

STS-104 SPACE SHUTTLE MISSION REPORT

September 2001



**National Aeronautics and
Space Administration**

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

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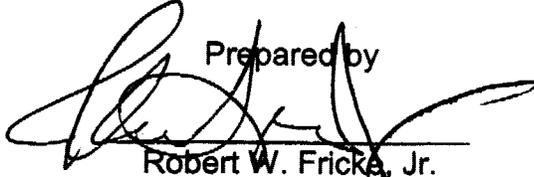
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STS-104

SPACE SHUTTLE

MISSION REPORT

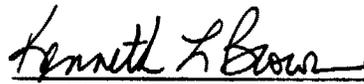
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INTRODUCTION

The Space Transportation System (STS)-104 Space Shuttle Program Mission Report presents a discussion of the Orbiter subsystem operation and the in-flight anomalies that were identified during the mission. The STS-104 flight was the tenth mission to the International Space Station (ISS), and it delivered the final major assembly, the Airlock and associated gas tanks, to complete the first phase of the construction of the ISS.

The STS-104 report summarizes the activities of the mission, as well as presenting a summary of the External Tank (ET), Solid Rocket Booster (SRB), Reusable Solid Rocket Motor (RSRM), and Space Shuttle main engine (SSME) performance during this one-hundred and fifth mission of the Space Shuttle Program. STS-104 was the eightieth mission since the return to flight, and the twenty-fourth flight of the OV-104 (Atlantis) vehicle. This flight delivered the Airlock and its oxygen and nitrogen gas tanks to the ISS.

The flight vehicle consisted of the OV (Orbiter vehicle) -104 Orbiter, an ET, which was the twelfth Super Lightweight Tank (SLWT), and it was designated ET-1098; two Block IIA SSMEs and one Block II SSME that were designated as S/Ns 2056, 2051, and 2047 in positions 1, 2, and 3, respectively; and two SRBs that were designated B1108. The two RSRMs were designated RSRM-80 with one installed in each SRB. The individual RSRMs serial numbers were 360L080A for the left SRB and 360L080B for the right SRB.

The primary objective of the STS-104 mission was to launch and install the U. S. Airlock and four high-pressure gas tanks on the orbiting ISS. The Airlock (A/L) is a pressurized flight element consisting of two cylindrical chambers attached end-to-end by a connecting bulkhead and hatch. The A/L became the primary path for extravehicular activity (EVA) egress and ingress from the ISS for both the U. S. extravehicular mobility unit (EMU) and the Russian Orlan space suits. The Airlock is the stowage area for EMU hardware as well as a staging area for crewmembers preparing to go EVA. A combination of the Russian depressurization pump, which is Government furnished equipment (GFE), and pressure equalization valves located within the hatches accommodate the depressurization/pressurization capability of the Airlock. The addition of the Airlock permits ISS-based EVAs to be performed without loss of environmental consumables.

In addition to the Airlock, this flight also launched four high-pressure gas tanks. Two oxygen and two nitrogen high-pressure gas tanks were mounted on a double Spacelab pallet (SLP) for launch and on-orbit were mated to the Airlock by extravehicular robotics (EVR) and EVA operations.

The secondary objective of the STS-104 mission was to perform IMAX Cargo Bay Camera-3 Dimension (ICBC-3D) operations in conjunction with ISS activities.

The STS-104 flight was planned as a 11 day plus 1 day, plus 2-contingency-day flight, of which six days were planned to be spent docked to the ISS. The capability for an additional day was provided for one fully operational backup day for an unscheduled EVA (an additional docked day) or a flight day 4 rendezvous, which protected an any-day launch capability. The two contingency days were available for weather avoidance for landing or other Orbiter contingency operations. The sequence of mission events is shown in Table I, and the Orbiter In-Flight Anomaly List is shown in Table II.

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

The five-person crew of the STS-104 flight consisted of Steven W. Lindsey, Lt Col., U. S. Air Force, Commander; Charles O. Hobaugh, Capt., U. S. Marine Corps, Pilot; Michael L. Gernhardt, Ph. D. Civilian, Mission Specialist 1; Janet L. Kalvandi, Ph. D., Civilian, Mission Specialist 2; and James F. Reilly, Ph. D., Civilian, Mission Specialist 3.

STS-104 was the fourth space flight for Mission Specialist 1, the third space flight for the Commander and Mission Specialist 2, the second space flight for the Mission Specialist 3, and the first space flight for the Pilot.

MISSION SUMMARY

The STS-104 mission was successfully launched at 193:09:03:58.991 G.m.t. (4:04 a.m. e.d.t. on July 12, 2001) following a flawless countdown with no anomalies or unscheduled holds. All Orbiter subsystems performed satisfactorily during ascent. The STS-104 mission was the tenth U. S. mission to the International Space Station (ISS), during which the Airlock and four high-pressure gas tanks as well as additional supplies and experiments were delivered to the ISS.

