reported in other documentation.

## **PHOTOGRAPHY AND VIDEO TAPE ANALYSIS**

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

A total of eleven 16-mm films, nine 35-mm films and 24 videos of launch operations were screened. No anomalous events or conditions were noted that would affect the Orbiter entry and landing.

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

A total of 57 excellent quality frames imaging the External Tank (ET) were obtained from the film in the 35-mm camera in the liquid oxygen umbilical well. Analysis of these frames has shown that the ET thermal protection subsystem (TPS) was in good condition after ET separation. No anomalous conditions were noted during the review of the photography.

A total of 35 excellent quality hand-held pictures of the ET were acquired using the 35mm Nikon F5 camera with a 400mm lens. The first picture was taken 14 minutes 54 seconds after liftoff, and the ET was 1.6 km distance from the Orbiter. Approximately five and one-half minutes of continuous viewing of the ET was acquired.

Views were obtained of the nose, aft dome, the +Z side of the ET (facing Orbiter during flight), both limbs (+Y and -Y) and the far side of the ET. The ET was fully illuminated with very little shadowing.

In analyzing the photographs, no unusual marks or divots were noted. The tumble rate of the ET was approximately 5 deg/sec, and the rate of separation from the Orbiter was approximately 8 meters/second.

### **LANDING PHOTOGRAPHY AND VIDEO TAPE ANALYSIS**

The landing photography and video data were reviewed and no anomalous conditions were noted.

**TABLE I.- STS-92 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	285:23:12:12.162 285:23:12:14.211 285:23:12:16.137
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	285:23:16:31.991 285:23:16:32.151 285:23:16:32.311 285:23:16:32.471
Main Propulsion System Start <sup>a</sup>	ME-3 Start command accepted ME-2 Start command accepted ME-1 Start command accepted	285:23:16:54.458 285:23:16:54.572 285:23:16:54.704
SRB Ignition Command (Liftoff)	Calculated SRB ignition command	285:23:17:00.011
Throttle up to 104.5 Percent Thrust <sup>a</sup>	ME-3 Command accepted ME-1 Command accepted ME-2 Command accepted	285:23:17:03.757 285:23:17:03.763 285:23:17:03.772
Throttle down to 72 Percent Thrust <sup>a</sup>	ME-3 Command accepted ME-1 Command accepted ME-2 Command accepted	285:23:17:29.358 285:23:17:29.364 285:23:17:29.372
Throttle up to 104.5 Percent Thrust <sup>a</sup>	ME-3 Command accepted ME-1 Command accepted ME-2 Command accepted	285:23:17:50.159 285:23:17:50.164 285:23:17:50.172
Maximum Dynamic Pressure (q)	Derived ascent dynamic pressure	285:23:18:03
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	285:23:18:57.69 285:23:18:58.53
End RSRM <sup>a</sup> Action <sup>a</sup> Time	RH SRM chamber pressure mid-range select LH SRM chamber pressure mid-range select	285:23:19:00.04 285:23:19:01.15
SRB Physical Separation <sup>a</sup>	LH APU A turbine speed - LOS LH APU B turbine speed - LOS	285:23:17:00.01 285:23:19:03.05
SRB Separation Command	SRB separation command flag	285:23:19:03
OMS Assist Ignition	Left engine bi-prop valve position Right engine bi-prop valve position	285:23:19:13.3 285:23:19:13.3
OMS Assist Cutoff	Left engine bi-prop valve position Right engine bi-prop valve position	285:23:19:54.7 285:23:19:54.7
Throttle Down for 3g Acceleration <sup>a</sup>	ME-3 command accepted ME-1 command accepted ME-2 command accepted	285:23:24:23.929 285:23:24:23.931 285:23:24:23.938
3g Acceleration	Total load factor	285:23:24:31.5
Throttle Down to 67 Percent Thrust <sup>a</sup> for cutoff	ME-3 command accepted ME-1 command accepted ME-2 command accepted	285:23:25:19.290 285:23:25:19.292 285:23:25:19.299
SSME Shutdown <sup>a</sup>	ME-3 command accepted ME-1 command accepted ME-2 command accepted	285:23:25:25.650 285:23:25:25.652 285:23:25:25.659

