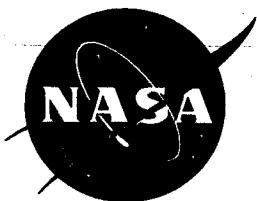


STS-112 SPACE SHUTTLE MISSION REPORT

December 2002



**National Aeronautics and
Space Administration**

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

NOTE

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Orbiter and Subsystems

MSFC Elements (SRB,
RSRM, SSME, ET,
SRSS, and MPS

Payloads/Experiments

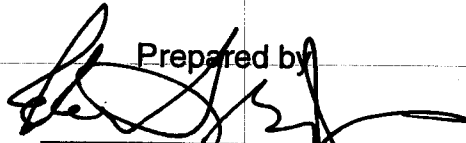
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STS-112

SPACE SHUTTLE

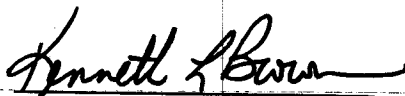
MISSION REPORT

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December 2002

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INTRODUCTION

The Space Transportation System (STS) -112 Space Shuttle Program Mission Report presents a discussion of the Orbiter activities of the mission, as well as presenting a summary of the External Tank (ET), Solid Rocket Booster (SRB), Reusable Solid Rocket Motor (RSRM), and Space Shuttle main engine (SSME) performance during this one-hundred and eleventh mission of the Space Shuttle Program. The STS-112 flight was the fifteenth flight to the International Space Station (ISS). STS-112 was the eighty-sixth mission since the return to flight, and the twenty-sixth flight of the Orbiter vehicle (OV) -104 (Atlantis) vehicle.

The flight vehicle consisted of the OV -104 Orbiter; an ET, which was the fifteenth Super Lightweight Tank (SLWT), and it was designated ET-115; three Block II SSMEs that were designated as S/Ns 2048, 2051 and 2047 in positions 1, 2 and 3 respectively, and two SRBs that were designated B115. The two RSRMs were designated RSRM-87 with one installed in each SRB. The individual RSRM serial numbers were 360W087A for the left SRB and 360W087B for the right SRB.

The primary objective of the STS-112 mission was to launch the ISS 9A CE Integrated Truss Segment (ITS-S1) and install that truss on the ISS Stage Utilization Flight (UF) -2. The 9A launch package (LP) also included Utilization Experiments. The Shuttle crew performed three extravehicular activities (EVAs) using the ISS airlock. The EVA tasks included connection of fluid lines and utility umbilicals between the ITS S0 and S1 trusses, and installing external cameras, an S-Band antenna and EVA hardware and equipment. Additional tasks performed were the connection of the crew external translation aid (CETA) cart to the Mobile Transporter (MT), releasing launch locks and removing and stowing keel pins and drag links. The crew transferred ISS hardware and Utilization Experiments from the Orbiter middeck to the ISS and returned ISS hardware and Utilization Experiments from the ISS to the Orbiter for return to Earth. Orbiter nitrogen and oxygen were also transferred to the ISS from the Orbiter.

The two secondary objectives of the flight were also performed. These were the Spatial Heterodyne Imager for Mesospheric Radicals (SHIMMER) operations, and the Ram Burn Observation (RAMBO) for Shuttle plume modeling. The RAMBO payload required one dedicated dual-engine orbital maneuvering subsystem (OMS) firing and a pre-burn state vector for burn-monitoring predictions.

The STS-112 flight was an 11 day, plus 1-day plus 2-contingency-day flight, of which seven days were to be docked to the ISS. The one additional day was provided, should and additional docked day be required for a fourth EVA. The two contingency days were available for landing weather avoidance or other Orbiter contingency operations. The sequence of mission events is shown in Table I, and the Orbiter In-Flight Anomaly List is shown in Table II.

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

The six crewmembers that were on the STS-112 mission consisted of Jeffrey S Ashby, Captain, U. S. Navy, Commander; Pamela A. Melroy, Col., USAF, Pilot; David A. Wolf, M. D. Civilian, Mission Specialist 1; Sandra H. Magnus, Ph. D., Civilian, Mission

Specialist 2; Piers J. Sellers, Ph. D., Civilian, Mission Specialist 3; and Fyodor Nikolayevich Yurchikhin, Ph. D., Civilian, Mission Specialist 4.

STS-112 was the fourth space flight for Mission Specialist 1, the third space flight for the Shuttle Commander, the second space flight for the Pilot, and the first space flight for Mission Specialist 2, Mission Specialist 3 and Mission Specialist 4.

MISSION SUMMARY

The STS-112 mission was originally scheduled to launch on October 2, 2002; however, Hurricane Lili entered the Gulf of Mexico. The exact path could not be determined until late in its forward movement; consequently, a decision was made to power down the Johnson Space Center (JSC) Mission Control Center and the launch was rescheduled for October 7, 2002.

The STS-112 mission was launched at 280:19:45:51.018 G.m.t. on October 7, 2002, on the fifteenth mission to the International Space Station (ISS).

An orbital maneuvering subsystem (OMS) assist maneuver was performed following Solid Rocket Booster (SRB) separation. The maneuver was initiated at 280:19:48:02 G.m.t. (00:00:02:09 MET) and was 75.6 seconds in duration.

Immediately prior to External Tank (ET) separation, the reaction control subsystem (RCS) primary thruster L4D failed off because of the low chamber-pressure on the initial thruster firing (Flight Problem STS-112-V-01). The maximum pressure reached was 16 psia, which is indicative of the fuel-valve main-stage not opening. The remaining two down-firing thrusters performed nominally during ET separation. No mission impact occurred and the thruster remained deselected for the remainder of the mission.

The modular auxiliary data system (MADS) recorder appeared to perform nominally during ascent. However, when the tape was being repositioned for the recording of entry data, an anomalous signature was observed. Further analysis of the MADS anomaly showed that the recorder operated nominally during ascent. When the MADS recorder was commanded to stop recording at the 30-percent tape mark, a command to rewind the tape to the beginning of tape (BOT) was issued. The recorder responded nominally until at the 3.9-percent tape mark, where the recorder stopped and the sequence 2 telemetry indication was displayed. The tape should have stopped even though the indication was 3.9 percent. KSC engineering reported that this reading can be up to 5-percent and be at the BOT window. The recorder BITE indication remained good; and the sequence-2 telemetry indication should not have been displayed at that time. Troubleshooting was performed to determine the condition of the recorder. It consisted of power resets and commands for the recorder to record, each of which was unsuccessful. The MADS recorder did not record data during entry and landing. The postflight investigation determined the cause of the problem was that the tape ran off the reel.

The postlaunch data review determined that none of the system-A NASA Standard Initiators (NSIs) for the SRB holddown posts received the Fire 1 command. The master events controller (MEC) provides the signals to fire those NSIs so the MEC is suspect as well as all of the wiring between the MEC in the Orbiter and the pyrotechnic initiator controller (PIC) rack on the ground. The data indicate that the PICs were properly armed but then had a gradual bleed-off of voltage, which is indicative of no firing. Recovery and disassembly of the SRBs revealed 8 unfired NSIs. The MEC was not used for the remainder of the mission so there was no mission impact. Kennedy Space Center has the failure investigation team in operation to resolve this anomaly. However, the failure investigation team was unable to determine the cause of the problem.

SSME data dropouts were noted during Solid State Recorder dumps of ascent data. An evaluation has determined the fault to be Merritt Island launch area (MILA) ground data problem. The Solid State Recorder was not the cause of the data dropouts.

The OMS 2 maneuver was performed at 280:20:24:31 G.m.t. (00:00:38:40 MET) and was 62.8 seconds in duration. The differential velocity (ΔV) was 96.1 ft/sec, and the orbit was 85.1 by 126.4 nautical miles (nmi) following the maneuver. The OMS performed satisfactorily throughout the maneuver.

The payload bay doors were opened as planned at 280:21:23:09 G.m.t. (00:01:37:18 MET). All voltages were nominal and the motors opened the doors in nominal dual-motor time.

When stowing the emergency egress net (trampoline), the crew reported a problem with the release mechanism. This net was stretched across the opening in the middeck aft wall, where the internal airlock used to be, and provided the crew with a surface to stand on in the event of a pad emergency egress, as well as during normal ingress. The net was only in place through ascent and once on-orbit, it was stowed and not used again for the remainder of the mission. The net was tensioned during installation on the ground and this tension was maintained through the use of two ratcheting mechanisms (the release mechanisms). When the crew stowed the net on-orbit, the ratchets are released by turning a knob on each mechanism. The crew was able to release the tension and stow the net. However, they reported that the knob had come off one of the mechanisms. The crew reported that a knob was rotated in the wrong direction because of the extreme tension of the net. The crew reported that the tension on the net was very high. The crew has stowed the loose parts (knob, bolt, washer) in the lost and found bag. Because there was the possibility for additional failed parts remaining inside of the mechanism that could come out and float into the cabin, the crew taped over the hole in the mechanism where the knob was attached.

The NC1 maneuver was performed with both OMS engines at 280:23:23:46 G.m.t. (00:03:37:55 MET) and was 39.8 seconds in duration. The ΔV delivered was 60.3 ft/sec, and the resultant orbit was 115.8 by 127.1 nmi.

The crew reported on flight day (FD) 1 that the system management (SM) alert-light on panel F7 was not fully illuminated. The crew further stated that at full brightness, the SM alert light remained dim. The crew stated that the light was acceptable as-is and no further action was required on orbit. KSC will perform troubleshooting to determine the cause of the problem.

The remote manipulator system (RMS) was powered up for the RMS checkout and payload bay survey. The checkout was successfully completed and the arm was moved to the pre-cradle position where it remained through FD 4.

The Orbiter docking system (ODS) was powered up at 281:19:48 G.m.t. (01:00:02 MET), ring extension was completed nominally, and the system was powered down at 281:19:58 G.m.t. (01:00:12 MET).

At approximately 281:20:27 G.m.t. (01:00:41 MET), the pressure control system (PCS) 1 oxygen supply pressure measurement failed off-scale high. The indication returned to normal approximately 5.5 minutes later. This same measurement failed off-scale low for a period of 17 hours on STS-77 when this same O₂N₂ panel was installed on the OV-105 vehicle. The panel was removed and during the repair activity, the oxygen pressure

transducer was examined but not anomalies were noted. As a result, the transducer was not changed and the panel successfully passed the acceptance test. There are three additional backup measurements that continued to operate satisfactorily. As a result, this condition did not impact the successful conclusion of the mission.

The trajectory control sensor (TCS) was initialized for rendezvous tools checkout at 281:21:14 G.m.t. (01:01:28 MET). The TCS performed nominally during the checkout.

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

Maneuver	Time, G.m.t./MET	ΔV , ft/sec	Firing time, Sec	Orbit, nmi.
NC3 (OMS-4) (Right engine)	281:20:00:34 01:00:14:43	13.6	18	121.7 by 126.8
NH (OMS-5) (dual engine)	282:10:43:16 (01:14:57:25)	145.5	93.6	126.8 by 204.4
NC4 (OMS-6) (dual OMS)	282:11:31:26.7 01:15:45:35.7	131.3	83.2	196.6 by 209.9
NCC (multi-axis RCS)	282:12:06:02 01:16:20:11	0.9	-	196.5 by 209.6
Ti (OMS-7) (left OMS)	282:13:03:45.3 01:17:17:54.3	10.1	11.6	199.6 by 213.1
MC1	282:13:23:44 01:17:37:53	0.44	0.1	199.7 by 213.1
Planar Null (+y-axis RCS)	282:13:47:23 01:18:01:32	-	-	199.7 by 213.1
MC-2 (RCS)	282:13:51:45.7 01:18:05:54.7	0.6	2.1	199.6 by 213.2
MC-3 (RCS)	282:14:08:46.0 01:18:22:55.0	0.4	1.7	199.6 by 213.1
MC-4 (RCS)	282:14:18:46.5 01:18:32:55.5	3.2	13.8	200.4 by 213.6

The ODS was powered up for docking operations at 282:14:49 G.m.t. (01:19:03 MET) and the ISS was captured at 282:15:16 G.m.t. (01:19:30 MET). Ring retraction and hook closure were completed nominally. It appears that at least one high-energy damper was stuck and that the new ring-retraction procedure worked well. The ODS was powered off at approximately 282:15:40 G.m.t. (01:19:54 MET).

An evaluation of the Orbiter relative velocity data from docking indicates that the axial contact velocity was higher than desired (0.19 ft/sec versus 0.13 ft/sec maximum allowed in the specification), and that the level was considered to be "out-of family". All crew training is based on an initial contact velocity of 0.1 ± 0.03 ft/sec. The requirement specification for the Orbiter docking system (ODS) hardware is an axial contact-velocity of 0.2 ft/sec. The current docking mechanism was qualification tested at 0.4 ft/sec at high and low temperatures. Therefore, damage to the ODS hardware was not anticipated. Results of the Orbiter assessment of the docking contact conditions indicate that the 0.2-ft/sec contact-velocity was well within the capability of the docking mechanism. The Orbiter docking mechanism for ISS was a derivative of the MIR docking mechanism, which was designed for 0.5 ft/sec closing rate. A review of the downlist data revealed two indications of a translational hand controller (THC) input without subsequent thruster

firings immediately prior to docking. The most probable cause for this condition is that the THC was not held for the required 160 ms required to assure that the thrusters fire.

Following docking, the crew reported problems with the communications system. The ISS crew could not hear the ground on the air-to-ground (A/G) 1 loop or the Orbiter crew on the intercommunications (ICOM) A loop. The Orbiter crew could hear the ground on A/G 1 and the ISS crew on ICOM A. After a period of time, the ISS crew was able to hear the ground on A/G 1; however, the failure persisted on ICOM A. It is believed that A/G 1 was recovered by a power cycle of the docking audio interface unit (DAIU) on the ISS. Troubleshooting was performed in an attempt to recover ICOM A but was unsuccessful. This troubleshooting included using multiple audio terminal units (ATUs), multiple handheld microphones (HHMs) and both audio central control units (ACCUs), as well as additional power cycles of the DAIU. There were acceptable workarounds so there was no mission impact.

After docking, the crew reported problems with two HHMs during setup of the on-orbit audio system. The crew tried the HHMs on the middeck ATU and both did not work. The crew then tried the same two HHMs on one of the airlock ATUs and again the HHMs did not work. A third HHM was obtained from spares and worked fine. Four HHMs were manifested for STS-112. The on-board sparring was adequate to support the mission so there was no mission impact. The crew was asked to tag the problem HHMs. The STS-112 units will be tested during postflight operations to determine the cause of the problem.

The RMS was powered to support the unberthing of the S1 truss. The Shuttle RMS provided video coverage of the unberthing, which was performed by the Space Station remote manipulator system (SSRMS) at 283:10:42:36 G.m.t. (02:14:56:45 MET). Following the unberthing, the truss was moved to the installation location on the ISS.