A review of main propulsion system (MPS) ascent data revealed that the Space Shuttle main engine (SSME) -2 liquid hydrogen (LH₂) inlet pressure after main engine cutoff (MECO) was higher than normal. Following MECO, the LH₂ pre valves close, and nominally the three SSME inlet pressures rise to between 60 and 65 psia before the pre valve relief valves open and relieve the pressure. Also, the LH₂ manifold pressure typically comes up to just under 35 psia and then is relieved through the return-to-launch-site (RTL) dump valves. During this mission, the SSME-2 LH₂ inlet pressure rose to 78 psia before falling off and following the other two engine-pressure readings. Also, with this extra rise in the SSME-2 inlet pressure, the LH₂ manifold pressure rose to 43 psia before the RTL dump valves were opened. This performance has been attributed to extra heat being transferred into the system by the Block II SSME. This was the first flight of a Block II SSME, and the extra heat that was put into the system by the engine is being investigated.

The evaluation of vehicle propulsion performance during ascent was made using vehicle acceleration and preflight propulsion prediction data. The average flight-derived engine specific impulse (I_{sp}) was 452.9 seconds as compared to an SSME tag value of 451.89 seconds at the 104.5 percent power level.

The orbital maneuvering subsystem (OMS) 2 maneuver was performed at 193:09:42:31.616 G.m.t. (00:00:38:32.625 MET) and was 64.0 seconds in duration. The differential velocity (ΔV) was 96.8 ft/sec, and the orbit was 85.1 by 127.0 nautical miles (nmi.) following the maneuver. The OMS performed satisfactorily throughout the maneuver.

The payload bay doors were opened at 193:10:45:12 G.m.t. (00:01:41:13 MET). All voltages were nominal and the motors opened the doors in nominal dual-motor time.

At 193:10:47 G.m.t. (00:01:43 MET), the crew reported that a hand-held microphone (HHM) was "cutting in and out" resulting in unreliable voice communications. The crew confirmed that the switch configuration was correct. The HHM was changed out with a spare and the failed HHM was tagged and stowed.

During the extravehicular mobility unit (EMU) checkout, when the crew began removing the lithium hydroxide (LiOH) canister from EMU 3, a white pasty substance was found between the battery and the portable life support system (PLSS). The photographs downlinked were consistent with a potassium hydroxide (KOH) leak from the battery stored in this EMU. The crew performed a cleanup of the EMU, double-bagged the battery that had leaked and stowed the battery in the wet trash. Evaluations of the potential mission impacts that may result from the leaking potassium hydroxide (KOH) electrolyte from the battery were made. Each of the remaining batteries in EMUs 1 and 2, as well as the stowed batteries, was inspected and no signs of leaking electrolyte were found. It was concluded that with the exception of the EMU 3 battery that had

leaked, all of the remaining EMU batteries were acceptable for use. In addition, the decision was made to not perform any cleaning of EMU 3. The EMU was not transferred to the International Space Station (ISS) and was instead returned on this mission.

During installation and checkout of the centerline camera at the 10-degree zoom position, the crew reported that the green crosshairs on the monitor were not within the target ring. The crew used both the prime and secondary cameras. The Orbiter Docking System (ODS) camera misalignment workaround procedure corrected the camera misalignment. The system provided accurate video throughout the final rendezvous and docking sequence.

The remote manipulator system (RMS) was powered at 194:01:59 G.m.t. (00:16:55 MET) to perform the RMS checkout. The checkout was temporarily suspended while a payload bay survey and water dump survey were performed. Following completion of the surveys and a successful checkout, the RMS was powered down.

The supply water tank C quantity transducer exhibited quantity measurement dropouts at approximately 194:08:25 G.m.t. (00:23:21 MET). The dropouts occurred at a tank quantity of approximately 65 percent and lasted for about 15 seconds. This problem is believed to be associated with minor contamination of the quantity gage potentiometer and did not impact supply water tank usage.