<sup>a</sup>MSFC supplied data



**TABLE I.- STS-92 SEQUENCE OF EVENTS  
(Continued)**

<b>Event</b>	<b>Description</b>	<b>Actual time, G.m.t.</b>
MECO	MECO command flag MECO confirm flag	285:23:25:26 285:23:25:27
ET Separation	ET separation command flag	285:23:25:46
APU Deactivation	APU-2 GG chamber pressure APU 1 GG chamber pressure APU 3 GG chamber pressure	285:23:31:05.263 285:23:32:27.211 285:23:32:43.578
OMS-1 Ignition and Cutoff	Left engine bi-prop valve position Right engine bi-prop valve position	Not performed - direct insertion trajectory flown
OMS-2 Ignition	Left engine bi-prop valve position Right engine bi-prop valve position	286:00:00:32.9 286:00:00:32.9
OMS-2 Cutoff	Left engine bi-prop valve position Right engine bi-prop valve position	286:00:01:26.9 286:00:01:27.1
Payload Bay Doors (PLBDs) Open	PLBD right open 1 PLBD left open 1	286:00:53:19 286:00:54:38
OMS-3 Ignition	Left engine bi-prop valve position Right engine bi-prop valve position	286:02:35:58.4 286:02:35:58.4
OMS-3 Cutoff	Right engine bi-prop valve position Left engine bi-prop valve position	286:02:36:29.6 286:02:36:29.8
OMS-4 Ignition	Right engine bi-prop valve position Left engine bi-prop valve position	286:23:53:52.8 286:23:53:52.9
OMS-4 Cutoff	Right engine bi-prop valve position Left engine bi-prop valve position	286:23:55:31.5 286:23:55:31.6
OMS-5 Ignition	Right engine bi-prop valve position Left engine bi-prop valve position	287:12:28:54.7 287:12:28:54.8
OMS-5 Cutoff	Right engine bi-prop valve position Left engine bi-prop valve position	287:12:29:27.4 287:12:29:27.5
OMS-6 Ignition	Left engine bi-prop valve position Right engine bi-prop valve position	287:14:09:00.2 N/A
OMS-6 Cutoff	Left engine bi-prop valve position Right engine bi-prop valve position	287:14:09:17.0 N/A
Docking ring capture	Capture	287:17:45:10
Docking with ISS	Docking ring final position	287:17:57:55
Z1 Truss Grapple	Payload captured	288:15:57:14
Z1 Truss Release	End effector open	288:19:05:30
Airlock Depressurization (End)	Airlock differential pressure 1	289:14:25:39
Begin First Extravehicular Activity	Mission Operations Directorate determination	289:14:26:00
End First Extravehicular Activity	Mission Operations Directorate determination	289:20:53:00
Airlock Repressurization (Start)	Airlock differential pressure 1	289:20:54:42
Cabin Depressurization (End)	Cabin pressure	289:21:03:03
Airlock Depressurization (End)	Airlock differential pressure 1	290:14:12:07
Begin Second Extravehicular Activity	Airlock differential pressure 1	290:14:14:00