The attachment of the S1 truss onto the ISS S0 truss was performed using the SSRMS. The Shuttle RMS operated as a camera platform and provided video coverage. The RMS performed nominally during the S1 attachment and the first EVA. Following the EVA, the RMS was cradled, latched and powered down at 283:23:09 G.m.t. (03:03:23 MET).

Early during the first extravehicular activity (EVA), an "all stop" was called to the crew when the Space Station remote manipulator system (SSRMS) elbow joint came close to the Orbiter's starboard payload bay door. Initial calculations indicated that the clearance was approximately 2 feet. However, updated calculations by the operations team indicate that the clearance was possibly less than 2 inches. Video during the event shows the elbow being close to the forward outboard corner of the door, but the video is inconclusive as to whether or not there was contact. However, there was no apparent motion of the door during the event and the SSRMS current data does not indicate that a resistance was encountered. Also, the crew stated that they do not believe that there was contact. This data in addition to video of the door after the event, which appears nominal, indicate that there was no contact.

The first EVA was successfully completed with a total EVA time of 7 hours and 1 minute. The EVA, which was conducted from the ISS airlock, was officially started when the extravehicular mobility units (EMUs) were placed on internal battery power at 283:15:21 G.m.t. (02:19:35 MET). During the EVA, the major tasks completed by the crew were the release of the crew EVA translation aid (CETA) cart launch locks, connection of the zenith side power umbilicals, and deployment of the S-band antenna. The last hour of

the EVA was completed without the use of the SSRMS, but the SSRMS was back on line to support the second EVA. The EVA concluded when repressurization of the airlock was initiated at 283:22:22 G.m.t. (03:02:36 MET).

The first reboost session was started at 285:10:52:48 G.m.t. (04:15:06:57 MET) when all of the down-firing vernier thrusters were fired. The session lasted one hour. The performance of the RCS was nominal throughout the operation. The reboost imparted a ΔV of 11.9 ft/sec resulting in an overall average altitude increase of 3.4 nmi for a final orbit of 216 by 204 nmi.

The second EVA was successfully completed with a total EVA time of 6 hours and 4 minutes. The EVA was conducted from the ISS airlock and officially started when the EMUs were placed on internal battery power at 285:14:30 G.m.t. (04:18:44 MET). The EVA was very successful in that all tasks but one were completed. In addition, two get-ahead tasks were also completed. The crew could not install the photovoltaic radiator (PVR) spool positioning devices (SPDs) on two quick disconnects (12 and 13) on the P6 truss. This problem was evaluated by the ISS Program personnel and determined to not be a problem for this mission. The EVA concluded when repressurization of the airlock was initiated at 285:20:34 G.m.t. (05:00:48 MET).

The second reboost session was started at 287:11:20:50 G.m.t. (06:15:34:59 MET). The session lasted the scheduled 35 minutes. The performance of the RCS was nominal throughout the operation. The reboost imparted a ΔV of 6.9 ft/sec resulting in an overall average altitude increase of 1.96 nmi for a final orbit of 219.4 by 203.3 nmi.

During final preparations for the third EVA, the crew reported that the wrist tether point of the EV (extravehicular) 1 crewmember right-hand glove was torn and had come apart on one end. The crew verified that the glove bladder was not damaged and the EVA preparations continued. Postflight evaluation of the glove condition will be performed in an attempt to determine the cause of the tear.

The total third EVA time was 6 hours and 36 minutes for the third EVA. The EVA was conducted from the ISS airlock and officially started when the EMUs were placed on internal battery power at 287:14:11 G.m.t. (06:18:25 MET). The EVA was very successful in that all tasks plus one get-ahead task were completed. The EVA concluded when repressurization of the airlock was initiated at 287:20:47 G.m.t. (07:01:01 MET).

The total EVA time for the three excursions was 19 hours 41 minutes. These EVAs increase the EVA man-hours in space by 39 hours and 22 minutes.

Undocking from the ISS was completed with no anomalies. The ODS was powered up at 289:12:52:36 G.m.t. (08:17:06:45 MET), and undocking was completed at 289:13:13:24 G.m.t. (08:17:27:33 MET). The hook-8 individual position indication toggled very briefly at the start of hook opening, however, this signature has been seen on previous missions and is not an issue. Following undocking, the ODS was powered down at 289:13:17:55 G.m.t. (08:17:32:04 MET).

Shortly after the undocking from the ISS while working the nominal water configuration, the crew reported that the talkback indication on the supply water crossover valve switch stayed barberpole (should be closed) when the crew tried to open the valve. This condition was indicative of the circuit breaker not transferring power. The crew pushed in on the closed circuit breaker, which caused the talkback indicator to go to the closed

position; however, when the switch was cycled to open, the talkback indicator again went to barberpole. Another cycle of the circuit breaker to open and then closed resulted in the talkback being midway between barberpole and open and closed when it should have been closed. One crewmember then pushed the circuit breaker while another crewmember operated the switch. The operation opened the valve and the talkback indicated open. With the valve in the correct position, the crew opened the circuit breaker. The circuit breaker and the supply water crossover valve remained open for the remainder of the mission and this condition did not impact the successful completion of the mission.

Following undocking, the initial Orbiter separation maneuver began with a +Z-axis pulse of primary RCS thrusters at 289:13:13 G.m.t. (08:17:27 MET). The ISS flyaround operations were nominal and terminated with a 5.76-second +X pulse at 289:14:30 G.m.t. (08:18:44 MET). Final separation from ISS was accomplished with a 21-second +X-axis pulse of primary RCS thrusters L1A and R1A at 289:15:00 G.m.t. (08:19:14 MET). The ΔV delivered was 5.5 ft/sec and the resulting orbit was 200.8 by 219.9 nmi.

Following the successful undocking from the ISS, the primary RCS thruster F3F heater failed-on during the ISS flyaround activities. The failure was initially masked because of the hot thrusters created by the flyaround activities. The decision was made to not awaken the crew to turn off the heater because the temperatures remained relatively stable within 7 °F of the upper limit. The plan to fire that thruster during the RCS hot fire was deleted, and no other firings of that thruster were planned during the mission. If the thruster temperatures approach the upper limit, the crew can perform manual cycling of the heater. This failure did not impact the successful completion of the mission.

During general-purpose computer (GPC) set contraction operations at 289:15:29 G.m.t. (08:19:43 MET), when taking GPC 3 to standby, the talkback indication failed to change from run to barberpole as expected. The talkback was reported to have behaved as expected when the mode switch was subsequently moved to halt, back to standby, and back to halt in accordance with the procedures. Subsequently, a GPC checkout procedure was performed during which GPC 3 was moded from halt to standby, standby to run, run to standby and standby to halt, and no GPC errors were noted during the procedure.

The flight control subsystem (FCS) checkout was performed satisfactorily using auxiliary power unit (APU) 1 to support the checkout with a start time of 290:12:32:07 G.m.t. (09:16:46:16 MET). The run time was 5 minutes, 39 seconds, and 14 pounds of fuel were used during the APU 1 operation. The total run time was too short to require spray cooling from the water spray boiler (WSB). FCS, APU, and hydraulics performance was nominal.

Following FCS checkout, the RCS hot-fire was performed nominally. The hot-fire began at 290:13:21:59 G.m.t. (09:17:36:08 MET) and ended at 290:13:26:38 G.m.t. (09:17:40:47 MET). Primary thruster F3F was not fired due to its failed-on heater and thruster L4D was not fired since it had previously failed off. All other thrusters were fired at least once for a duration of at least 240-milliseconds. A review of thruster chamber-pressure data confirmed that all of the thruster firings were satisfactory.

An OMS 8 dual engine orbit-adjust maneuver was performed at 290:20:26:51 G.m.t. (10:00:41:00 MET) and was 50.8 seconds in duration. The ΔV was 93.9 ft/sec, and the

resultant orbit was 146.6 by 219.9 nmi following the maneuver. The OMS performed satisfactorily throughout the maneuver.

The payload bay doors (PLBDs) were closed and latched for the first KSC landing opportunity on the nominal end-of-mission landing day at 291:15:05:45 G.m.t. (10:16:19:54 MET). All payload bay door close and latch operations occurred in dual motor time.

The deorbit maneuver for the first KSC, landing opportunity on the planned landing day, was a dual engine straight-feed firing that was performed on orbit 170 at 291:14:36:14 G.m.t. (10:18:50:23 MET). The maneuver was 132.4 seconds in duration with a ΔV of 250.8 ft/sec. The orbit after the deorbit maneuver was 25.4 by 219.9 nmi.

Entry interface occurred at 291:15:12:21 G.m.t. (10:19:26:30 MET) and entry was completed satisfactorily. Main landing gear touchdown occurred on KSC concrete runway 33 at 291:15:43:40 G.m.t. (10:20:03:49 MET) on October 18, 2002. The drag chute was deployed at 291:15:43:51 G.m.t. The nose gear touchdown occurred at approximately 291:15:43:49 G.m.t. The drag chute was jettisoned at 291:15:44:18 G.m.t. Wheels stop occurred at 291:15:44:33 G.m.t. The rollout was normal in all respects. The flight duration was 10 days 20 hours 03 minutes 49 seconds. The APUs were shut down approximately 26 minutes and 20 seconds after landing.

PAYLOADS AND EXPERIMENTS

SUMMARY

The STS-112/ISS 9A mission was very successful in that all International Space Station (ISS) on-orbit utilization science objectives were accomplished with the exception of the commercial generic Bioprocessing apparatus (CGBA) experiment. Contingency procedures that were designed to correct a software problem that prevented proper CGBA sample cooling were unsuccessful in preventing the loss of ISS utilization science for 1 of the 3 samples that were returned on the Shuttle. The loss had no impact to the ISS on-orbit operations.

TRANSFER ACTIVITIES

The crews successfully transferred 31,237 lb (14,198 kg) of payload and logistics from the Shuttle to the ISS, and 1,846 lb (839 kg) from the ISS to the Shuttle for return to earth. Transfers to the ISS included the 27,766 lb (12,621 kg) S1-Integrated-Truss-Segment (ITS), 1,855 lb (843 kg) of science and logistics from the Shuttle middeck, 1,658 lb of water transferred in 16 contingency water containers (CWCs) and three payload water reservoirs (PWRs), 68 lb (31 kg) of nitrogen, and 28 lb (13 kg) of oxygen (O₂). In addition to the 28 lb of O₂ transferred to the station Airlock O₂ tank, 32 lb (14.5 kg) of Shuttle O₂ was used during the three EVA pre-breathe operations.

The items that were transferred to the Shuttle for return are shown in the following list.

1. Russian Translational Hand Controller;
2. Treadmill Vibration Isolation System (TVIS) PCMMIA cards;
3. Extravehicular activity (EVA) cuff checklist;
4. Ground straps;
5. Ground strap connectors;
6. Truss Roller Shaft in Ziploc Bag;
7. Carbon Dioxide Removal Assembly (CDRA) desiccant absorber Orbital Replacement Unit (ORU);
8. Internal thermal control system (ITCS) filter;
9. Russian navigation device;
10. Two Hasselblad cameras;
11. Computer-based control system (CBCS) 5A adapter cable;
12. CBCS electrical and communications power cable;
13. CBCS 5A.1 contingency power cable;
14. Small waste bag;
15. Large waste bag;
16. External male quick-disconnect coupling caps;
17. External television camera group connector caps;
18. Four cargo transfer bags (CTBs) of foam;
19. Interface umbilical assembly restraint bolt
20. Vacuum cleaner
21. Pistol grip tool (PGT)
22. PGT battery;
23. Operations data file; and
24. 8 mm videotape.

PRIORITIES COMPLETED

The following provides a list of the priorities completed during the mission.

1. Installed S1 ITS on the SO truss and completed all ITS checkouts;
2. Connected zenith tray power umbilicals;
3. Connected the 1553 data connector;
4. Connected nadir tray power umbilicals;
5. Deployed S-band Antenna Subassembly (SASA);
6. Transferred all critical equipment per the 9A Transfer list;
7. Transferred and installed the treadmill vibration isolation system (TVIS) and associated support hardware. Returned failed TVIS for analysis;
8. Performed mandatory daily maintenance for powered middeck and U.S. Laboratory payloads;
9. Performed all middeck transfers from the Shuttle to the ISS and from ISS to Shuttle;
10. Installed all Spool Positioning Devices (SPDs), including eight STS-113/ISS11A get-ahead SPD tasks;
11. Completed all zenith and nadir tray utility connections;
12. Performed thermal radiator rotary joint (TRRJ) and drive lock assembly (DLA) checkout;
13. Deployed S1 truss center radiator;
14. Disconnected the space flyer unit (SFU) Harness, repositioned to radiator beam line heaters and activated S1 fluid line secondary heaters;
15. Connected S1 to S0 fluid jumpers;
16. Connected Ammonia Tank Assembly nitrogen and ammonia lines;
17. Removed and stowed inboard & outboard keel pin and drag link, rotated S0 MT starboard stop down;
18. Released CETA Cart;
19. Installed both External Television Camera Groups (ETVCG) and Luminaries to ISS external locations;
20. Transferred Water, Oxygen and Nitrogen to the ISS;
21. Released S1/S3 utility line clamps ;
22. Removed Flex Hose Rotary Coupler (FHRC) launch restraint bolts;
23. Opened Radiator Beam Valve Module Multilayer Insulation (MLI) flaps;
24. Performed Zeolite Crystal Growth (ZCG) experiment activation;
25. Performed two ISS reboost maneuvers;
26. Performed imagery survey of the ISS exterior during Orbiter flyaround after undocking;
27. Performed EVA Radiation Monitoring (EVARM);
28. Performed Station DTO 13005-U;
29. Performed DTO 264;
30. Performed all medical DSOs; and
31. Returned additional ISS hardware that were determined during real-time operations for return to Earth.

ISS PROBLEMS/ANOMALIES

Complications with the Mobile Servicing System (MSS) power up/down configurations were experienced during the S1 truss activation and caused the Space Station remote manipulator system (SSRMS) to be unavailable for the last part of the first EVA. The power up/down of the MSS caused the remote workstation (RWS) to be out of

synchronization with the Mobile Remote Servicer (MRS) base station (MBS)/SSRMS. The event was specific to the S1 activation and the problem was corrected prior to the second EVA. The remaining tasks of the first EVA were successfully completed without the use of the SSRMS.

The Zenith Bay 5 Face 2 shroud (SO to S1) did not fit as expected, thus resulting in an exposed portion of Velcro and a gap in the passive thermal protection of the truss. The ISS Program determined that this was not an issue because of the lack of sensitive equipment or structure near the exposed area.