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

| Maneuver | Time, G.m.t./MET | ΔV, ft/sec | Firing time, sec | Orbit, nmi. |
|--------------------------------|-----------------------------|--------------------------------------|-----------------------------|--------------------|
| NC-1 (OMS 3) (Dual engine) | 193:12:40:32 00:03:36:33 | 141.8 | 92.6 | 126.2 by 165.1 |
| NC-2 (OMS 4) (Right engine) | 194:00:15:11 00:15:11:12 | 7.9 | 10.4 | 128.7 by 166.4 |
| NC-3 (OMS 5) (Dual engine) | 194:10:12:50 01:01:08:51 | 121.3 | 77 | 158.0 by 204.2 |
| NC-4 (OMS 6) (Dual engine) | 194:23:01:22 01:13:57:23 | 58.2 | 37.2 | 191.6 by 204.5 |
| TI (OMS-7) (Left engine) | 195:00:33:18 01:15:29:19 | 10.3 | 12.8 | 197.4 by 205.0 |
| MC-1 (RCS) | 195:00:53:07 01:15:49:08 | 0.1 | 0.4 | 197.3 x 205.0 |
| Out of Plane Null (RCS) | 195:01:08:00 01:16:04:01 | - | - | - |
| MC-2 (RCS) | 195:01:23:12 01:16:19:13 | 0.2 | 1.0 | 197.3 x 205.0 |
| MC-3 (RCS) | 195:01:40:14 01:16:36:15 | 0.1 | 0.5 | 197.4 x 205.1 |
| MC-4 (RCS) | 195:01:50:11 01:16:46:12 | 2.7 | 11.6 | 198.5 x 205.2 |

The Orbiter space vision system (OSVS) checkout was performed and during the checkout, the liquid crystal display monitor went blank. The crew cycled the power and regained the OSVS.

The trajectory control system (TCS) performance during the rendezvous and docking operations with the ISS was nominal. The TCS was energized at a range of 2.5 miles and provided accurate range and range-rate data throughout its operational period.

The ISS contact and capture occurred at approximately 195:03:05 G.m.t. (01:18:01 MET). A successful ring-in and hard mating was subsequently performed. The alignment was temporarily lost during the drive-in of the ring, apparently the result of dampers 1 and 2 being stuck. The drive-in was temporarily stopped and the ring realigned without further action. This phenomenon has been observed in several past missions.

During hook closure, the Androgynous Peripheral Docking System (APDS) hook 8 closed indication was intermittent. At 195:03:23:03 G.m.t. (01:18:19:04 MET), the closed indication for hook 8 came on as expected. However, the indication was lost 3 seconds later and remained off for 109 seconds before returning to the closed state. The indication appeared after the hook group had reached the fully closed position. Toggling was also noted on hook 8 just prior to the hooks opening during undocking. Toggling of this type has not been observed on previous flights. However, there was no mission impact as the toggling had no impact on ODS operations or capabilities.

The temperature of the coldplate return line for the forward bulkhead floodlight reached 36 °F during rendezvous and docking. Previous OV-104 flight data shows significantly colder temperatures on this line than on other vehicles (Flight Problem STS-104-V-01). Flight data from OV-103 and OV-105 show temperatures above 60 °F. The data indicates that OV-104 may have a configuration problem with the water-loop insulation being incorrectly installed and/or the sensor being incorrectly located. The line needs to be maintained above 32°F to avoid freezing the water. A plan was implemented to increase water coolant loop 1 pump cycles from 1 cycle every four hours to one cycle every hour for the remainder of the flight to ensure that freezing did not occur. The postflight Kennedy Space Center (KSC) troubleshooting and inspection with the blankets removed revealed a section of line 10 inches long that was not wrapped with the LT-80 aluminum tape at the temperature-sensor location.

The first extravehicular activity (EVA) was successfully completed with the airlock being installed on the ISS. Both EMUs performed nominally during the 5-hour 59-minute EVA. The other planned tasks completed were airlock passive common berthing mechanism (PCBM) cover removal, towel bar installation, launch-to-activation jumper cable removal, starboard CBM inspection, airlock-to-node jumper cable mating, setup of oxygen and nitrogen tank orbital replacement unit (ONTO) worksite, and payload bay cleanup. In addition four get-ahead tasks were attempted, three of which were successful. These tasks included an inspection and photography of pressurized mating adapter 2 and reattachment of loose Velcro, opening of the Node nadir CBM window cover, and evaluation the P601 connector soft-dock configuration. The attempt to remove the P608 connector cap was unsuccessful.

During the EVA, the crew reported that the handhold that was to be attached to the seat track could not be attached properly as only one bolt could be secured. The bolt-hole for the second bolt did not align properly. The handhold was brought into the crew cabin for troubleshooting. The crew inspection showed that the spring detent on the handhold shoe was not functioning properly (failed in extended position) and this prevented the handhold from moving into the soft-dock position on the seat track. The handhold was stowed for return in the same location as it was stowed for launch.

The Shuttle RMS was used to support the EVA and it performed nominally.

At approximately 196:22:34 G.m.t. (03:13:30 MET), the flash evaporator system (FES) high-load and accumulator feedline A system 1 heater failed to cycle on when expected (Flight Problem STS-104-V-02). The accumulator line temperature sensor, which is located near the thermostat, typically indicates no-less-than 64 °F prior to the heater cycling on. The accumulator line temperature dropped to 53 °F at which time the system 2 heater was selected and nominal heater cycling was observed. The high-load line temperature sensor, which typically indicates no-less-than 120 °F, dropped to 89 °F prior to selection of the system-2 heater. No mission impact occurred.