**TABLE I.- STS-92 SEQUENCE OF EVENTS  
(Continued)**

<b>Event</b>	<b>Description</b>	<b>Actual time, G.m.t.</b>
Begin Second Extravehicular Activity	Airlock differential pressure 1	290:14:14:00
Pressurized Mating Adapter Grapple	Payload captured	290:15:43:30
Pressurized Mating Adapter Release	End effector open	290:17:59:35
Reboost Maneuver 1 Ignition	As reported	290:21:03:00
End Second Extravehicular Activity	Mission Operations Directorate determination	290:21:20:00
Airlock Repressurization start	Airlock differential pressure 1	290:21:21:30
Reboost Maneuver 1 Cutoff	As reported	290:21:33:34
Airlock Depressurization (End)	Airlock differential pressure 1	291:14:27:01
Begin Third Extravehicular Activity	Airlock differential pressure 1	291:14:30:00
End Third Extravehicular Activity	Mission Operations Directorate determination	291:21:17:00
Airlock Repressurization start	Airlock differential pressure 1	291:21:17:28
Reboost Maneuver 2 Ignition	As reported	291:22:45:59
Reboost Maneuver 2 Cutoff	As reported	291:23:18:19
Airlock Depressurization start	Airlock differential pressure 1	292:14:58:03
Begin Fourth Extravehicular Activity	Airlock differential pressure 1	292:15:00:00
End Fourth Extravehicular Activity	Mission Operations Directorate determination	292:21:56:00
Airlock Repressurization start	Airlock differential pressure 1	292:21:56:32
Reboost Maneuver 3 Ignition	As reported	292:22:23:32
Reboost Maneuver 3 Cutoff	As reported	292:22:53:04
Cabin Repressurization Start	Cabin pressure	292:20:42:38
Undocking from ISS	Undock complete	294:15:08:21
Flight Control System Checkout APU Start APU Stop	APU 2 GG chamber pressure APU 2 GG chamber pressure	295:14:22:26.017 295:14:37:04.625
Payload Bay Doors Close	PLBD left close 1 PLBD right close 1	296:14:52:02 296:14:56:38
Payload Bay Doors Reopen	PLBD right open 1 PLBD left open 1	296:16:35:58 296:16:37:18
Payload Bay Doors Close	PLBD left close 1 PLBD right close 1	297:18:14:47 297:18:16:54
Payload Bay Doors Reopen	PLBD right open 1 PLBD left open 1	297:21:42:36 297:21:43:57
Payload Bay Doors Close	PLBD left close 1 PLBD right close 1	298:16:58:19 298:17:00:00
APU Activation for Entry	APU-1 GG chamber pressure APU-2 GG chamber pressure APU-3 GG chamber pressure	298:19:47:06.388 298:20:15:56.482 298:20:16:07.676

**TABLE I.- STS-92 SEQUENCE OF EVENTS  
(Concluded)**

Deorbit Burn Ignition	Left engine bi-prop valve position Right engine bi-prop valve position	298:19:52:00.1 298:19:52:00.1
Deorbit Burn Cutoff	Right engine bi-prop valve position Left engine bi-prop valve position	298:19:55:03.5 298:19:55:03:7
Entry Interface (400K feet)	Current orbital altitude above	298:20:28:17
Blackout end	Data locked (high sample rate)	No blackout
Terminal Area Energy Management	Major mode change (305)	298:20:53:13
Main Landing Gear Contact	LH main landing gear tire pressure 1 RH main landing gear tire pressure 2	298:20:59:42 298:20:59:42
Main Landing Gear Weight on Wheels	LH MLG weight on wheels RH MLG weight on wheels	298:20:59:42 298:20:59:42
Drag Chute Deployment	Drag chute deploy 1 CP volts	298:20:59:46.3
Nose Landing Gear Contact	NLG LH tire pressure 1	298:20:59:54
Nose Landing Gear Weight On Wheels	NLG weight on wheels 1	298:20:59:54
Drag Chute Jettison	Drag chute jettison 1 CP Volts	298:21:00:21.1
Wheel Stop	Velocity with respect to runway	298:21:00:49
APU Deactivation	APU-1 GG chamber pressure APU-2 GG chamber pressure APU-3 GG chamber pressure	298:21:26:20.651 298:21:26:35.504 298:21:26:50.077