Two SPDs did not get installed onto the P6 photovoltaic radiator (PVR) quick disconnects (QDs). The QDs on the P6 were found to have different dash numbers than all the other 1-inch QDs. This was an oversight prior to launch. The ISS Program determined that these QDs are not to be used for system isolation in the future and that there is no need to install SPDs on these two QDs.

During the command to position the TRRJ, telemetry indicated a low voltage. This low voltage caused the fault detection isolation and recovery (FDIR) system to keep shutting down the TRRJ motor on both strings. The FDIR system was inhibited and operations continued. Checkout proceeded with the FDIR inhibited, and the TRRJ was successfully rotated.

SPATIAL HETRODYNE IMAGER FOR MESOPHERIC RADICALS

The Spatial Hetrodyne Imager for Mesospheric Radicals (SHIMMER) successfully completed data takes on flight day (FD) 10 and 11 and accomplished 100 percent of their mission objectives. Using an ultraviolet camera system, SHIMMER made observations of the Earth's limb when searching for Hydroxi gas that is a contributor to the loss of Ozone in the Earth's atmosphere. The Shimmer equipment was also used to record imagery of the moon's limb.

On FD 2 during the attitude adjustment for a SHIMMER data take, the crew reported that the attitude adjustments were going in the wrong direction. It was learned that an error existed in the SHIMMER application graphical interface on the SHIMMER payload and general support computer (PGSC): the labels on -ZLV and +ZLV buttons were switched. After determining the cause of the problem, the SHIMMER operated properly during the data takes.

RAM BURN OBSERVATION

The Ram Burn Observation (RAMBO) payload, that was sponsored by the Department of Defense (DoD) and required no on-orbit hardware, was manifested as a payload of opportunity. No dedicated orbital maneuvering subsystem (OMS) firings were scheduled during the mission due to the lack of available propellant and timeline. The OMS-firing state vectors were provided to the customer for potential viewing opportunities; data are currently being reviewed to determine if successful RAMBO observations were made.

VEHICLE PERFORMANCE

LAUNCH DELAY

The STS-112 mission was originally scheduled to launch on October 2, 2002; however, Hurricane Lili entered the Gulf of Mexico. The exact path could not be determined until late in its forward movement; consequently, a decision was made to power down the Johnson Space Center (JSC) Mission Control Center and the launch was rescheduled for October 7, 2002.

SOLID ROCKET BOOSTERS

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

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

Both SRBs were recovered and returned to KSC for inspection, disassembly and refurbishment. The inspection revealed that both SRBs were in excellent condition. No anomalous SRB conditions were noted during the postflight operations.

The postlaunch data review determined that none of the system-A NASA Standard Initiators (NSIs) for the SRB holddown posts received the Fire 1 command. The master events controller (MEC) provides the signals to fire those NSIs so the MEC is suspect as well as all of the wiring between the MEC in the Orbiter and the pyrotechnic initiator controller (PIC) rack on the ground. The data indicate that the PICs were properly armed but then had a gradual bleed-off of voltage, which is indicative of no firing. Recovery and disassembly of the SRBs revealed 8 unfired NSIs. The MEC was not used for the remainder of the mission so there was no mission impact. Kennedy Space Center has the failure investigation team in operation to resolve this anomaly. However, the failure investigation team was unable to determine the cause of the problem.

REUSABLE SOLID ROCKET MOTORS

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

The maximum in-flight trace shape variation of pressure versus time during the 62- to 80-second time frame was calculated to be 0.864 percent at 77.5 seconds and 0.614 percent at 71.0 seconds for the left and right motors, respectively. These values were well within the 3.2-percent allowable limits. The maximum steady-state thrust differential values were near the nominal values experienced in previous flights.

Power application and operation of all field-joint heaters was accomplished routinely. Field-joint heaters operated for 13 hours 12 minutes during the final launch countdown. Power was applied to the heating elements an average of 11 percent of the time during the LCC time frame.

Power application and operation of all igniter-joint heaters was accomplished routinely. The igniter-joint heaters operated for 13 hours 3 minutes during the final launch countdown. Power was applied to the heating elements 43 percent of the time during the LCC time frame.

The heated, ground-supplied, aft skirt purges maintained the case/nozzle joint and flex bearing temperatures within the required LCC ranges. The purge was activated two times for a total of 10 hours 26 minutes during the time of recorded data for the countdown. The first heater activation lasted only 12 minutes, as the heater did not function. The heater was deactivated, the problem was resolved and the heater and purge was reactivated. It was not necessary to activate the aft-skirt purge to maintain the nozzle-case joint temperatures at or above the minimum LCC temperature. As a result, it was also not required to thermally condition the flex bearing above the minimum required temperature of 60 °F. During the LCC time frame, the nozzle/case joint temperatures were nominal and ranged from 80 °F to 86 °F and 78 and 86 °F for the left-hand and right-hand motors, respectively. The final flex bearing mean bulk temperature (FBMBT) was determined to be 82 °F.

All ground environmental instrumentation (GEI) and operational flight instrumentation (OFI) performed within established requirements. All available data were recorded, transmitted and analyzed. The analysis showed that the left-hand motor acreage sensor at 270 degrees and station 931.48 read 5 °F high. Analysis showed that all other sensors operated as expected.

Reconstructed motor performance parameters adjusted to a 60 °F propellant mean bulk temperature (PMBT) are shown in the following table. The predicted PMBT at launch was calculated to be 81 °F.

MOTOR PERFORMANCE PARAMETERS

Parameter	CEI Specification Limit (60 °F)	Left Motor Delivered	Right Motor Delivered
Web time, seconds	105.4 – 116.7	110.4	110.2
Action time, seconds	115.2 – 131.2	122.7	122.3
Head end pressure, psia	847.9 – 965.7	917.6	920.1
Maximum sea level thrust, MLbf	2.88 – 3.26	3.08	3.09
Web time average pressure, psia	629.9 – 700.5	668.7	669.7
Web time average vacuum thrust, MLbf	2.46 – 2.74	2.62	2.62
Web time total impulse, MLbf sec	285.8 – 291.6	289.0	289.0
Action time impulse, MLbf seconds	293.7 – 299.7	297.1	296.8
ISP average delivered, Lbf sec/Lbm	266.5 – 270.3	269.0	268.6
Loaded propellant weight, Lbm	>1103750	1104868	1105555

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

The predicted and actual propulsion systems performance is shown in the following RSRM Propulsion Performance table on the page. The final propellant mean bulk

temperature calculation was made postflight with reconstructed data that showed a nominal temperature of 81 °F.

RSRM PROPULSION PERFORMANCE

Parameter	Left motor, 81 °F		Right motor, 81 °F	
	Predicted	Actual	Predicted	Actual
Impulse gates				
I-20, 10 ⁶ lbf-sec	65.45	66.50	65.17	66.60
I-60, 10 ⁶ lbf-sec	175.20	176.99	174.59	177.51
I-AT, 10 ⁶ lbf-sec	296.80	297.46	296.99	297.22
Vacuum Isp, lbf-sec/lbm	268.6	269.2	268.6	268.8
Burn rate, in/sec @ 60 °F At 625 psia	0.3668	0.3690	0.3656	0.3699
Event times, seconds ^a				
Ignition interval	0.232	N/A	0.232	N/A
Web time ^b	109.0	108.0	109.5	107.8
50 psia cue time	119.1	117.3	119.6	117.4
Action time ^b	121.3	120.1	121.8	119.7
Separation command	124.0	-	124.0	-
PMBT, °F	81	81	81	81
Maximum ignition rise rate, psia/10 ms	90.8	N/A	90.8	N/A
Decay time, seconds (59.4 psia to 85 K)	3.1	3.7	3.1	3.3
Tailoff Imbalance Impulse Differential	Predicted N/A		Actual 502.5	

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

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

^b Referenced to liftoff time (ignition interval).

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

EXTERNAL TANK

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

During prelaunch operations, the ice/frost red team reported a small crack in the second valley, -Z side of the -Y thrust panel and a small crack on the forward side of the -Y vertical strut. Both cracks were typical and acceptable. There were no changes in the cracks from the first tanking.

The pressurization systems functioned properly throughout engine start and flight. The minimum LO₂ ullage pressure experienced during the ullage pressure slump was 14.0 psid.

ET separation was confirmed. The postflight analysis of the impact point showed the ET impact to be 78.9 nautical miles uprange from the preflight predicted impact point.

The STS-112 mission was the first flight of the Shuttle Observation Camera System. The system performed as expected up to the time of SRB separation. At SRB separation, the plume from the SRB booster separation motors (BSMs) coated the lens in residue, making it impossible to discern anything but general shapes.

SPACE SHUTTLE MAIN ENGINES

Prelaunch operations of the Space Shuttle main engines (SSMEs) were smooth with no LCC or OMSRD violations noted. The ignition confirm limits and mainstage redline margins were satisfactory. All Interface Control Document (ICD) start and shutdown transient requirements were met. Engine performance during start, mainstage, and shutdown was nominal and as predicted. Engine cutoff times were within the nominal limits for SSME 1, 2 and 3, respectively. Controller and software performance was satisfactory with no in-flight anomalies identified from the review of the data.

The preliminary reconstructed specific impulse (I_{sp}) was 452.9 seconds and the tag value was 451.6 seconds, so the flight-derived I_{sp} was 1.3 seconds higher than predicted. The Block II engines I_{sp} are typically approximately 0.8 to 1.3 seconds higher than that predicted from ground testing data.

Main engine cutoff (MECO) occurred 505.X seconds after SRB ignition. The commanded maximum dynamic pressure (max Q_d) throttle-down was a two-step throttle-down to 72 percent.

SHUTTLE RANGE SAFETY SYSTEM

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

ORBITER SUBSYSTEMS PERFORMANCE

Main Propulsion Subsystem

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

Tabulation data for the prelaunch, MECO, post-MECO, entry and landing events revealed no anomalous valve movements. All timings were within the required specification and within the current database. The aft hazardous gas concentrations during both loading sequences were nominal. The peak hydrogen concentration during the second loading was 184 ppm, which compares favorably with previous data from this vehicle.

The liquid hydrogen (LH_2) loading operations were normal throughout the entire process. Based on an analysis of loading system data, the LH_2 load at the end of replenish was nominal, which was well within loading accuracy requirements.

The LO₂ loading operations were completed satisfactorily. Based on an assessment of the load at the end of replenish showed the load to be well within the required MPS loading accuracy.

The overall gaseous hydrogen (GH₂) system performance during the ascent phase was nominal. All three flow-control valves (FCVs) performed nominally. The gaseous oxygen (GO₂) fixed-orifice pressurization system performed as predicted. Reconstructed data from engine and MPS parameters closely matched the actual ET ullage pressure measurements. Helium system performance for the SSMEs and pneumatic Helium systems were also nominal. Entry Helium usage was 59.6 lbm, which is well within the allowable requirements.

Two File IX requirements were not met during the flight and these are discussed in the following paragraphs.

While performing the MPS low-pressure Helium decay check, the pneumatic regulator outlet pressure decay was 2.6 psi/min. The allowable leakage for this requirement is 2.4 psi/min. This increased decay rate was most likely the result of increased leakage of one of the 3-way solenoid valves, which are already documented as having known leakage.

When the LO₂ Inboard fill/drain valve was commanded closed at T-4 minutes 48 seconds, the valve closed in 4.9 seconds. The requirement for this valve is to close in 5.0 to 9.0 seconds. This requirement is important to make sure that the valve is not slamming due to loss of snubbing pressure. After reviewing the software sequence, it was determined that the sequence, combined with a valve that was slightly fast, is what caused this failure. To satisfy the interval requirement, the low-pressure actuation test will be performed on this valve. All valve timings will be checked on the ground, and the timings will continue to be monitored in-flight to ensure there are no drastic changes.

Reaction Control Subsystem

The reaction control subsystem (RCS) performed nominally with one in-flight anomaly identified during the mission. This anomaly is discussed in a following paragraph and it did not impact the mission.

A total of 11 maneuvers, which included one 1-hour reboost period that raised the altitude of the International Space Station (ISS) approximately 3.4 nautical miles (nmi), and one 35-minute reboost period that raised the orbit 1.96 nmi. Both reboost periods were completed satisfactorily.

A total of 7148.5 lbm propellants (4389.1 lbm - oxidizer, 2759.4 lbm - fuel) were used from the RCS during the mission. A total of 1559.4 lbm of orbital maneuvering subsystem (OMS) propellants were also used by the RCS during the mission. The primary RCS thrusters had 5771 firings and a total firing time of approximately 989.84 seconds. The vernier RCS thrusters had 4462 firings and a total firing time of 26,865.92 seconds.

The RCS window protect maneuver was initiated at 280:19:47:51.8 G.m.t. (00:00:02:00.8 MET) and was terminated 2.08 seconds later. This maneuver provided a method of protecting the windows of the Orbiter from booster separation motor exhaust

products. This maneuver results in improved window clarity during the mission and a reduction in the turnaround effort following the mission.

Immediately prior to External Tank (ET) separation, the RCS primary thruster L4D failed off because of the low chamber-pressure on the initial thruster firing (Flight Problem STS-112-V-01). The maximum pressure reached was 16 psia, which is indicative of the fuel valve main stage not opening. Redundancy management deselected the thruster after it failed to reach the minimum threshold pressure of approximately 26 psia within the allotted time frame (320 msec). The remaining two down-firing thrusters performed nominally during ET separation. No mission impact occurred and the thruster remained deselected for the remainder of the mission. This thruster and all other thrusters on that manifold will be replaced.

Maneuver	Time, G.m.t./MET	ΔV , ft/sec	Firing time, Sec	Orbit, nmi.
NCC (multi-axis RCS)	282:12:06:02 01:16:20:11	0.9	-	196.5 by 209.6
MC1	282:13:23:44 01:17:37:53	0.44	0.1	199.7 by 213.1
Planar Null (+y-axis RCS)	282:13:47:23 01:18:01:32	-	-	199.7 by 213.1
MC-2 (RCS)	282:13:51:45.7 01:18:05:54.7	0.6	2.1	199.6 by 213.2
MC-3 (RCS)	282:14:08:46.0 01:18:22:55.0	0.4	1.7	199.6 by 213.1
MC-4 (RCS)	282:14:18:46.5 01:18:32:55.5	3.2	13.8	200.4 by 213.6

The first reboost session was started at 285:10:52:48 G.m.t. (04:15:06:57 MET) when all of the down-firing vernier thrusters were fired. The session lasted one hour. The performance of the RCS was nominal throughout the operation. The reboost imparted a ΔV of 11.9 ft/sec resulting in an overall average altitude increase of 3.4 nmi for a final orbit of 216 by 204 nmi.