The first ISS reboost maneuver was initiated at 197:01:18:12 G.m.t. (03:16:14:13 MET) when reaction control subsystem (RCS) thrusters L3A and R3A were fired, and the maneuver had a one-hour duration. The primary RCS thruster pulse widths were 160 ms and the firing period was 11.6 seconds from start of one pulse firing until the next firing. Breaks for attitude maintenance limited the maneuver to 262 pulses. Attitude maintenance was performed with the vernier thrusters. The aft down-firing vernier thrusters had an average duty cycle of 8.08 seconds on and 3.52 seconds off. The resulting orbit was 201 by 207 nmi., an increase of 1.9 nmi., and the ΔV delivered was 6.8 ft/sec.

The crew experienced a loss of video downlink at 197:23:14 G.m.t. (04:14:10 MET). This loss was caused by a known problem with the interface between the PD100 camcorder video output connector and the cable. The problem occurred on both dedicated video recorders. The crew was briefed prior to the flight on this condition, and as a result was able to regain a good video-downlink signal.

The ISS relinquished attitude control to the Orbiter at 198:00:59 G.m.t. (04:15:55 MET) in support of Detailed Test Objective (DTO) 261, ISS On-Orbit Loads Validation. Five primary RCS thruster pulses were performed with 200 seconds between each pulse. The ISS resumed attitude control at 198:04:07 G.m.t. (04:19:03 MET).

When the sequential still video (SSV) was checked out, it appeared to function nominally upon activation. However, when its use was attempted during rendezvous and docking on flight day (FD) 3, it did not operate. The crew reported that there were no light emitting diodes (LEDs) lit and that the compression encoder box was hot. The ground controllers asked the crew to reseal the cable connectors, but the SSV was not recovered. On FD 5, the crew completed a change-out of the compression encoder box internal 2-ampere fuse (as per the SSV malfunction procedure in the Photo/TV Checklist), cycled the power to the encoder box, and reseated the cable connectors. The SSV was recovered and functioned nominally.

The Mission Management team approved a recommendation to extend the mission one day to provide an additional docked day prior to performing the third EVA.

The second EVA of the mission was completed satisfactorily. All EMU hardware and tools performed nominally during the 6-hour 29-minute EVA. Two high-pressure gas tanks were installed on the airlock as planned. Since adequate EVA time remained, the crew performed a task planned for the third EVA by installing a third high-pressure gas tank. In addition, a flight-releasable grapple fixture (FRGF) was installed, and three of four trunnion covers were installed.

The Shuttle RMS was used to support the EVA and it performed nominally. The RMS assisted in the installation of two oxygen tanks and one nitrogen tank on the airlock.

The second ISS reboost maneuver was initiated at 199:09:59:12 G.m.t. (06:00:55:13 MET) when primary RCS thrusters L3A and R3A were fired, and the maneuver had a one-hour duration. The primary RCS thruster pulse widths were 160 ms and the firing period was 11.6 seconds from start of one pulse firing until the next firing. Breaks for attitude maintenance limited the maneuver to 270 pulses. Attitude maintenance was performed with the vernier thrusters. The aft down-firing vernier thrusters had an average duty cycle of 8.08 seconds on and 3.52 seconds off. The resulting orbit was 203.7 by 207.8 nmi., an increase of 2.0 nmi., and the ΔV delivered was 6.9 ft/sec.

The third ISS reboost maneuver was initiated at 200:07:35:04 G.m.t. (06:22:31:05 MET) when vernier RCS thrusters F5L and F5R were fired, and the maneuver had a one-hour duration. There was no predefined duty cycle and the thrusters were turned off as necessary to maintain the required attitude within the 5-degree deadband. The maneuver was performed with the RCS in straight feed with the B regulators operating under general-purpose computer (GPC) control. The resulting orbit was 211.1 by 208.6 nmi., an increase of 4.3 nmi., and the ΔV delivered was 14.9 ft/sec. The RCS performed nominally throughout the maneuver.

On orbit 127 at acquisition of signal (AOS) of the Tracking and Data Relay Satellite (TDRS), the Ku-band system was powered up from standby and acquired the forward link as indicated by a strong automatic gain control (AGC) signal of -90 dBm. However, the electronic assembly 1 did not indicate either "detect" or track. (Flight Problem STS-104-V-03) After unsuccessful attempts to recover normal operations by commanding different antenna steering modes, the ground controller commanded the system off and had the crew cycle the Ku-band circuit breakers. The crew then powered the system back on and normal operations were recovered. Postflight testing of the Ku-band system will be performed in an effort to isolate the cause of this problem.