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

No.	Title	Reference	Comments
STS-92-V-01	Ku-Band System Failed	286:14:07 G.m.t. 00:14:50 MET IPR 102V-0003 CAR 92RF03	<p>At approximately 286:14:07 G.m.t. (00:14:50 MET), the Ku-band system failed to transmit or receive in the communications mode. Troubleshooting consisted of power cycling the Ku-band system and performing self-tests. The power cycle did not recover transmit or receive capabilities and the self-tests failed. Circuit analysis suggests that the most probable cause of the failure is the exciter sub-shop replaceable unit (SRU) located within the DEA. The exciter is a common circuit associated with the forward and return link functions as well as the self-test. During the rendezvous operations, the Ku-band system did not work in the radar mode. The hardware was configured with gimbals locked and powered off. The antenna was stowed following the EVAs.</p> <p>KSC: Postflight troubleshooting will be performed.</p>
STS-92-V-02	ODS Centerline Camera Misalignment	286:15:17 G.m.t. 00:16:00 MET CAR 92RF04	<p>At approximately 286:15:17 G.m.t. (00:16:00 MET), the crew called down that the primary Orbiter Docking System (ODS) centerline (C/L) camera was misaligned. They reported that at the 10-degree zoom setting, the monitor-generated crosshair was just outside the target circle in the lower left. At 39 degrees zoom, the monitor-generated crosshair was just inside the target circle at the upper right. The primary camera was removed and the backup camera was installed. The crew reported that the misalignment was much worse and that the crosshair did not appear in the target circle at any zoom setting. The crosshair was below the target circle and slightly to the left with the camera zoomed in. As the camera zoomed out, the crosshair moved to the right. The crew reinstalled the primary camera and noticed some raised paint around the mounting holes. The crew was asked to take digital photographs of the aft deck monitor with each camera installed and zoom settings of 10, 22, and 39 degrees. The primary camera was determined to be acceptable for the rendezvous and docking.</p>

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

No.	Title	Reference	Comments
STS-92-V-02 (Continued)	ODS Centerline Camera Misalignment (Continued)	286:15:17 G.m.t. 00:16:00 MET CAR 92RF04	<p>A mission chit was submitted requesting the crew perform some troubleshooting of the misalignment; however, the troubleshooting was not performed because of the crew workload and timeline constraints.</p> <p>KSC: Postflight, KSC will perform normal alignment checks. Additional troubleshooting on the OV-103 hardware will be based on the OV-104 troubleshooting results.</p>
STS-92-V-03	Cabin Payload 3 Bus Loss	288:12:57:18 G.m.t. 02:13:40:18 IPR 102V-0005	<p>At 288:12:57:18 G.m.t. (02:13:40:18 MET), a 14-ampere current increase was observed on mid main bus B. Approximately 2.5 seconds later, the current dropped 20 amperes. During the same time period, the Orbiter interface unit (OIU) 1 and the Orbiter Space Vision System (OSVS) was lost. A review of the equipment lost indicated that the cabin payload (CAPBL) 3 bus was lost. With the loss of the CABPL 3 bus, the function of the keel camera, RMS side-view camera, ODS C/L camera, payload timing buffer, and DDCU starboard system B were also lost. The CAPBL 3 bus is powered by a 15-ampere RPC, which receives its power from the Orbiter mid main bus B when the cabin payload power switch is in the main B position. The observed current spike equates to the signature expected when the output of a 15-ampere RPC is shorted (125 to 150 percent of rated load for 2 to 3 seconds, then trips off.</p> <p>OIU 2 was used for ISS data and the spare OSVS unit was powered from the panel A11 DC utility outlet using the breakout box. To protect the RPC from being reset, the crew placed a switch guard over the Cabin Payload switch. Evaluation has isolated three components, a 35-ampere diode in the MPCA2, the OSVU and the keel camera as the potential cause based upon the current spike signature and their circuit protection device characteristics. Though considered unlikely, a wiring short is also a potential cause. In-flight workarounds were evaluated for possible additional failures.</p>