The second reboost session was started at 287:11:20:50 G.m.t. (06:15:34:59 MET). The session lasted the scheduled 35 minutes. The performance of the RCS was nominal throughout the operation. The reboost imparted a ΔV of 6.9 ft/sec resulting in an overall average altitude increase of 1.96 nmi for a final orbit of 219.4 by 203.3 nmi.

Following undocking, the initial Orbiter separation maneuver began with a +Z-axis pulse of primary RCS thrusters at 289:13:13 G.m.t. (08:17:27 MET). The ISS flyaround operations were nominal and terminated with a 5.76-second +X pulse at 289:14:30 G.m.t. (08:18:44 MET). Final separation from ISS was accomplished with a 21-second +X-axis pulse of primary RCS thrusters L1A and R1A at 289:15:00 G.m.t. (08:19:14 MET). The ΔV delivered was 5.5 ft/sec and the resulting orbit was 200.8 by 219.9 nmi.

Following the successful undocking from the ISS, the primary RCS thruster F3F heater failed-on during the ISS flyaround activities. The failure was initially masked because of the hot thrusters created by the flyaround activities. The decision was made to not awaken the crew to turn off the heater because the temperatures remained relatively stable at 150 °F, which is within 7 °F of the upper limit. The plan to fire that thruster during the RCS hot fire was deleted, and no other firings of that thruster were planned

during the mission. If the thruster temperatures approach the upper limit, the crew can perform manual cycling of the heater. This failure did not impact the successful completion of the mission. The thruster will be removed for repair, and the other thrusters on that manifold will also be removed for preventative maintenance.

After the flight control subsystem (FCS) checkout, the RCS hot-fire was performed nominally. The hot-fire began at 290:13:21:59 G.m.t. (09:17:36:08 MET) and ended at 290:13:26:38 G.m.t. (09:17:40:47 MET). Primary thruster F3F was not fired due to its failed-on heater and thruster L4D was not fired since it had previously failed off. All other thrusters were fired at least once for a minimum duration of 240-milliseconds. A review of thruster chamber-pressure data confirmed that all of the thruster firings were satisfactory.

The following table shows how the attitude control of the combined ISS and Orbiter were shared during the docked operations.

ATTITUDE CONTROL OF THE ISS/ORBITER DURING DOCKED OPERATIONS

Control Responsibility	Start, G.m.t.	End, G.m.t	Elapsed Time, D:H:M:S	Comments
ISS	282:16:09:18	285:10:02:49	02:17:53:31	Initial handoff to ISS
Orbiter	285:10:02:49	285:12:39:15	00:02:36:26	Reboost 1
ISS	285:12:39:15	286:11:54:41	00:23:15:26	
Orbiter	285:11:54:41	286:15:00:20	00:03:05:49	Water dump
ISS	286:15:00:20	287:10:31:30	00:19:31:10	
Orbiter	287:10:31:30	297:12:29:14	00:01:57:44	Reboost 2
ISS	287:12:29:14	289:12:17:50	01:23:48:36	ISS control until undocking

Orbital Maneuvering Subsystem

The orbital maneuvering subsystem (OMS) performed satisfactorily throughout the mission. No in-flight anomalies or significant problems were identified during the review and analysis of the data.

A total of 23,309 lbm (14,579 lbm - oxidizer and 8730 lbm - fuel) of OMS propellants were consumed during the mission. A total of 1559.4 lbm of OMS propellants were provided during interconnect operations to the RCS. As a means of saving propellant, the NC2 and NPC maneuvers were deleted and the ΔV that was to be imparted to the vehicle was combined into the NC3 maneuver that was performed by the OMS.

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

OMS MANEUVERS

Maneuver	Time G.m.t./MET	ΔV ft/sec	Firing time sec	Orbit nmi.
OMS assist (Dual OMS)	280:19:48:02 00:00:02:09	N/A	75.6	N/A
OMS-2 (Dual OMS)	280:20:24:30 00:00:38:40	96.1	62.8	85.1 by 126.4
NC1 (OMS-3) (Dual OMS)	280:23:23:46 00:03:37:31	60.3	39.8	115.8 by 127.1
NC3 (OMS-4) (Right OMS)	281:20:00:34 01:01:14:43	13.6	18.0	121.7 by 126.8
NH (OMS-5) (Dual OMS)	282:10:43:16 01:14:57:25	145.5	92.5	126.8 by 204.4
NC4 (OMS-6) (Dual OMS)	282:11:31:26 01:15:45:35	131.3	82.3	196.6 by 209.9
Ti (OMS-7) (left OMS)	282:13:03:45 01:17:17:54	10.1	12.2	199.6 by 213.1
Orbit Adjust (OMS-8) (Dual OMS)	290:20:26:51 10:00:41:00	93.9	50.8	146.6 by 219.9
Deorbit (Dual OMS)	291:14:36:14.284 10:18:50:23.266	250.8	132.4	25.4 by 219.9

The deorbit maneuver for the first Kennedy Space Center (KSC) landing opportunity on the planned landing day was a dual engine straight-feed firing that was performed on orbit 170.

Power Reactant Storage and Distribution

The power reactant storage and distribution (PRSD) subsystem performance was nominal throughout the STS-112 mission. No LCC or OMRSD violations occurred during the countdown and mission, and no in-flight anomalies were noted during the analysis of the data. All File IX requirements were satisfied during the mission.

The PRSD subsystem supplied the fuel cells with 2377 lbm of oxygen and 299 lbm of hydrogen for the production of 3481 kWh of electrical energy. In addition, the environmental control and life support system (ECLSS) was supplied 154 lbm of oxygen for life support. The average power level for the mission was 13.4 kW. A 118-hour mission extension was possible at the average power level with the reactants remaining at landing, and at extension day power level of 12.9 kW, a 123-hour mission extension was possible.

PRSD tanks 4 and 5 were depleted to residual quantities during the mission. The Orbiter landed with 1393 lbm of oxygen and 160 pounds of hydrogen remaining.

During the long periods of low vehicle acceleration while on-orbit, oxygen tanks 3 and 4 fluid stratified. When the fluids destratified following RCS thruster firings, the corresponding pressure drop and quantity increase were observed. In all cases, the fluid remained in the single-phase region. These conditions did not create any impact on operations and are expected to occur during normal flights.

Approximately a total of 60 lbm of oxygen were transferred from the Orbiter PRSD system to the ISS high-pressure oxygen tanks [using a transfer line and the oxygen recharge compressor assembly (ORCA)] for use during the prebreathing for the three EVAs conducted from the ISS airlock as well as life support after undocking.

Fuel Cell Powerplant Subsystem

The overall performance of the fuel cell powerplant (FCP) subsystem was nominal during the mission. There were no OMRSD or LCC violations, nor were any in-flight anomalies found during the analysis of the data. The average power level and load was 13.4 kW and 434 amperes. The fuel cells produced 2676 lbm of potable water and 3481 kWh of electrical energy while using 2377 lbm of oxygen and 299 lbm of hydrogen.

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

The actual fuel cell voltages at the end of the mission were 0.2 Vdc above the predicted for fuel cell 1, 0.3 Vdc above predicted for fuel cell 2, and 0.15 Vdc above the predicted for fuel cell 3. The voltage margin above the minimum performance curve at 200 amperes at the end of the mission was 0.9 Vdc for fuel cell 1, 1.2 Vdc for fuel cell 2, and 1.1 Vdc for fuel cell 3.

The overall thermal performance of the fuel cell, water line, and reactant purge heater systems was nominal, except for the B temperature controller on the water relief line nozzle heater. The fuel cell water relief nozzle temperature was cycling between 277 and 272 °F during prelaunch operations, and its normal cycling range is 157 to 235 °F. While troubleshooting, control bus AB1 was dropped and the temperature rose to 340 °F, thus narrowing the problem to temperature controller B that is contained in mid-power-control-assembly (PCA)-2 or in the associated temperature return wiring, which is also contained in the mid-PCA-2. A waiver was submitted that allowed this condition to be flown as is, and there was no impact to the flight.

The prelaunch cell performance monitor (CPM) data were documented during the prelaunch operations. All of the CPM values remained stable for the entire mission. The fuel cell monitoring system was activated and provided full-rate data during on-orbit operations for 12 minutes. None of the fuel cell individual cell voltages indicated any problems and no pin sharing was indicated.

Auxiliary Power Unit Subsystem

The auxiliary power unit (APU) subsystem performance was nominal throughout the mission. No in-flight anomalies or significant problems were identified during the evaluation of the data. All in-flight checkout requirements were completed satisfactorily.

The flight control subsystem (FCS) checkout was performed satisfactorily using APU 1 to support the checkout with a start time of 290:12:32:07 G.m.t. (09:16:46:16 MET). The run time was 5 minutes, 39 seconds, and 19 pounds of fuel were used during the APU 1 operation. The total run time was too short to require spray cooling from the water spray boiler (WSB). FCS, APU, and hydraulics performance was nominal.

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

APU RUN TIMES AND FUEL CONSUMPTION

Flight phase	APU 1 (S/N 207)		APU 2 (S/N 203)		APU 3 (S/N 311)	
	Time, Min:sec	Fuel consumption, lb	Time, Min:sec	Fuel consumption, lb	Time, min:sec	Fuel consumption, lb
Ascent	22:11	52	22:30	53	22:46	53
FCS checkout	5.39	19				
Entry ^a	69:07	136	98:29	182	69:24	139
Total	96:57	207	120:59	235	92.10	192

^a APUs were shut down 26 minutes 20 seconds after landing.

During ascent, the APU 1 exhaust gas temperature (EGT) 1 transducer was erratic. The transducer was also erratic during entry, dropping 200 °F during a 15-minute period, and then recovered to normal operation soon after landing. The transducer will be removed and replaced before the next flight of this vehicle.

Hydraulics/Water Spray Boiler Subsystem

The hydraulics/WSB subsystem performed satisfactorily throughout the mission. STS-112 was the second flight of the OV-104 vehicle with the water additive. Propylene Glycol Monomethyl Ether (PGME), added to all three WSBs. No overcooling or undercooling conditions were noted in the data. Spray cooling was noted at 56 and 105 seconds after MECO on systems 1 and 2, respectively. System 3 began spray cooling 6 seconds after MECO.

There were no unexpected decreases in reservoir quantity, indicating that the systems had no gross leakage. Priority valve checks at APU activation were all well below the 1-second specification.

The APU/HYD system 1 was selected for FCS checkout. Hydraulic system 1 operation was nominal.

Electrical Power Distribution and Control Subsystem

The electrical power distribution and control (EPDC) subsystem performed nominally during all mission phases. The data review and analysis did not identify any abnormal conditions. Also, all File IX requirements were satisfied.

As a result of the pyrotechnic initiator controller problem discussed in the Postflight Pad Inspection section of this report, a post-landing troubleshooting plan was developed to inspect the Orbiter (OV-104) for potential causes. As of this writing, the tests have shown nominal performance in the following areas:

1. Runway inspections and resistance checks were nominal;
2. MEC 1 commands to the T-0 umbilical connector J61 were nominal; and
3. Signal path pin pull tests and harness flex tests have been nominal while commands were being issued.

Orbiter Docking System

The Orbiter docking system (ODS) was powered up at 281:19:48 G.m.t. (01:00:02 MET), ring extension was completed nominally, and the system was powered down at 281:19:58 G.m.t. (01:00:12 MET).

The ODS was powered up for docking operations at 282:14:49 G.m.t. (01:19:03 MET) and the ISS was captured at 282:15:16 G.m.t. (01:19:30 MET). Ring retraction and hook closure were completed nominally. It appears that at least one high-energy damper was stuck and that the new ring-retraction procedure worked well. The ODS was powered off at approximately 282:15:40 G.m.t. (01:19:54 MET).

The ODS valves were used during the docked operation. The Orbiter was docked to the ISS pressurized mating adapter (PMA) 2 and the vestibule was pressurized from the ISS. The post-docking vestibule leak check was nominal.

The vestibule depressurization valves were used to depressurize the vestibule to vacuum before undocking, and the pre-undocking vestibule leak check was nominal.

The external airlock waterline heater reconfiguration from string A heaters to String B heaters was performed as part of the in-flight checkout. String C heaters were not required.

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

An evaluation of the data from docking indicates that the axial contact velocity was higher than desired (0.19 ft/sec versus 0.13 ft/sec maximum allowed in the specification and this is considered to be "out-of family". All crew training is based on an initial contact velocity of 0.1 ± 0.03 ft/sec. The requirement specification for the ODS hardware is an axial contact-velocity of 0.2 ft/sec. The current docking mechanism was qualification tested at 0.4 ft/sec at high and low temperatures. Therefore, damage to the ODS hardware is not anticipated. Results of the Orbiter assessment of the docking contact conditions indicate that a 0.2-ft/sec contact-velocity was well within the capability of the docking mechanism. The Orbiter docking mechanism for ISS is a derivative of the MIR docking mechanism, which was designed for 0.5 ft/sec closing rate. A review of the downlist data revealed two indications of a translational hand controller (THC) input without subsequent thruster firings immediately prior to docking. The most probable cause for this condition is that the THC was not held for the required 160 ms required to assure that the thrusters fire.

Atmospheric Revitalization Pressure Control Subsystem

The atmospheric revitalization pressure control subsystem (ARPCS) performed normally throughout the duration of the flight. To minimize the use of consumables used and maintain pressure for gas transfer to the ISS, the 14.7-psia cabin regulators were not activated for service after orbital insertion.

At approximately 281:20:27 G.m.t. (01:00:41 MET), the pressure control system (PCS) 1 oxygen supply pressure measurement failed off-scale high. The indication returned to normal approximately 5.5 minutes later. This same measurement failed off-scale low for a period of 17 hours on STS-77 when this same O₂N₂ panel was installed on the OV-105 vehicle. The panel was removed and during the repair activity, the oxygen pressure transducer was examined but not anomalies were noted. As a result, the transducer was

not changed and the panel successfully passed the acceptance test. There are three additional backup measurements that continued to operate satisfactorily. As a result, this condition did not impact the successful conclusion of the mission, and since two other sensor measurements provide the same information, further action will not be taken to remove and replace the sensor.

The Orbiter docked and opened hatches with the ISS at 282:16:51 G.m.t. (01:21:05 MET). All three extravehicular activities (EVAs) on this mission were performed from the ISS Airlock. Due to the large amount of oxygen (O₂) exhausted into the cabin atmosphere during the ISS pre-breathe procedure, Orbiter cabin pressure during the docked period was maintained by the introduction of the O₂ from the ISS pre-breathe and the ISS pressure control system.

During the docked period, approximately 69 lbm of nitrogen (N₂) and approximately 60 lbm of O₂ were transferred to the ISS tanks via the transfer lines on the airlock.

After the third EVA, a repressurization of the entire stack (Orbiter and ISS) to a pressure of 14.7 psia was accomplished with Orbiter O₂ at 288:18:10 G.m.t. (07:22:24 MET). After this, normal pressure control was maintained for the remainder of the flight.