EMUs 1 and 2 were transferred to the airlock in preparation for the third EVA. A depressurization and repressurization cycle of the equipment lock was satisfactorily completed. Also a leak check of the crew lock was successfully performed.

The third EVA of the mission, and the first conducted out of the ISS airlock, was satisfactorily completed. Both EMUs performed nominally during the 4 hour 1 minute EVA. The fourth high-pressure gas tank was installed on the airlock during the EVA. The Shuttle RMS was used to support the EVA and it performed nominally.

The Orbiter assumed attitude control of the mated stack at 203:04:01 G.m.t. (09:18:57 MET) in preparation for undocking from the ISS. Successful undocking from the ISS was completed at 203:04:54 G.m.t. (09:19:50 MET). Initial ISS separation was initiated with a +Z pulse of primary RCS thrusters L4U, R4U, and F3U at 203:04:54:17 G.m.t. (09:19:50:18 MET). The ISS flyaround was performed nominally. Final separation from the ISS was accomplished with a 11.53 second +X pulse of primary RCS thrusters L3A and R3A at 203:06:15:36 G.m.t. (09:21:11:37 MET). The ΔV was 3.0 ft/sec and the resulting orbit was 211.2 by 208.4 nmi.

After undocking from the ISS, the Ku-band system was placed in the RADAR mode at 203:05:06 G.m.t. (09:20:02 MET) and acquired the ISS at a range of 170 ft. The radar

maintained lock on the ISS during the flyaround. The Ku-band system was placed back in the communications mode at 203:06:26 G.m.t. (09:21:22 MET).

The trajectory control system (TCS) was used following undocking and performed nominally. The TCS provided valid data throughout the flyaround activities and out to a range of 463 ft. At that range, the TCS lost track and was deactivated.

Two additional occurrences of the Ku-band system failing to detect and track the forward link were noted. The events occurred on orbit 148 while on the West TDRS satellite and on orbit 153 on the East TDRS satellite. The Ku-band system recovered normal operation from both events without power cycling the system.

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

Following FCS checkout, the RCS hot-fire was performed nominally. The hot-fire began at 204:01:24:58 G.m.t. (10:16:20:59 MET) and ended at 204:01:31:46 G.m.t. (10:16:27:47 MET). A review of thruster chamber-pressure data confirmed that all of the firings were satisfactory, with each thruster performing at least two pulses of 320-millisecond duration.

During the 24 hours prior to stowing the Ku-band antenna, several additional occurrences of the Ku-band system failing to detect and track the forward link were noted. In each instance, the Ku-band system recovered normal operation.

The payload bay doors were closed and latched for the nominal end-of-mission Kennedy Space Center (KSC) landing opportunities at 205:00:54:40 G.m.t. (11:15:50:41 MET). Both KSC landing opportunities on the planned landing day was waived because of unacceptable weather conditions. The payload bay doors were reopened. The payload bay doors were closed and latched on the first extension day at 206:00:01:09 G.m.t. (12:14:57:10 MET) in preparation for landing on the first KSC opportunity.

The deorbit maneuver for the first KSC landing opportunity on the first extension day was a dual-engine straight-feed firing. The maneuver was performed on orbit 200 at 206:02:31:35.22 G.m.t. (12:17:27:36.22 MET). The maneuver was 190.0 seconds in duration with a ΔV of 347.0 ft/sec.

Entry interface (EI) occurred at 206:03:07:09 G.m.t. (12:18:03.10 MET), and entry was completed satisfactorily. Main landing gear touchdown occurred on KSC concrete runway 15 at 206:03:38:55 G.m.t. (12:18:34:56 MET) on July 24, 2001. The drag chute was deployed at 206:03:38:58 G.m.t. The nose gear touchdown occurred at 206:03:39:06 G.m.t. The drag chute was jettisoned at 206:03:39:39 G.m.t. Wheels stop occurred at 206:03:40:36 G.m.t. The rollout was normal in all respects. The flight duration was 12 days 18 hours 34 minutes 56 seconds. The APU's were shut down 18 minutes 8 seconds after landing.

During entry when the Orbiter vent doors were opened, the left-hand vent door 8 and 9 closed indications went off and the motor 1 open indication came on as expected. However, the motor 2 open-indication failed off and the motor continued to run. After

driving for 10 seconds, the motor was shut down by the software. The motor-2 open indication came on approximately 1 minute and 45 seconds later.

PAYLOADS AND EXPERIMENTS

SUMMARY

During the eight docked days, three extravehicular activities (EVAs) were performed to install the Joint Airlock and four high-pressure gas tanks on the International Space Station (ISS). During the EVAs, eight get-ahead tasks were also performed. On non-EVA days, Airlock activation and checkout, middeck hardware transfer, utilization experiment transfers and water transfer were performed. Specific scenes of the Orbiter approach and undocking, ISS assembly tasks and the EVAs were documented using the IMAX-3D in-cabin camera and the IMAX cargo bay camera-3D (ICBC-3D).