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

No.	Title	Reference	Comments
STS-92-V-03	Cabin Payload 3 Bus Loss (Continued)	288:12:57:18 G.m.t. 02:13:40:18 IPR 102V-0005	At JSC, the OSVU failed a pin-to-pin test in both directions, but passed the pin-to-chassis test for both pins. The unit was sent to Canada for further troubleshooting and repair. KSC: Postflight troubleshooting on the vehicle was performed at KSC.
STS-92-V-04	WSB 3 Vent Temperatures Erratic on Controller B	295:14:27 G.m.t. 09:15:10 MET CAR 92RF07 IPR 102V-0009	At approximately 295:14:27 G.m.t. (09:15:10 MET), during the WSB 3 vent heater operation prior to FCS checkout, slightly off-nominal heater cycling was observed while on he B controller. Following FCS checkout, a bakeout was performed to ensure that there was no ice accumulation in the vent nozzle. An ice signature was not observed during the bakeout. During the pre-entry operation of the WSB 3 vent heater on flight days 12 and 13, off-nominal heater cycling was again observed on the B controller. The heater on and off points appeared to be changing with each heater cycled within a band of 140 to 190 °F. During the flight day 13 operation, WSB 3 was switched to the A controller, and the heater cycles were normal. The B controller was subsequently reselected and normal heater cycles continued. The B controller was again selected on flight day 14 during deorbit preparations, and the vent did not come up to temperature. The A controller was selected and the heater performed nominally. KSC: Hardware removal and replacement is planned.
STS-92-V-05	WBS 2 Vent Temperature Dropped Off on Controller A.	295:14:27 G.m.t. 12:20:47 MET CAR 92RF04	WSB 2 vent nozzle temperature dropped off prior to APU/HYD system 2 after startup. Normally, the vent temperature decreases after spray cooling is observed on the corresponding boiler. The drop in temperature was slower than what is typically observed during spray-cooling initiation. KSC: Hardware removal and replacement is planned.
STS-92-V-06	FES Shutdowns on Primary B Controller	296:14:19 G.m.t. 10:15:02 MET CAR 92RF09 102V0008	At 296:14:19 G.m.t. (10:15:02 MET), after the radiator bypass and flash evaporator system (FES) checkout, the FES primary B controller shut down in full up mode. After the shutdown, the high-load duct heaters were configured to

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

No.	Title	Reference	Comments
STS-92-V-06	FES Shutdowns on Primary B Controller (Continued)	296:14:19 G.m.t. 10:15:02 MET CAR 92RF09 102V0008	<p>A/B to preclude ice formation in the inboard ducts. An entry pocket checklist procedure to flush the high-load cord was initiated after the shutdown. Following the flush procedure, the high-load core was allowed to run on secondary controller for 7 minutes per the procedure. After that time, a restart on the primary B controller in full-up mode was attempted and this resulted in the second shutdown. The FES was then successfully restarted on the primary A controller.</p> <p>For the FES checkout on the second landing day opportunity, a modified radiator bypass/FES checkout was performed. The secondary high-load core on the B feedline controlled the evaporator outlet temperature nominally at 62 °F. This checkout together with other FES operations performed at different times during the mission helped to clear the B feedline and the spray valve of being the cause of the shutdown. The mid-point sensor is believed to be the cause of the problem.</p> <p>KSC: Troubleshooting of this hardware will be performed on the vehicle</p>
STS-92-V-07	Dedicated Signal Conditioner OM2 Card 22 Failed	292:14:28 G.m.t. 06:15:11 MET CAR 92RV06 IPR 102V-0007	<p>At 292:14:28 G.m.t. (06:15:11 MET), dedicated signal conditioner (DSC) OM2 card 22 failed and this caused four measurements to go off-scale low at -75 °F. The four measurements are three hydraulic system temperatures and one APU temperature measurement. The hydraulic system measurements are the left inboard elevon actuator return line temperature, the left main landing gear brake line temperature B, and the right main landing gear brake line temperature D. The APU measurement is the APU 2 water line temperature.</p> <p>The left inboard elevon actuator return line temperature is one of several that are 1 the control logic for circulation pump 2 runs. The loss of this measurement had no mission impact. The hydraulic brake line temperatures monitor heater operation on those lines and the loss of insight had</p>

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

No.	Title	Reference	Comments
STS-92-V-07	Dedicated Signal Conditioner OM2 Card 22 Failed (Continued)	292:14:28 G.m.t. 06:15:11 MET CAR 92RV06 IPR 102V-0007	no mission impact. Finally, the APU water line temperature monitors heater operation for the APU injector cooling system. There was no impact to the mission from the loss of this measurement. KSC: Troubleshooting will be performed.