After undocking, ARPCS 1 system was placed on service in a configuration with O₂ flow through the payload O₂ cross-connection and a full switchover was observed on this subsystem. This configuration was necessary to allow the ARPCS system 2 O₂ flow sensor to monitor the flow. All other flow sensors on this vehicle are inoperable. PCS System 2 was placed on service during the following day and a full switchover was observed on system 2.

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

Atmospheric Revitalization Subsystem

The atmospheric revitalization subsystem (ARS) performance was nominal throughout the duration of the flight, and hardware checkout was completed nominally and in accordance with the file IX requirements. These requirements included the checkout of the secondary cabin-temperature controller and the checkout of the primary water coolant loop 1 actuator and its response to temperature.

During the launch phase, the crew compartment temperature was 75.6 ° F at launch was 1.6 degrees warmer than predicted preflight temperature of 74 ° F that was provided through the STS-112 environmental control and life support subsystem (ECLSS)/payload thermal compatibility verification analysis. The temperature also exceeded the flight rule limit of 75 ° F air temperature. The cabin temperature continued to climb until it peaked to 78.43 ° F 5 hours and 10 minutes into the flight.

At launch, the cabin humidity was 38.0 percent and the humidity level peaked to 42.8 percent at 1 hour and 54 minutes after launch. The heat exchanger outlet air temperature at launch was 55.4 and that temperature level peaked to 64.15 ° F at approximately 4 minutes 09 seconds into the flight. Cabin humidity averaged 34-percent for the flight, and peaked at 49.6 percent during deorbit preparations on FD 12.

At launch, the cabin carbon dioxide partial pressure (ppCO₂) sensor indicated a value of 1.15 mmHg and peaked to 1.46-mmHg 17 minutes into the flight. During the on-orbit

operations, the Orbiter cabin ppCO₂ peaked at 7.6 mmHg while docked to the ISS with the hatches open. The carbon dioxide (CO₂) peaked at 286:16:41 G.m.t. (05:20:55 MET) when the station CO₂ removal assembly (CDRA) was acting as the primary control device and had been powered down. STS-112 was the first flight that the CO₂ levels in the Orbiter-cabin and ISS volumes were controlled by ISS CDRA and Vozdukh hardware. Upon the Orbiter docking with the ISS and opening of the common ISS/Orbiter hatches 282:16:51 G.m.t. (01:21:05 MET), the CDRA had not been powered and the ISS CO₂ level was controlled by the Vozdukh. The CDRA was powered and operational at approximately 282:20:55 G.m.t. (01:23:09 MET) and Vozdukh at that time was operating at a setting of 4.5. Eleven hours prior to the cabin ppCO₂ peak at 7.6 mmHg, the CDRA was powered down to maneuver to an Orbiter wastewater dump attitude. In this attitude, station power is limited so non-critical hardware such as CDRA is powered down. As the Orbiter cabin ppCO₂ reached 7.6 mmHg, a lithium hydroxide (LiOH) cartridge was installed in the Orbiter crew compartment to prevent the CO₂ level from climbing further. The CDRA was repowered approximately 55 minutes later and the cabin indicated ppCO₂ decreased to a level below 4.0 mmHg during the next nine hours.. Vozdukh was powered down at 287:09:55 G.m.t.(06:14:09 MET) and the control of the CO₂ level in the entire stack relied solely on the operation of CDRA. The stack continued to rely on CDRA removing CO₂ until 288:20:30 G.m.t. (08:00:39 MET) when the shuttle crew compartment ppCO₂ climbed to 6.77 mmHg (below Flight Rule CO₂ concentration limit of 7.6 mmHg), at which time the crew was requested to install a LiOH cartridge prior to their sleep period. In addition, Vozdukh was repowered and within 3 hours the Orbiter cabin ppCO₂ level dropped to 3.35 mmHg.

Seven LiOH cartridges were transferred to the ISS in return for seven older cartridges from the ISS. Two of the ISS transfer cartridges that had the oldest pack dates of the transfer cans were returned to the LiOH facility where samples will be removed and transferred to JSC for reactivity testing. The other five transfer cartridges were used by the Orbiter during the remainder of the mission with one being installed after undocking. A total of 17 LiOH cartridges were spent of which five of the total number of cartridges had been transferred from the ISS.

The floodlight cold plate temperature sensor on the 576 bulkhead indicated the temperature averaged approximately 68.5 °F during the mission. The temperature decreased to a minimum of 66.29 °F at 290:03:39 G.m.t. (09:15:53 MET) after undocking from the ISS.

During the on-orbit phase of the mission, the cabin temperature averaged 74 °F. The Orbiter cabin temperature during the docked portion of the mission had temperature level varied from a low of 72.7 °F to temperature highs of 76.3 °F, with an average temperature of 74.5 °F.

During the landing phase of the flight, the heat exchanger outlet temperature peaked to 60.05 °F at 6 minutes and 49 seconds after wheel stop, with the cabin air temperature peaking to 74.85 °F at 31 minutes after wheel stop and prior to crew egress. The temperature at landing was 72.3 °F, below the 75-degree cabin air temperature limit. The cabin humidity peaked near 51.6 percent approximately 9 minutes and 38 seconds after wheel stop.

Active Thermal Control Subsystem

The active thermal control subsystem (ATCS) performed nominally throughout the mission. No in-flight anomalies were identified from the review and analysis of the data.

At about 1 minute and 34 seconds into the ascent phase of the mission, pre-evaporative cooling occurred that resulted in a drop in flash evaporator system (FES) outlet temperatures from 84.9 °F to about 64.1 °F. This amount of pre-evaporative cooling is within the flight history of the FES. This amount of pre-evaporative cooling had no impact on the mission with FES duct temperatures remaining nominal throughout the mission. At approximately 280:21:04 G.m.t. (00:01:18 MET), the FES controller was switched from primary A command to primary B command after the supply water system was configured to gang together tanks C and D to supply water through the feedline B system. This allowed for water to accumulate in tanks A and B for eventual transfer to the ISS in contingency water containers (CWCs) and portable water reservoirs (PWRs) while still retaining the FES cooling capability required for the duration of the warmer attitude phases of the mission. The radiator flow was initiated at 280:21:07 G.m.t. (00:01:21MET). The FES high load evaporator was inhibited 27 minutes later. The FES was under primary B command from 280:21:04 G.m.t. (00:01:18 MET) through 289:12:12 G.m.t. (08:16:26 MET). At the end of that period, the FES was switched from primary B command to primary A command because the filling of CWCs for transfer to ISS had been completed.

On entry day, the radiator coldsoak was begun at 291:10:42 G.m.t. (10:14:56 MET) at which time it ended with the initiation of the radiator bypass/FES checkout. The radiator bypass/FES checkout produced nominal results and ended one hour 5 minutes later with the configuring of the FES to primary B full-up mode. The payload bay doors were closed at about 291:12:04:50 G.m.t. (10:16:18:59 MET). Approximately 40 minutes later, the FES was configured from primary B command to primary B GPC in preparation for entry. The radiators were configured for radiator flow approximately 11 minutes before landing. Approximately 2 minutes after landing, the radiator flow control assemblies were switched from normal-setpoint control to high-setpoint control in preparation for activation of the ammonia boiler system (ABS). Approximately 6 minutes after landing, the ABS primary A general-urpouse computer (GPC) controller was enabled to begin cooling. ABS system A cooled to a FES outlet of about 34.9 °F. The ammonia tank A began blowdown approximately 45 minutes after landing, thus signaling the depletion of the ammonia tank. The ABS primary A GPC controller was inhibited and the secondary B controller was enabled. By this time, the ground support crew was ready to initiate ground support equipment (GSE) cooling resulting in the primary A GPC being deactivated after just about eight minutes of operation. Ground cooling was initiated at 57 minutes after landing.

Supply and Waste Water Subsystem

The Supply Water and Waste Management Systems performed nominally throughout the mission and all of the scheduled in-flight checkout requirements were satisfied. Supply water was managed through the use of the FES, and water transfer to the ISS. Supply-water nozzle-dumps were not performed during this mission. The line heater maintained the supply-water dump-line temperature between 71.5 °F and 87.8 °F throughout the mission.

Three wastewater (from waste tank) nozzle dumps at an average rate of 2.04 percent/minute (3.3 lbs/min) were performed. One ISS-contingency water container (CWC) containing approximately a 16 lb mixture of condensate and technical water and two Payload Water Reservoirs (PWRs) containing iodinated water were dumped nominally through the wastewater dump nozzle. The Shuttle Urine Pre-treat Assembly (SUPA) was manifested for STS-112, and condensate collection in a CWC was

implemented to minimize waste dumps while docked to ISS. The Oxone Hose Section flown on STS-112 contained two tablets and the tablet change-out occurred during the post-sleep time period instead of pre-sleep time period.

As a result of condensate separation/collection, two CWCs of Shuttle condensate were filled and dumped overboard through the wastewater dump nozzle. The waste dump isolation valve was closed prior to connecting the CWC/PWR into the waste cross-tie quick disconnect (QD) to prevent back flow from the waste tank. The wastewater dump line temperature was maintained between 53.4 °F and 77.2 °F throughout the mission.

Vacuum vent line temperature was maintained between 58.6 °F and 75.7 °F.

Sixteen CWCs were filled with supply water and transferred to the ISS, for a total of 1603.7 lb. Eight of the CWCs transferred were potable and eight were technical water. The calculated average fill rate was 101 lb/hr. In addition, three PWRs of iodinated water (54.4 lb) were filled and transferred to ISS.

During prelaunch operations, the supply water tank A quantity sensor exhibited a quantity dropout at a tank quantity of 34.78 percent. The tank quantity dropped to a negative 11 percent for one second and recovered. In addition, the tank quantity sensor dropped a number of times at different quantity levels during the mission. The tank A quantity sensor dropped for the first time in this vehicle, and the occurrence was documented for future reference. Such dropouts have been experienced in previous flights and the problem was caused by either contamination of the collector bar and/or a surface defect on the collector bar of the potentiometer. Either of these conditions may cause an intermittent break in continuity. These dropouts are understood problems and are deferred to the Orbiter Major Modification (OMM) for a quantity sensor with direction from the Problem Resolution Team.

At 289:12:15 G.m.t. (08:16:30 MET) while performing the nominal supply water system reconfiguration, the crew reported that the talkback on the supply water crossover valve switch on panel R11L remained in the barber-pole configuration, indicating that the circuit breaker was not transferring power. When the crew attempted to open the valve later in the mission, one crewmember pushed in the circuit breaker while the other crewmember operated the switch. With this teamwork, the crew was able to open the crossover valve and obtained the talkback to OPEN position. This circuit breaker anomaly did not impact to the mission timeline.

Waste Collection Subsystem

The waste management subsystem performed satisfactorily throughout the mission.

Smoke Detection and Fire Suppression Subsystem

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

Flight Data Subsystem

The flight data subsystem performed satisfactorily. No in-flight anomalies were identified in the data review and analysis. One minor problem was identified during the mission and it is discussed in the following paragraph.

During GPC set contraction operations at 289:15:29 G.m.t. (08:19:43 MET), when taking GPC 3 to standby, the talkback indication failed to change from run to barberpole as expected. The talkback was reported to have behaved as expected when the mode switch was subsequently moved to halt, back to standby, and back to halt in accordance with the procedures. Subsequently, a GPC checkout procedure was performed during which GPC 3 was moded from halt to standby, standby to run, run to standby and standby to halt, and no GPC errors were noted during the procedure.

Flight Control Subsystem

The FCS performed satisfactorily throughout the mission. No in-flight anomalies were identified in the data. One minor problem was noted during the FCS checkout and it is discussed in a later paragraph.

The FCS checkout was performed satisfactorily using APU 1 to support the checkout with a start time of 290:12:32:07 G.m.t. (09:16:46:16 MET).

STS-112 was the fifth flight in which a special FCS checkout secondary actuator test was performed (two runs, negative stimulus first). In the first positive stimulus of this special test, a 2.3 second hesitation was observed in the speedbrake channel 3 secondary differential pressure. This was the third time that a hesitation has been observed on the rudder/speedbrake power drive unit (S/N 406), and the first time since the initiation of these special tests. Speedbrake channel 3 performance during the second negative and positive stimuli was nominal and speedbrake performance during entry and landing was nominal. This hesitation condition has been attributed to tight tolerances and friction under cold temperatures.

Also, the Orbiter relative velocity during the docking with the ISS was higher than desired (0.19 ft/sec versus 0.13 ft/sec maximum allowed in the specification. A review of the downlist data revealed two indications of a translational hand controller (THC) input without subsequent thruster firings immediately prior to docking. The most probable cause for this condition is that the THC was not held for the required 160 ms required to assure that the thrusters fire.

Flight Software

The flight software performed satisfactorily throughout the mission with no in-flight anomalies identified during the data review and analysis.

Displays and Controls Subsystem

The displays and controls subsystem performed nominally and no in-flight anomalies were identified from the data. However, two minor problems were identified and these are discussed in the following paragraphs.

The crew reported on flight day (FD) 1 that the system management (SM) alert-light on panel F7 was not fully illuminated. The crew further stated that at full brightness, the SM alert light remained dim. The crew stated that the light was acceptable as-is and no further action was required on orbit. KSC will perform troubleshooting to determine the cause of the problem.

Shortly after the undocking from the ISS while working the nominal water configuration, the crew reported that the talkback indication on the supply water crossover valve switch

stayed barberpole (should be closed) when the crew tried to open the valve. This condition was indicative of the circuit breaker not transferring power. The crew pushed in on the closed circuit breaker, which caused the talkback indicator to go to the closed position; however, when the switch was cycled to open, the talkback indicator again went to barberpole. Another cycle of the circuit breaker to open and then closed resulted in the talkback being midway between barberpole and open and closed when it should have been closed. One crewmember that pushed the circuit breaker while another crewmember operated the switch. The operation opened the valve and the talkback indicated open. With the valve in the correct position, the crew opened the circuit breaker. The circuit breaker and the supply water crossover valve remained open for the remainder of the mission and this condition did not impact the successful completion of the mission.

Communications and Tracking Subsystem

The communications and tracking subsystem performed nominally in support of the mission. No in-flight anomalies were noted in the data; however, a problem arose concerning the intercommunications system, which is discussed in the following paragraph. One other problem concerning the hand-held microphone failures is discussed the Government Furnished Equipment/Flight Crew Equipment section of this report.