The Orbiter reaction control subsystem (RCS) was used to successfully perform three ISS reboost maneuvers, which increased the ISS altitude eight nautical miles (nmi.) to a final orbit of 211 by 208 nmi.

The preflight planned mission duration of 11 days was extended to 12 days to allow an additional docked day to resolve ISS Airlock activation problems as well as provide the crew with the required time off. Orbiter undocking occurred at 203:04:54 G.m.t. (09:19:50 MET) on July 22, 2001.

All of the ISS major mission objectives were accomplished during the mission. A total of 20 ISS tasks were completed during the mission. One task was performed in support of a subsequent flight, and five tasks were deferred or not completed.

ISS MISSION ACCOMPLISHMENTS

The following items comprise a list of the ISS mission accomplishments during the period of the STS-104/ISS7A mission.

1. Transferred nine contingency water containers (CWCs);
2. Transferred critical systems, maintenance and crew-related cargo from Orbiter middeck to the ISS;
3. Verified nominal operation of Node 1 starboard hatch mechanism prior to first EVA;
4. Performed an inspection during the first EVA to ensure that the common berthing mechanism (CBM) latching, bolting and sealing surfaces were free of foreign objects and debris before moving the Joint Airlock to the capture position;
5. Installed the joint Airlock to Node 1 starboard CBM using the Space Station remote manipulator system (SSRMS);
6. Installed and performed a checkout of the four high pressure gas tanks (HPGTs) on the joint airlock;
7. Activated and performed a checkout of the Joint Airlock:
 - a. Outfitting and checkout of Node/Airlock intermediate ventilator (IMV);
 - b. Activation and checkout of Airlock system;
 - c. Relocate Intravehicular (IV) hatch and install module pressurization equalization valve (MPEV);
 - d. Checkout of EVA hardware;
 - e. Installation of Node hatch MPEV;
 - f. Activation and checkout oxygen and nitrogen system; and
 - g. Filling and transfer of five payload water reservoirs (PWRs).

8. Performed Joint Airlock outfitting;
 - a. Checkout Airlock depressurization pump; and
 - b. Checkout metal oxide (METOX).
9. Performed three docked reboost maneuvers;
10. Transferred remaining cargo and utilization equipment from middeck to ISS;
11. Transferred powered experiments and utilization to the ISS and returned powered experiments and utilization to middeck;
12. Transferred and stowed returning cargo and utilization rack to middeck;
13. Performed the third EVA from the Joint Airlock;
14. Performed the utilization requirements;
15. Performed IMAX-3D operations for filming of 7A activities in the Russian and U. S. Segments, and performed ICBC-3D operations of docking, EVA activities, undocking and flyaround of ISS;
16. Installed oxygen recharge compressor assembly (ORCA);
17. Performed tasks associated with CSA-CP exchange and return to the Orbiter;
18. Performed Development Test Objective (DTO) 692 – ISS Waste Containment Subsystem (WCS) refurbishment (including evaluation by ISS crewmembers).
19. Performed DTO 261 – ISS On-Orbit Loads Evaluation; and
20. Performed Orbiter flyaround of the ISS.

The following list of items represent the real-time additions to the crew tasks.

1. Performed additional transfer to ISS:
 - a. Fecal canisters and bags for Russian toilet;
 - b. Photographic/Video equipment (camera trades and VTR equipment);
 - c. One IMAX-3D roll of film and one roll of exposed film tape;
 - d. Grab sample container; and
 - e. Sample purge kit, Silver biocide kit and hose adapter.
2. Performed additional transfers to Shuttle for return to Earth:
 - a. Incubation bag;
 - b. TVIS PCMCIA card;
 - c. Russian circuit boards (2)
 - d. Russian food containers (22)
 - e. Increment crew clothing;
 - f. Seat track studs;
 - g. Formaldehyde monitoring kit (FMK) (2);
 - h. Contingency water containers (2);
 - i. Digital tapes of TVIS and IRED activities;
 - j. 35 mm film (40 rolls)
 - k. Hi 8 mm video tapes (20);
 - l. Photographic/video cassettes (60);
 - m. Inter-module ventilation (IMV) valve;
 - n. Nuts and bolts bag;
 - o. MACE II PCMCIA card (7);
 - p. BBND hard drive; and
 - q. IWIS battery and PCMCIA card.
3. Performed the following EVA get-ahead tasks:
 - a. Inspected and photographed MLI on pressurized mating adapter (PMA) 2;
 - b. Opened Node 1 nadir CBM window cover for 7A.1 MPLM docking;
 - c. Soft-docked P601 connector on PMA 3;

- d. Inspected P608 connector cap on PMA 3 and identified damaged cap as source of problem;
 - e. Inspected the BMRRM and no obvious binding was found;
 - f. Inspected Floating Potential Probe (FPP) light emitting diode (LED) – light was off;
 - g. Photographed Unity emblem – flaking was noted; and
 - h. Closed Space Station remote manipulator system (SSRMS) super bolt covers.
- 4. Obtained U. S. Laboratory condensate sample;
 - 5. Obtained internal active thermal control system (IATCS) samples;
 - 6. Installed REGUL 1; and
 - 7. Installed the PL2 multiplexer/demultiplexer (MDM) into the ISS Laboratory.