## **DOCUMENT SOURCES**

In an attempt to define the official as well as the unofficial sources of data for the STS-92 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-92 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
APAS	Androgynous Peripheral Attachment System
APFR	articulating portable foot restraint
APU	auxiliary power unit
ARPCS	atmospheric revitalization pressure control system
ARS	atmospheric revitalization system
ATCS	active thermal control system
CABPL	cabin payload
CBM	common berthing mechanism
c.d.t.	central daylight time
CID	circuit isolation device
C/L	centerline
CMG	control moment gyro
DC/dc	direct current
DCU	dedicated converter unit
DDCU	dc-to-dc converter unit
DEA	deployed electronics assembly
DSC	dedicated signal conditioner
DSO	Detailed Supplementary Objective
DTO	Developmental Test Objective
$\Delta V$	differential velocity
EAFB	Edwards Air Force Base
ECLSS	environmental control and life support system
EGN	Enhanced Gaseous Nitrogen
EGT	exhaust gas temperature
EI	entry interface
EMU	extravehicular mobility unit
EO	ET/Orbiter
EOM	end of mission
EPDC	electrical power distribution and control
ET	External Tank
ETSD	EVA Tool Stowage Device
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
FD	flight day
FES	flash evaporator system
FOM	figure of merit
FRGF	flight releasable grapple fixture

ft/sec	feet per second
GAS	Get Away Special
GFE	Government furnished equipment
GH <sub>2</sub>	gaseous hydrogen
G.m.t.	Greenwich mean time
GN&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
HPOTP	hydrogen pump oxidizer turbopump
ICBC3D	IMAX Cargo Bay Camera 3 Dimension
IMAX	Camera system
IMU	inertial measurement unit
In/sec	inch per second
$I_{sp}$	specific impulse
ISS	International Space Station
ITS	Integrated Truss Structure
IVA	intravehicular activity
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
LED	light emitting diode
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
MBM	manual berthing mechanism
MECO	main engine cutoff
MET	mission elapsed time
MIS-WIS	Micro Wireless Instrumentation System
MLG	main landing gear
MLP	Mobile Launch Platform
mmHg	millimeter mercury
MPCA	mid power control assembly
MPS	main propulsion system
MSBLS	microwave scanning beam landing system
MSFC	Marshall Space Flight Center
NASA	National Aeronautics and Space Administration
NASDA	Japanese Space Agency
nmi.	nautical mile

NPSP	net positive suction pressure
NSTS	National Space Transportation System (i.e., Space Shuttle Program)
ODS	Orbiter Docking System
OFI	Operational Flight Instrumentation
OI	Operational Instrumentation
OIU	Orbiter Interface Unit
OMRSD	Operations and Maintenance Requirements and Specifications Document
OMS	orbital maneuvering subsystem
OPS	Operations
OSL	off-scale low
OSVS	Orbiter Space Vision System
OV	Orbiter Vehicle
PAL	protuberance air load
PCG	Protein Crystal Growth
PGME	Propylene Glycol Monomethyl Ether
PGSC	payload and ground support computer
PMA	pressurized mating adapter
PMBT	propellant mean bulk temperature
POGO	longitudinal oscillation
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
QD	quick disconnect
RCS	reaction control subsystem
RMS	Remote Manipulator System
RPC	remote power controller
RSRM	Reusable Solid Rocket Motor
RSS	rotational service structure
RTAS	Rocketdyne Truss Attachment System
RTL	return to launch site (abort mode)
RTV	room temperature vulcanizing (material)
S&A	safe and arm
SAFER	simplified aid for EVA Rescue
SASA	S-band antenna structural assembly
SGANT	Space ground antenna
SLF	Shuttle Landing Facility
SLP	Spacelab Logistics Pallet
SLWT	super lightweight tank
S/N	serial number
SRB	Solid Rocket Booster
SRSS	Shuttle range safety system
SRU	Shop Replaceable Unit
SSME	Space Shuttle main engine
SSVEO	Space Shuttle Vehicle Engineering Office
STS	Space Transportation System
SWAR	Sea water activated release

SWIS	Shuttle-based Wireless Instrumentation System
TACAN	tactical air navigation
TCS	trajectory control sensor/thermal control system
TPS	thermal protection system/subsystem
V	Volts
WCS	waste collection system
WSB	water spray boiler
XPOP	X axis perpendicular to orbital plane