Following docking, the crew reported problems with the communications system. The ISS crew could not hear the ground on the air-to-ground (A/G) 1 loop or the Orbiter crew on the intercommunications (ICOM) A loop. The Orbiter crew could hear the ground on A/G 1 and the ISS crew on ICOM A. After a period of time, the ISS crew was able to hear the ground on A/G 1; however, the failure persisted on ICOM A. It is believed that A/G 1 was recovered by a power cycle of the docking audio interface unit (DAIU) on the ISS. Troubleshooting was performed in an attempt to recover ICOM A but was unsuccessful. This troubleshooting included using multiple audio terminal units (ATUs), multiple handheld microphones (HHMs) and both audio central control units (ACCUs), as well as additional power cycles of the DAIU. There were acceptable workarounds so there was no mission impact from this condition.

During the mission, four time-frames of Tracking and Data Relay Satellite (TDRS) events were affected by data hits on the return link. The data hits in two of the time-frames were related to geographical and environmental effects. The data hits in the two other cases have been attributed to satellite/network issues. Mission data analysis does not support there being any problem involving Orbiter hardware and all of the evaluators agree with that conclusion.

Operational Instrumentation/Modular Auxiliary Data System

The operational instrumentation (OI) subsystem performed satisfactorily throughout the STS-112 mission. No in-flight anomalies were identified during the review and analysis of the data. The modular auxiliary data system (MADS) had a significant problem in that no data were recorded during entry. A discussion of this problem is contained in the following paragraph.

The MADS recorder appeared to perform nominally during ascent. Further analysis of the MADS anomaly showed that the recorder operated nominally during ascent. However, when the tape was being repositioned follow ascent for the recording of entry data, an anomalous signature was observed. When the MADS recorder was

commanded to stop recording at the 30-percent tape mark, a command to rewind the tape to the beginning of tape (BOT) was issued. The recorder responded nominally until at the 3.9-percent tape mark, where the recorder stopped and the sequence 2 telemetry indication was displayed. The tape should have stopped even though the indication was 3.9 percent. KSC engineering reported that this reading can be up to 5-percent and be at the BOT window. The recorder BITE indication remained good; and the sequence-2 telemetry indication should not have been displayed at that time. The recorder built-in test equipment (BITE) indication remained good throughout this entire operation. Troubleshooting was performed to determine the condition of the recorder. It consisted of power resets and commands for the recorder to record, each of which was unsuccessful. The MADS recorder did not record data during entry and landing. The postflight investigation determined the cause of the problem to be that the tape came off of the reel of the recorder.

This recorder had a total of 17 flights on three Orbiter vehicles and the records show that the last time the recorder was serviced was 1994. The contractor reported that this recorder was sent in for a repair of a faulty tape sensor. Troubleshooting by the contractor did not isolate the anomaly; consequently adjustments were made and the recorder was returned to inventory.

Structures and Mechanical Subsystems

The structures and mechanical subsystems performed nominally throughout the mission. No in-flight anomalies or significant problems were identified during the review and analysis of the data. The landing parameters are shown in the following table

LANDING PARAMETERS

Parameter	From Threshold, ft	Speed, Keas	Sink rate, ft/sec	Pitch rate, deg/sec
Main gear touchdown	3169.7	186.2	-3.09	N/A
Nose gear touchdown	5476.4	160.2	N/A	-5.32
Brake initiation speed		87.0 keas		
Brake-on time		22.81 seconds		
Rollout distance		8294.0 feet		
Rollout time		52.21 seconds		
Runway		33 (Concrete) KSC		
Orbiter weight at landing		202709.1 lb		
Brake sensor Location	Peak Pressure, Psia	Brake assembly		Gross energy, million ft-lb
Left-hand inboard 1	1031.4	Left-hand inboard		11.31
Left-hand inboard 3	1031.4			
Left-hand outboard 2	887.0	Left-hand outboard		9.13
Left-hand outboard 4	887.0			
Right-hand inboard 1	1043.7	Right-hand inboard		13.01
Right-hand inboard 3	1043.7			
Right-hand outboard 2	994.2	Right-hand outboard		15.45
Right-hand outboard 4	994.2			

The payload bay doors were opened as planned at 280:21:23:09 G.m.t. (00:01:37:18 MET). All voltages were nominal and the motors opened the doors in nominal dual-motor time.

When stowing the emergency egress net (trampoline) the crew reported a problem with the release mechanism. This net was stretched across the opening in the middeck aft wall, where the internal airlock used to be, and provided the crew with a surface to stand on in the event of a pad emergency egress, as well as during normal ingress. This problem is discussed in more detail in the Government Furnished Equipment/Flight Crew Equipment section of this report.

The payload bay doors (PLBDs) were closed and latched for the first KSC landing opportunity on the nominal end-of-mission landing day at 291:15:05:45 G.m.t. (10:16:19:54 MET). All payload bay door close and latch operations occurred in dual motor time.

Thermal Control Subsystem

The thermal control subsystem performed satisfactorily throughout the STS-112 mission and no temperature violations to the vehicle or vehicle subsystems were noted. Some minor problems were identified from the data and these are discussed in the following paragraphs.

The fuel-cell water-relief-nozzle secondary controller failed on prior to liftoff. While still on the pad, this condition resulted in a nozzle temperature near 270 °F. An over-temperature controller inhibits the heater when the temperature rises above 270 °F. After achieving the on-orbit phase of the mission, the nozzle temperature was maintained above 270 °F by the Orbiter attitude and increasing beta angle (putting solar flux on the starboard side of the vehicle). This prevented the over-temperature controller from controlling (inhibiting the heater) for the remainder of the mission.

The androgynous peripheral attachment system (APAS) capture-latch temperatures were 13 °F cooler than the coldest start-up temperatures previously seen on this vehicle. The colder temperatures were caused by the APAS shading the forward bulkhead during rendezvous. This condition was confirmed from ISS photographs taken during rendezvous. The operational lower limit of the capture latches (-22 °F) was not violated during this time.

The F3F thruster heater system failed 'ON' during the ISS fly-around maneuver. An evaluation showed that the temperature would remain below the 182 °F non-operational limit. The one planned pulse that was to be performed during the RCS hot-fire was deleted to ensure that the non-operational limit was enforced for this thruster. The failed 'ON' heater did not exceed the operational limit of 157 °F during the remainder of the mission. It reached a steady-state condition of 151 °F in the -ZLV -XVV attitude.

A concern existed about the steady warming of the starboard forward RCS, which began after the general heater reconfiguration. The condition was evaluated. The warming effect, coincidental with the reconfiguration, was caused by the -ZLV -XVV attitude and a beta angle (-34° to -44°) which put sun on the STBD side of the vehicle. The warming effect is not unusual by itself, however the coincidence with the general heater reconfiguration made the phenomenon appear to be of significance.

A partially detached blanket was discovered on the ODS. The blanket does not appear to have been installed in accordance with the print. The closeout photographs of this blanket made while the vehicle was at the pad supported this conclusion. The depressurization vents are underneath the blanket. In addition, the blanket appears to have been installed upside out with the outer mold line (OML) and inner mold line (IML) of the blanket reversed. This could be attributed to the fact that this serial number blanket now has both outer covers made of beta cloth. It is suspected that the blanket became detached when the vestibule was depressurized for undocking. The subsequent attitudes environments, as determined from the vehicle longerons, were not such that a temperature violation would have occurred.

Aerothermodynamics

Wing structural thermocouple temperature data did not indicate an asymmetric transition; however, aileron deflection data, and yaw thruster firings indicated that asymmetric drag occurred on the left wing around Mach 10.3. The time of transition from laminar to turbulent flow requires MADS recording of the surface temperature data; however, the MADS recorder did not operate during entry.

The acreage maximum structural heating data was within the range expected for this type of mission and within the flight history of this vehicle. The temperature rise data on the starboard aft fuselage side was the highest temperature rise recorded on the OV-104 vehicle

Local heating was also normal. Coating degradation was noted on the right-hand radial carbon carbon (RCC) panel 16. However, the preliminary evaluation does not indicate abnormal entry heating as the cause.

Thermal Protection Subsystem and Windows

The thermal protection subsystem (TPS) performed satisfactorily. The postlanding inspection of the Orbiter TPS identified a total of 79 damage sites of which 26 had a major dimension of 1-inch or larger. This total does not include the numerous damage sites on the base heat shield that are attributed to SSME vibration/acoustics, exhaust plume recirculation and the flame-arrestment sparkler system. The distribution of these impacts on the vehicle is shown in the following table.

TPS DAMAGE SITES

Orbiter Surfaces	Hits > 1 Inch	Total Hits
Lower Surface	21	47
Upper Surface	1	6
Window Area	3	19
Right Side	0	4
Left Side	1	3
Right OMS Pod	0	0
Left OMS Pod	0	0
Total	26	79

The Orbiter lower surface sustained 47 damage sites of which 21 had a major dimension of 1-inch or larger. A total of 19 damage sites occurred on the lower surface between the nose landing gear and the main landing gear doors. Eight of these lower surface

damage sites had a major dimension of one inch or greater. Nine of the 19 damage sites between the landing gear doors occurred on the right-hand wing glove.

The largest damage site on the lower surface measured 3 inches by ½ inch by 3/8 inch, and was located to the left of the centerline between the main landing gear wheel wells. The second largest hit on the lower surface measured 3 inches by ¼ inch by 3/8 inch and was located aft of the nose landing gear door at approximately the same position to the left of the centerline. Both of these damage sites had relatively large length to width ratios. The similarity of the locations of the two hits and the large length-to width ratios suggests that the damage sites were caused by the same source.

A total of 14 damage sites on the lower surface were located in the vicinity of the LH₂ umbilical door. Most of these damage sites were caused by pieces of the umbilical purge barrier flailing in the airstream and impacting the TPS tiles before detaching.

A triangular-shaped tile corner (measuring 2 ½ inches by 2 ½ inches) was missing. The location of the missing tile piece was on the inboard end of the right-hand inboard elevon, approximately one-third of the elevon chord length downstream of the leading edge.

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

COMPARISON OF LOWER SURFACE DAMAGE SITE DATA FROM LAST TEN FLIGHTS

Parameter	STS -97	STS -98	STS -102	STS -100	STS -104	STS -105	STS -108	STS -109	STS -110	STS -111
Lower surface, total hits	78	73	44	42	108	144	95	63	70	47
Lower surface, hits > 1 in.	10	8	10	4	4	25	22	14	18	21
Longest damage site, in.	3.0	3.0	1.0	2.5	4.5	5	8.0	3.5	3.5	3.0
Deepest damage site, in.	0.5	0.5	0.12	0.12	0.25	0.06	0.37	0.12	0.62	0.50

A total of 19 damage sites, with 3 having one dimension greater than one inch, were identified on the window perimeter tiles. The largest damage site in the window area was above window 3 and had dimensions of 2 inches long by 2 inches by 1/8 inch deep. Damage to the window perimeter tiles on the forward-facing windows is attributed to impacts made by the forward RCS paper covers with room temperature vulcanizing (RTV) material adhesive on the back. The hazing and streaking was moderate on forward-facing windows 2, 3, 4 and 5. In addition to hazing, streaks were observed on windows 3 and 4. These streaks may also be the result of impacts by RTV adhesive used on the forward RCS paper covers.

There was less than usual tile damage on the Orbiter base heat shield. The SSME dome heat shield closeout blankets were in good overall condition. Slight fraying was observed on the SSME 1 blanket at the 6 o'clock position. Two large damage sites (approximately 3 inches by 3 inches) were located on the body flap upper surface tiles adjacent to the body flap stub. These two sites appeared to be failed repair sites.

In summary, both the total number of Orbiter TPS damage sites and the number of sites that were 1-inch or larger were well within the established family. The potential identification of debris damage sources for this mission will be based on laboratory analysis of the Orbiter postlanding microchemical samples, inspection of the recovered SRB components, film analysis and aerodynamic debris particle trajectory analysis. The results will be published in the STS-112 Debris/Ice/TPS Assessment and Integrated Photographic Analysis report.

Gas Sample Analysis

The analysis of the gas samples contained in the six bottles showed the samples to be acceptable and within the nominal range for percentage of hydrogen. Constituents present in each bottle greater than 0.1 percent were determined. Back-pressure calculations of actual pressure assumed all bottles were a total volume of 250 cc.

The analysis was performed using an AeroVac Mass Spectrometer with a 0 to 1000 Torr capacitance manometer. The backup analysis was accomplished using a Finnegan 9001 Gas Chromatograph with Discharge Ionization Detection (DID). A backup analysis was made of all constituents with the exception of Helium.

Computations to determine the amount of hydrogen contributed by the pyrotechnic used to open and close the sampling bottle assumed that the composition would match that of experimental values obtained under controlled conditions. They indicated that the ratio of hydrogen to carbon monoxide is 0.54. Corrected hydrogen, therefore, is the value of carbon monoxide multiplied by 0.54 and that solution subtracted from the hydrogen detected.

The table showing the data measured from the bottles is presented in the Shuttle Flight Data and In-Flight Anomaly List (JSC 19413). This document may be accessed on the Space Shuttle Vehicle Engineering Office home page under the MER heading.

EXTRAVEHICULAR ACTIVITY

The crew performed three extravehicular activities (EVAs) successfully with all planned tasks completed. The total EVA time was 19 hours 41 minutes for a total man-hours EVA of 39 hours 22 minutes.

FIRST EXTRAVEHICULAR ACTIVITY

The first EVA was successfully completed with a total EVA time of 7 hours and 1 minute. The EVA, which was conducted from the International Space Station (ISS) airlock, was officially started when the extravehicular mobility units (EMUs) were placed on internal battery power at 283:15:21 G.m.t. (02:19:35 MET). During the EVA, the major tasks completed by the crew were the mating the Zenith tray utilities; release of the radiator beam launch locks; deployment of the S-band antenna; release of the crew EVA translation aid (CETA) cart launch locks and coupling to mobile transporter (MT); installation of S1 nadir external television camera group (ETVCG); mating of the Nadir tray; and release of the thermal radiator rotary joint (TRRJ) drive-lock assembly (DLA) launch locks. The last hour of the EVA was completed without the use of the Space Station remote manipulator system (SSRMS), but the SSRMS was back on line to support the second EVA. The EVA concluded when repressurization of the airlock was initiated at 283:22:22 G.m.t. (03:02:36 MET).

Early during the first EVA, an "all stop" was called to the crew when the SSRMS elbow joint came close to the Orbiter's starboard payload bay door. Initial calculations indicated that the clearance was approximately 2 feet. However, updated calculations by the operations team indicated that the clearance was possibly less than 2 inches. Video during the event shows the elbow being close to the forward outboard corner of the door, but the video was inconclusive as to whether or not there was contact. However, there was no apparent motion of the door during the event and the SSRMS current data does not indicate that a resistance was encountered. Also, the crew stated that they do not believe that there was contact. This data in addition to video of the door after the event, which appears nominal, indicate that there was no contact.