The task of opening the Node 1 nadir CBM window cover for 7A.1 MPLM docking was performed in support of subsequent flight.

The following tasks were either not completed or deferred to a later mission.

- 1. ORCA checkout – deferred to UF-1 mission; failed hose noted at time of original Airlock stowage; recommended move up to 7A.1 if possible, or at least complete fit check of ORCA hose;
- 2. SCU cover installation – Covers were not stowed during the 6A mission, Covers were found at KSC. Install prior to mission 8A;
- 3. Node 1 hatch window installation – deferred to UF-1 stage mission;
- 4. Install Airlock Rack Standoffs. Current procuring standoffs – launch on future mission; and;
- 5. Complete RF test – conduct test to determine if RF capability exists to update computer in real time through Node 1 hatch window.

There were no tasks deleted.

IMAX3D IN-CABIN CAMERA AND IMAX CARGO BAY CAMERA-3D OPERATIONS

The objective of the IMAX-3D and the IMAX cargo bay camera (ICBC-3D) systems was to document specific scenes of the Orbiter approach, undocking, flyaround, ISS assembly tasks, onboard crew activities and EVA tasks. A total of 100 percent of the objectives of the IMAX operations were satisfactorily completed.

A total of five rolls of exposed IMAX-3D film was returned on this flight. Four of these rolls were exposed during the docked phase of this mission, and one was exposed on the approach of the Soyuz at the beginning of the ISS 6A stage. A total of 12 scenes was filmed while docked plus two additional scenes of other activities. Additionally, three rolls of unexposed film were left on the ISS to document the ISS 7A stage operations, and these will be returned on the ISS 7A.1 mission.

SHUTTLE IONOSPHERIC MODIFICATION WITH PULSED LOCAL EXHAUST

The Shuttle ionospheric modification with pulsed local exhaust (SIMPLEX) firing of the thrusters was not performed because of conflicting on-orbit mission priorities.

VEHICLE PERFORMANCE

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.

At liftoff, there were no stud hang-ups based on Orbiter accelerometer data. Both SRB's were successfully separated from the vehicle at approximately T+122 seconds. Visual tracking indicated a normal descent and splash down. All 48 sea-water-activated release (SWAR) links (8 links per parachute) fired satisfactorily.

Both SRB's were recovered and returned to KSC for inspection, disassembly and refurbishment. The inspection revealed that both SRBs were in excellent condition. No anomalous SRB conditions were noted during the postflight operations. One item of note was the left-hand +Z range safety system antenna had the aft phenolic plate and most of the ablator missing; however, there was no evidence of ascent heating. The SRBs have been disassembled in preparation for refurbishment and reuse on a later flight.

REUSABLE SOLID ROCKET MOTORS

All Reusable Solid Rocket Motor (RSRM) systems performed satisfactorily during the countdown and the ascent phase of the mission. No LCC or OMRSD violations occurred during the countdown phase. No in-flight anomalies were identified during the review of the data. All RSRM temperatures were maintained within acceptable limits throughout the countdown. The motor performance parameters were all within contract end item (CEI) specification limits and are shown in the table on the following page.

Data indicate that the flight performance of both RSRM's was within the allowable performance envelopes, and was typical of the performance observed on previous flights. The maximum trace shape variation of pressure versus time during the 62-80 second time frame was calculated to be 0.517 percent at 80 seconds on the left motor and 1.144 percent at 70 seconds on the right motor. The values were within the 3.2 percent allowable limits. Delivered burn rates were 0.3710 and 0.3714 inch/second for the left and right motors, respectively.

All RSRM temperatures were maintained within acceptable limits throughout the countdown. The field joint heaters operated for 13 hours 39 minutes during the final launch countdown. Power was applied to the heating elements 29 percent, which is average, of the time during the LCC time frame. All field joint heaters operated as expected. The igniter joint heaters operated for 13 hours 30 minutes during the final launch countdown. Power was applied to the heating elements 39 percent of the time during the LCC time frame of the final launch countdown to maintain the igniter joints in their normal operating range.