SECOND EXTRAVEHICULAR ACTIVITY

The second EVA was successfully completed with a total EVA time of 6 hours and 4 minutes. The EVA was conducted from the ISS airlock and officially started when the EMUs were placed on internal battery power at 285:14:30 G.m.t. (04:18:44 MET). The EVA was very successful in that all tasks but one were completed. In addition, two get-ahead tasks were also completed. The crew installed 22 SPDs; connected ammonia tank assembly umbilicals; installed the ETVCG on the U. S. Laboratory Module; performed RTL test; removed radiator beam launch locks; installed S1/S3 line clamps; relocated articulating portable foot restraint (APFR) on CETA cart; and installed S1 TRRJ stinger bolts. The crew could not install the photovoltaic radiator (PVR) spool positioning devices (SPDs) on two quick disconnects (12 and 13) on the P6 truss. This problem was evaluated by the ISS Program and determined to not be a problem for this mission. The EVA concluded when repressurization of the airlock was initiated at 285:20:34 G.m.t. (05:00:48 MET).

During the second EVA, the biomedical electrocardiogram (ECG) signal for the EV2 crewmember was lost. Prior to the signal loss, a good ECG signal was received from the

EV2 crewmember. This condition resulted in the loss of biomedical data during the remainder of the second EVA. This condition did not impact the EVA as there is no requirement to terminate an EVA as a result of the loss of ECG data.

THIRD EXTRAVEHICULAR ACTIVITY

During final preparations for the third EVA, the crew reported that the wrist tether point of the EV (extravehicular) 1 crewmember right-hand glove was torn and had come apart on one end. The crew verified that the glove bladder was not damaged and the EVA preparations continued. Postflight evaluation of the glove condition will be performed in an attempt to determine the cause of the tear.

The total EVA time was 6 hours and 36 minutes for the third EVA. The EVA was conducted from the ISS airlock and officially started when the EMUs were placed on internal battery power at 287:14:11 G.m.t. (06:18:25 MET). The EVA was very successful in that all tasks plus one get-ahead task were completed. The crew tasks completed were retracting the inertial unit assembly (IUA) safing bolt as IUA removal and replacement was not required; connected S1/S0 fluid jumper; removed port and starboard keel pin and drag link; installed TRRJ SPDs (get-ahead task); reconfigured Space Flyer Unit (SFU); installed flexible hose rotary coupler (FHRC) bolts; installed pressurized mating adapter (PMA) SPDs; installed APFR on CETA cart; and installed FHRC SPDs). The EVA concluded when repressurization of the airlock was initiated at 287:20:47 G.m.t. (07:01:01 MET).

REMOTE MANIPULATOR SYSTEM

The Shuttle remote manipulator system (RMS) performed satisfactorily on this sixty-eighth flight of the RMS. No in-flight anomalies or problems were noted during the mission. The RMS provided viewing support during the installation of the S1 truss.

The RMS was powered up for the checkout and the payload bay survey. The checkout was successfully completed and the arm was moved to the pre-cradle position where it remained through flight day (FD) 4. On FD 3, the Orbiter docked with the ISS with the RMS in the pre-cradle position. This was the first flight where docking took place with the ISS while the RMS was out of the cradle position. One other instance of docking with the RMS uncradled occurred on STS-74 in a docking with the MIR Russian Space Station. Minimal changes in RMS joint angles with no brake slippage were noted during the docking operation.

The RMS was powered to support the unberthing of the S1 truss. The Shuttle RMS provided video coverage of the unberthing, which was performed by the Space Station remote manipulator system (SSRMS) at 283:10:42:36 G.m.t. (02:14:56:45 MET). Following the unberthing, the truss was moved to the installation location on the ISS.

The attachment of the S1 truss onto the ISS S0 truss was performed using the SSRMS. The Shuttle RMS operated as a camera platform and provided video coverage. The RMS performed nominally during the S1 attachment and the first EVA. Following the EVA, the RMS was cradled, latched and powered down at 283:23:09 G.m.t. (03:03:23 MET).

Early during the first extravehicular activity (EVA), an "all stop" was called to the crew when the SSRMS elbow joint came close to the Orbiter's starboard payload bay door. Initial calculations indicated that the clearance was approximately 2 feet. However, updated calculations by the operations team indicated that the clearance was possibly less than 2 inches. Video during the event shows the elbow being close to the forward outboard corner of the door, but the video is inconclusive as to whether or not there was contact. However, there was no apparent motion of the door during the event and the SSRMS current data does not indicate that a resistance was encountered. Also, the crew stated that they do not believe that there was contact. This data in addition to video of the door after the event, which appears nominal, indicate that there was no contact.

GOVERNMENT FURNISHED EQUIPMENT/FLIGHT CREW EQUIPMENT

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

When stowing the emergency egress net (trampoline), the crew reported a problem with the release mechanism. This net was stretched across the opening in the middeck aft wall, where the internal airlock used to be, and provided the crew with a surface to stand on in the event of a pad emergency egress, as well as during normal ingress. The net was only in place through ascent and once on-orbit, it was stowed and not used again for the remainder of the mission. The net was tensioned during installation on the ground and this tension was maintained through the use of two ratcheting mechanisms (the release mechanisms). When the crew stowed the net on-orbit, the ratchets are released by turning a knob on each mechanism. The crew was able to release the tension and stow the net. However, they reported that the knob had come off one of the mechanisms. The crew reported that the knob was rotated in the wrong direction because of the extreme tension on the net. The crew also reported that the tension on the net was very high. The crew has stowed the loose parts (knob, bolt, washer) in the lost and found bag. Because there was the possibility for additional failed parts remaining inside of the mechanism that could come out and float into the cabin, the crew taped over the hole in the mechanism where the knob was attached.

The trajectory control sensor (TCS) was initialized for rendezvous tools checkout at 281:21:14 G.m.t. (01:01:28 MET). The TCS performed nominally during the checkout.

After docking, the crew reported problems with two HHMs during setup of the on-orbit audio system. The crew tried the HHMs on the middeck ATU and both did not work. The crew then tried the same two HHMs on one of the airlock ATUs and again the HHMs did not work. A third HHM was obtained from spares and worked fine. Four HHMs were manifested for STS-112. The on-board sparing was adequate to support the mission so there was no mission impact. The crew was asked to tag the problem HHMs. The STS-112 units will be tested upon return to determine the cause of the problem.

The crew experienced a number of problems while trying to access the rendezvous proximity operators program (RPOP) payload and general support computer (PGSC) from the onboard PGSC network. The RPOP PGSC is used as the backup laptop running the RPOP application during rendezvous and undocking as well as running the wireless video system software during the extravehicular activities (EVAs). The problems were noted on flight day (FD) 3, 4, 5, 7, and 9. The problem was isolated to the hard drive in the RPOP PGSC. The hard drive was replaced on FD 9 and the PGSC was successfully returned to the network.

POSTLAUNCH PAD INSPECTION

The postlaunch inspection of the mobile launch platform (MLP) -3, Launch Pad B flight service structure (FSS), rotating service structure (RSS) and flame trench were conducted from Launch + 1.5 to 6.25 hours. No flight hardware was found.

Orbiter lift-off lateral acceleration data used to predict stud hang-ups that was received from the Orbiter contractor showed 0.15g. Inspection was performed and the south holddown studs were visually assessed as having no indication of hang-up. Erosion was typical on both the north and south posts. The north holddown post blast covers and the T-0 umbilical exhibited minimal exhaust plume damage. Both SRB aft-skirt GN₂ purge lines were intact and erect; however, the protective tape layering was partially eroded and exhibited fraying on the right-hand side.

The postlaunch data review determined that none of the system-A NASA Standard Initiators (NSIs) for the SRB holddown posts received the Fire 1 command. The master events controller (MEC) provides the signals to fire those NSIs so the MEC is suspect as well as all of the wiring between the MEC in the Orbiter and the pyrotechnic initiator controller (PIC) rack on the ground. The data indicated that the PICs were properly armed but then had a gradual bleed-off of voltage, which is indicative of no firing. Recovery and disassembly of the SRBs revealed 8 NSIs associated with the SRB holddown posts had not been fired. Also, one NSI for the release of the ET vent arm and one for the mobile launch platform tail service mast did not fire. The MEC was not used for the remainder of the mission so there was no mission impact.

The inspection of the Mobile Launch Platform and copper-path testing (T-0 umbilical through the PIC rack have been completed and no anomalies were noted with the exception of corrosion on the ground support equipment (GSE) T-0 umbilical connector pins. The affected PIC commands (arm, fire 1 and fire 2) from the MEC to the GSE PIC rack are through single wires. An STS-112 post-landing troubleshooting plan has been developed to inspect the Orbiter (OV-104) potential causes (MEC 1, vehicle copper paths and the T-0 connector). These tests at the time of this writing have shown nominal performance. The runway inspections and resistance checks were also nominal. The MEC 1 commands to the T-0 umbilical connector J61 were nominal. The signal path pin-pull tests and the harness flex test were successful while issuing MEC commands.

The LO₂ and LH₂ tail service masts (TSMs) appeared undamaged with both bonnets closed properly. The MLP deck was generally in good shape.

The GH₂ vent line latched on the fifth of eight teeth on the latching mechanism. The vent line was centered in the latching mechanism. The ground umbilical carrier plate (GUCP) 7-inch quick-disconnect (QD) probe appeared to be undamaged. The deceleration cable was in its nominal configuration, and the vent-line blanket was sooted.

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

The gaseous oxygen (GO₂) vent arm, ducts and structure appeared to be in nominal shape with no evidence of plume damage. The GO₂ vent seals were inspected and found to be in good shape with no indication of ET paint residue present. Mastic was chipped/missing from two locations on the upper surface of the GO₂ vent hood.

Debris findings included:

- A. An "Evacuation Route" sign was found laying on the 115-foot level Orbiter Weather Protection structure and it was determined that the sign was from the 125-foot level**
- B. An "Evacuation Route" sign on the 95-foot level was loose and wrapped around the banister;**
- C. SRB plug material was found on the south flame trench apron;**
- D. Significant erosion was noted on the north flame trench deflector and it was attributed to the left and right SRBs. Additionally, the fence was damaged with debris at the base of the fence; and**
- E. Loose bolts were found on the sound suppression pipes the southwest corner attachment points.**

Overall damage to the pad appeared to be normal.

DEVELOPMENT TEST OBJECTIVES/DETAILED SUPPLEMENTARY OBJECTIVES

DEVELOPMENT TEST OBJECTIVES

DTO 264 Space Station RMS Dynamic Validation During Shuttle and ISS Mated Flight - This detailed test objective (DTO) was performed during the installation of the S1 truss. No further activities were planned. Results of the data evaluation from this DTO will be reported in separate documentation.

DTO 700-14 Single String Global Positioning System - The miniature air to ground receiver (MAGR) Development Test Objective (DTO) for STS-112 was successfully completed. Engineering data were recorded onto the MAGR payload and general support computer (PGSC) for the entire planned time during the mission. The crew reported the daily MAGR status each day to assure ground personnel of proper data recording. During the final crew activity with the PGSC, the crew configured the MAGR PGSC for entry and stowed the computer in a modified middeck locker. The MAGR PGSC was programmed to record data during entry and landing and it performed nominally.

The MAGR receiver performed nominally most of the mission. An anomaly did occur on flight day (FD) 4 that had been previously documented in a program-approved Flight Software Waiver/Operations Note. The effect of this anomaly was a slightly degraded, but not out-of-tolerance receiver performance. A second anomaly that was also documented in a program-approved Flight Software Waiver/Operations Note appears to have occurred on FD6. This anomaly caused eventual loss of the MAGR function, but the conditions was corrected by performing the procedures documented in the Operations Notes. It is anticipated that the recorded MAGR PGSC data will confirm this second anomaly.

DTO 805 Crosswind Landing Performance (DTO of Opportunity) - Data were received on the heads-up-display tape and the slip angle indicated significant crosswinds gusting on final approach up to 15 knots, but not during the period just before touchdown and from touchdown through derotation. Final reconstruction of the data will determine if significant additional information were obtained on lateral directional handling qualities at landing.

DETAILED SUPPLEMENTARY OBJECTIVES

DSO 490B Bioavailability and Performance Effects on Promethazine During Space Flight - In-flight activities were accomplished as planned. The results of the postflight analysis will be reported in separate documentation.

DSO 493 Monitoring Latent Virus Reactivation & Shedding - In-flight activities were accomplished as planned; results will be reported after post flight analysis is complete.

DSO 498 Space Flight and Immune Function - Tests were performed with the crew preflight and postflight. The results for this process will be reported in separate documentation.

DSO 499 Eye Movements and Motion Perception Induced by Off-Vertical Axis Rotation (OVAR) - Tests were performed with the crew preflight and postflight. The results for this process will be reported in separate documentation.

DSO 501 Effects of Short-Duration Space Flight on Type 1/Type 2 Cytokine Balance and Its Endocrine Regulation - Tests were performed with the crew preflight and postflight. The results for this process will be reported in separate documentation.

DSO 503-S Test of Midodrine as a Countermeasure Against Postflight Orthostatic Hypotension - Tests were performed with the crew preflight and postflight. The results for this process will be reported in separate documentation.

DSO 634 Sleep/Wake Actigraphy and Light Exposure During Space Flight - In-flight activities were accomplished as planned; results will be reported after postflight analysis is completed.

DSO 635 Spatial Reorientation Following Space Flight - Tests were performed with the crew preflight and postflight. The results for this process will be reported in separate documentation.

PHOTOGRAPHY AND TELEVISION ANALYSIS

The launch videos and films were reviewed and evaluated following the STS-112 launch and no anomalous events or conditions were noted.

In addition, films from the new 35mm umbilical well camera, the 16mm umbilical camera as well as the hand-held 35mm cameras onboard the Orbiter provided good coverage of the ascent and ET after separation. No anomalous conditions were noted. However, in the 35mm hand-held photography of the ET, the ET was back-lighted by the Sun and analysis of the ET was not possible from that film.

No anomalous events were noted in the review of the landing videos. All aspects of the landing appeared to be normal.

TABLE 1. - STS-112 SEQUENCE OF EVENTS

EVENT	DESCRIPTION	ACTUAL
APU Activation	APU-1 GG chamber pressure APU-2 GG chamber pressure APU-3 GG chamber pressure	280:19:41:03.769 280:19:41:06.825 280:19:41:09.357
*SRB HPU Activation	LH HPU System A start command LH HPU System B start command RH HPU System A start command RH HPU System B start command	280:19:45:22.968 280:19:45:23.128 280:19:45:23.288 280:19:45:23.448
*Main Propulsion System Start	ME-3 Start command accepted ME-2 Start command accepted ME-1 Start command accepted	280:19:45:44.471 280:19:45:44.587 280:19:45:44.694
*SRB Ignition Command (Liftoff)	SRB Ignition command	280:19:45:51.018
*Throttle to 104.5 Percent	ME-2 Command accepted ME-3 Command accepted ME-1 Command accepted	280:19:45:54.847 280:19:45:54.871 280:19:45:54.874
*Throttle to 97 Percent	ME-2 Command accepted ME-3 Command accepted ME-1 Command accepted	280:19:46:08.447 280:19:46:08.471 280:19:46:08.474
*Throttle to 72 Percent	ME-2 Command accepted ME-3 Command accepted ME-1 Command accepted	280:19:46:23.328 280:19:46:23.351 280:19:46:23.354
*Throttle to 104.5 Percent	ME-2 Command accepted ME-3 Command accepted ME-1 Command accepted	280:19:46:38.368 280:19:46:38.391 280:19:46:38.395
Maximum Dynamic Pressure	Derived ascent dynamic performance	280:19:46:51
*Both RSRMs Chamber Pressure at 50 psi	RH RSRM chamber pressure LH RSRM chamber pressure	280:19:47:48.298 280:19:47:48.338
*End RSRM Action Time	LH RSRM chamber pressure RH RSRM chamber pressure	280:19:47:50.928 280:19:47:51.398
*SRB Physical Separation	LH APU B turbine speed – LOS	280:19:47:52.698
SRB Separation Command	SRB separation command flag	280:19:47:53
OMS Assist Maneuver ignition	Left engine bi-prop valve position Right engine bi-prop valve position	280:19:48:02.9 280:19:48:03.0
OMS Assist Maneuver Cutoff	Left engine bi-prop valve position Right engine bi-prop valve position	280:19:49:18.5 280:19:49:18.5
*Throttle Down for 3g Acceleration	ME-1 Command accepted ME-2 Command accepted ME-3 Command accepted	280:19:53:15.485 280:19:53:15.496 280:19:53:15.515
3g Acceleration	Total load factor	280:19:54:07.4
*Throttle Down to 67 Percent for Cutoff	ME-1 Command accepted ME-2 Command accepted ME-3 Command accepted	280:19:54:08.926 280:19:54:08.937 280:19:54:08.955
*SSME Shutdown	ME-2 Command accepted ME-1 Command accepted ME-3 Command accepted	280:19:54:15.166 280:19:54:15.177 280:19:54:15.196
MECO	MECO Command Flag MECO Confirmed Flag	280:19:54:16 280:19:54:16
ET Separation	ET separation command flag	280:19:54:37
APU Deactivation	APU-2 GG chamber pressure APU-1 GG chamber pressure APU-3 GG chamber pressure	280:20:03:12.151 280:20:03:34.295 280:20:03:49.578

TABLE 1. - STS-112 SEQUENCE OF EVENTS

EVENT	DESCRIPTION	ACTUAL
OMS 1 Ignition	Left engine bi-prop valve position Right engine bi-prop valve position	Not Performed – direct insertion trajectory flown
OMS 1 Cutoff	Left Engine bi-prop valve position Right engine bi-prop valve position	
OMS 2 Ignition	Left Engine bi-prop valve position Right engine bi-prop valve position	280:20:24:31.3 280:20:24:31.4
OMS 2 Cutoff	Left Engine bi-prop valve position Right engine bi-prop valve position	280:20:25:34.5 280:20:25:34.7
Payload Bay Doors	Right payload bay door open 1 Left payload bay door open 1	280:21:21:52 280:21:23:12
OMS 3 Ignition	Left Engine bi-prop valve position Right engine bi-prop valve position	280:23:23:46.2 280:23:23:46.3
OMS 3 Cutoff	Left Engine bi-prop valve position Right engine bi-prop valve position	280:23:24:26.2 280:23:24:26.3
OMS 4 Ignition	Left Engine bi-prop valve position Right engine bi-prop valve position	N/A 281:20:00:34.0
OMS 4 Cutoff	Left Engine bi-prop valve position Right engine bi-prop valve position	N/A 281:20:00:52.2
OMS 5 Ignition	Left Engine bi-prop valve position Right engine bi-prop valve position	282:10:43:16.5 282:10:43:16.6
OMS 5 Cutoff	Left Engine bi-prop valve position Right engine bi-prop valve position	282:10:44:50.2 282:10:44:50.3
OMS 6 Ignition	Left Engine bi-prop valve position Right engine bi-prop valve position	282:11:31:26.6 282:11:31:26.7
OMS 6 Cutoff	Left Engine bi-prop valve position Right engine bi-prop valve position	282:11:31:50.1 282:11:31:50.2
OMS 7 Ignition	Left Engine bi-prop valve position Right engine bi-prop valve position	282:13:03:45.2 N/A
OMS 7 Cutoff	Left Engine bi-prop valve position Right engine bi-prop valve position	282:13:03:58.0 N/A
Docking Ring Capture	Capture	282:15:16:08
Docking with ISS	Docking ring final position	282:15:32:23
Begin First Extravehicular Activity	As reported	283:15:21
End First Extravehicular Activity	As reported	283:22:22
First Reboost Maneuver (1 hr)	As determined in the MER	285:10:52:48
Begin Second Extravehicular Activity	As reported	285:14:30
End Second Extravehicular Activity	As reported	285:20:34
Second Reboost Maneuver (35 min)	As reported	287:11:20:50
Begin Third Extravehicular Activity	As reported	287:14:11
End Third Extravehicular Activity	As reported	287:20:47
Undocking Completed	Undock Complete	289:13:13:21
Flight Control Subsystem Checkout		
APU 1 Start	APU-1 GG chamber pressure	290:12:31:37.710
APU 1 Stop	APU-1 GG chamber pressure	290:12:37:42:531
OMS 8 Ignition	Left Engine bi-prop valve position Right engine bi-prop valve position	290:20:26:51.2 290:20:26:51.3
OMS 8 Cutoff	Left Engine bi-prop valve position Right engine bi-prop valve position	290:20:27:42.1 290:20:27:42.2
Payload Bay Doors Closed	Left payload bay door closed Right payload bay door closed	291:12:01:52 291:12:04:50

TABLE 1. - STS-112 SEQUENCE OF EVENTS

EVENT	DESCRIPTION	ACTUAL
APU Activation	APU-2 GG chamber pressure APU-1 GG chamber pressure APU-3 GG chamber pressure	291:14:31:16.282 291:15:00:23.509 291:15:00:35.338
Deorbit Burn Ignition	Left Engine bi-prop valve position Right engine bi-prop valve position	291:14:36:14.3 291:14:36:14.3
Deorbit Burn Cutoff	Right Engine bi-prop valve position Left engine bi-prop valve position	291:14:38:27.1 291:14:38:27.2
Entry Interface	Current orbital altitude above ellipsoid	291:15:12:21
Blackout End	Data locked (High sample rate)	No blackout
TAEM	Major mode cold (305)	291:15:37:16
Main Landing Gear Contact	MLG Left-hand inboard tire pressure MLG right-hand inboard tire pressure	291:15:43:41 291:15:43:41
Main Landing Gear Weight on Wheels	MLG left-hand weight on wheels MLG right-hand weight on wheels	291:15:43:41 291:15:43:41
Nose Landing Gear Contact	NLG right-hand inboard tire pressure	291:15:43:48
Nose Landing Gear at Weight-on- Wheels	NLG weight-on-wheels	291:15:43:49
Drag Chute Deployment	Drag Chute Deployment	291:15:43:50.7
Drag chute jettison	Drag chute jettison	291:15:44:18.3
Wheel stop	Velocity with respect to runway	291:15:44:33.2
APU Deactivation	APU-1 GG chamber pressure APU-2 GG chamber pressure APU-3 GG chamber pressure	291:16:09:28.120 291:16:09:42.815 291:16:09:58.007

* MSFC Supplied data.

TABLE II- STS-112 SPACE SHUTTLE VEHICLE ENGINEERING OFFICE IN-FLIGHT ANOMALY LIST

No.	Title	Reference	Comments
STS-112-V-01	Primary Thruster L4D Failed Off	280 19:56 G.m.t. IPR 114-V-0005 SPR 112RF01	<p>Immediately prior to External Tank (ET) separation, the RCS primary thruster L4D failed off because of the low chamber pressure on its initial firing. The maximum pressure reached was 16 psia, which is indicative of the fuel valve main stage not opening. The remaining two down-firing thrusters performed nominally during the ET separation and the remainder of the mission. There was no mission impact and the thruster remained deselected for the remainder of the mission.</p> <p>KSC: The thruster will be removed and replaced during the postflight turnaround activities. This will include the removal and replacement of all thrusters on the L4 manifold.</p>

DOCUMENT SOURCES

In an attempt to define the official as well as the unofficial sources of data for the STS-112 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-112 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
ACCU	audio central control unit
A/G	air-to-ground
APAS	androgynous peripheral attachment system
APFR	articulated portable foot restraint
APU	auxiliary power unit
ARPCS	atmospheric revitalization pressure control system
ARS	atmospheric revitalization system
ATCS	active thermal control system
ATU	audio terminal unit
BITE	built in test equipment
BOT	beginning of tape
CBCS	computer-based control system
CDRA	carbon dioxide removal assembly
CE	cargo element
CEI	contract end item
CETA	crew and equipment translation aid
CGBA	Commercial Generic Bioprocessing Apparatus
CO ₂	carbon dioxide
CPM	cell performance monitor
CTB	cargo transfer bag
CWC	contingency water container
DAIU	docking module interface unit
DID	discharge ionization detection
DLA	drive lock assembly
DoD	Department of Defense
DSO	Detailed Supplementary Objective
DTO	Developmental Test Objective
ΔV	differential velocity
ECLSS	Environmental control life support system
e.d.t.	Eastern daylight time
EGT	exhaust gas temperature
EMU	extravehicular mobility unit
EPDC	electrical power distribution and control
ET	External Tank
ETVCG	external television camera group
EV	extravehicular (crewmember designation during EVA)
EVA	extravehicular activity
EVARM	extravehicular activity radiation monitoring
FBMBT	flexible bearing mean bulk temperature
FCE	flight crew equipment
FCV	flow control valve
FCP	fuel cell powerplant
FCS	flight control system/subsystem

FCV	flow control valve
FD	flight day
FDIR	fault detection isolation and recovery
FES	flash evaporator system
FHRC	flex hose rotary coupler
FSS	Fixed Service Structure
ft/sec	feet per second
GEI	ground environment instrumentation
GFE	Government furnished equipment
G.m.t.	Greenwich mean time
GH ₂	gaseous hydrogen
GN ₂	gaseous nitrogen
GO ₂	gaseous oxygen
GPC	general-purpose computer
GPS	Global Positioning System
GSE	ground support equipment
GUCP	ground umbilical carrier plate
HED	high-energy damper
HHM	hand-held microphone
ICD	Interface Control Document
IML	inner mold line
I _{sp}	specific impulse
ISS	International Space Station
ITCS	Internal thermal control system
ITS	Integrated Truss Segment
IVA	intravehicular activity
JSC	Johnson Space Center
keas	knots estimated air speed
kg	kilogram
KSC	Kennedy Space Center
kW	kilowatt
kWh	kilowatt/hour
lbm/hr	pound per hour
lbm	pound mass
LCC	Launch Commit Criteria
LH ₂	liquid hydrogen
LiOH	lithium hydroxide
LMSO	Lockheed Martin Space Operations
LO ₂	liquid oxygen
LP	Launch Package
MADS	modular auxiliary data system
MAGR	miniature air-to-ground receiver
Max q _a	maximum dynamic pressure
MBS	Mobile Base System
MC	midcourse correction (rendezvous maneuver)
MEC	master events controller
MECO	main engine cutoff
MET	mission elapsed time
MILA	Merritt Island Launch Area
MLI	multilayer insulation

MLP	Mobile Launch Platform
Mlbf	million pounds force
MPS	main propulsion system
MRS	Mobile Remote Services
Msec	millisecond
MSS	Mobile Servicing System
MT	Mobile Transporter
N ₂	nitrogen
NASA	National Aeronautics and Space Administration
NC1, NC2	circularization maneuvers (rendezvous maneuver)
NC3, NC4	circularization maneuvers (rendezvous maneuver)
NCC	rendezvous circularization maneuver
nmi	nautical mile
NSI	NASA Standard Initiator
O ₂	oxygen
OAA	Orbiter Access Arm
ODS	Orbiter Docking System
OFI	operational flight instrumentation
OI	operational instrumentation
OML	outer mold line
OMM	Orbiter Major Modification
OMRSD	Operations and Maintenance Requirements and Specifications Document
OMS	orbital maneuvering subsystem
ORCA	oxygen recharge compressor assembly
ORU	orbital replacement unit
OV	Orbiter Vehicle
P _c	chamber pressure
PCS	pressure control system/portable computer system
PGME	Propylene Glycol Monomethyl Ether
PGSC	payload and general support computer
PGT	pistol grip tool
PIC	pyrotechnic initiator cartridge
PLBD	payload bay door
PMA	pressurized mating adapter
PMBT	propellant mean bulk temperature
ppCO ₂	partial pressure carbon dioxide
ppm	parts per million
PRSD	power reactant storage and distribution/Prototype Synchrotron Radiation Detector
psia	pound per square inch absolute
psid	pound per square inch differential
psi/min	pound per square inch per minute
PVR	photovoltaic radiator
PWR	payload water reservoir
QD	quick disconnect
RAMBO	ram burn observations
RCC	radial carbon carbon
RCS	reaction control subsystem
RMS	Remote Manipulator System
RPOP	rendezvous proximity operators program

RSRM	Reusable Solid Rocket Motor
RSS	rotating service structure/range safety system
RTV	room temperature vulcanizing (material)
RWS	remote workstation
S&A	safe and arm
SASA	S-band antenna assembly
SFU	space flyer unit
SHIMMER	Spatial Hetrodyne Image for Mesospheric Radicals
SLWT	super lightweight tank
SM	systems management
S/N	serial number
SO	starboard zero (truss)
SPD	spool positioning device
SRB	Solid Rocket Booster
SRSS	Shuttle range safety system
SSME	Space Shuttle main engine
SSRMS	Space Station Remote Manipulator System
STS	Space Transportation System
SUPA	Shuttle Urine Pretreat Assembly
SWAR	Sea-water activated release
T-	Time minus minutes to launch
TCS	Trajectory control sensor
TDRS	Tracking and Data Relay Satellite
Ti	terminal initiation maneuver
TPS	thermal protection system/subsystem
TRRJ	thermal radiator rotary joint
TSM	tail service mast
TVIS	treadmill vibration isolation system
UF	Utilization Flight
Vdc	Volts direct current
VOX	voice operated
WCL	water coolant loop
WRJ	wrist roll joint
WSB	water spray boiler
ZCG	Zeolite Crystal Growth-Sample Stowage