MOTOR PERFORMANCE PARAMETERS

| Parameter | CEI Specification Limit (60 °F) | Left Motor Delivered | Right Motor Delivered |
|--|---------------------------------------|----------------------------|-----------------------------|
| Web time, seconds | 105.4 – 116.7 | 109.9 | 109.9 |
| Action time, seconds | 115.2 – 131.2 | 122.6 | 121.6 |
| Head end pressure, psia | 847.9 – 965.7 | 914.1 | 920.1 |
| Maximum sea level thrust, MLBF | 2.88 – 3.26 | 3.09 | 3.11 |
| Web time average pressure, psia | 629.9 – 700.5 | 669.9 | 672.7 |
| Web time average vacuum thrust, MLBF | 2.46 – 2.74 | 2.62 | 2.63 |
| Web time total impulse, MLBF seconds | 285.8 – 291.6 | 288.2 | 289.5 |
| Action time impulse, MLBF seconds | 293.7 – 299.7 | 296.4 | 297.0 |
| ISP average delivered, LBF seconds/LBM | 266.5 – 270.3 | 268.1 | 268.6 |
| Loaded propellant weight, LBM | >1103750 | 1105996 | 1106450 |

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

It was necessary to activate the aft skirt purge three times during the 76 hours of recorded data for a total of 11 hours 4 minutes. There were two purge activations during the final countdown for a total time of 10 hours 50 minutes. It was not necessary to activate the aft skirt purge to maintain the nozzle/case joint temperatures above the minimum LCC temperature nor was the purge required to thermally condition the flex bearing above its minimum required temperature of 60 °F. Two purge activations for a total time of 10 hours 50 minutes were also necessary. During the LCC time frame, the nozzle/case joint sensor temperatures ranged from 80 to 86 °F on the left motor and 82 to 85 °F on the right motor. The final flexible bearing mean bulk temperature was determined to be 83 °F.

Reconstructed RSRM performance parameters at the 80 °F propellant mean bulk temperature (PMBT) are shown in the table on the following page.

All ground environmental instrumentation (GEI) and operational flight instrumentation performed within established requirements. All available data were recorded, transmitted and analyzed without incident. One item of note was that it was determined that the right-hand motor aft field joint sensor, located at the 15-degree position, read 5 °F low during the final countdown and all earlier tests.

The postflight inspection found the hardware was in good condition. The motor segments have been disassembled and will be refurbished and loaded with propellant in preparation for the next flight assignment.

EXTERNAL TANK

All External Tank (ET) objectives and requirements associated with propellant loading and flight operations were met. No significant oxygen or hydrogen leakage concentrations were detected in the intertank. All ET electrical equipment and instrumentation operated satisfactorily. Purge and heater operations were monitored and performed properly. No ET LCC or OMRSD violations occurred during the countdown, nor were any in-flight anomalies identified from the analysis of the data.

RSRM PROPULSION PERFORMANCE

| Parameter | Left motor, 80 °F | | Right motor, 80 °F | |
|--|-------------------|--------|--------------------|--------|
| | Predicted | Actual | Predicted | Actual |
| Impulse gates | | | | |
| I-20, 10 ⁶ lbf-sec | 66.45 | 66.64 | 66.71 | 66.86 |
| I-60, 10 ⁶ lbf-sec | 177.45 | 177.82 | 178.05 | 178.16 |
| I-AT, 10 ⁶ lbf-sec | 297.13 | 297.33 | 297.22 | 297.36 |
| Vacuum Isp, lbf-sec/lbm | 268.6 | 268.8 | 268.6 | 268.7 |
| Burn rate, in/sec @ 60 °F At 625 psia | 0.3701 | 0.3710 | 0.3709 | 0.3714 |
| Event times, seconds ^a | | | | |
| Ignition interval | 0.232 | N/A | 0.232 | N/A |
| Web time ^b | 107.6 | 107.0 | 107.2 | 107.2 |
| 50 psia cue time | 117.5 | 117.3 | 117.1 | 116.4 |
| Action time ^b | 119.7 | 119.8 | 119.3 | 118.8 |
| Separation command | 121.9 | - | 121.9 | - |
| PMBT, °F | 80 | 80 | 80 | 80 |
| 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 | 3.3 | 3.1 | 3.4 |
| Tailoff Imbalance Impulse | Predicted | | Actual | |
| differential, Klbf-sec | N/A | | 460.8 | |

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

^bReferenced to liftoff time (ignition interval).

The observed thermal protection system (TPS) cracks were acceptable. No unexpected ice/frost formations were observed during the countdown. There was no observed ice or frost on the acreage areas of the ET. Normal quantities of ice or frost were present on the liquid oxygen (LO₂) and liquid hydrogen (LH₂) feedlines.

The intertank compartment purge heater and temperature control system operated successfully. All temperatures were maintained within limits, all components within the intertank performed satisfactorily and there were no hazardous gas violations.

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 performed and since it occurred within expected tolerances, entry and break-up occurred within the expected footprint approximately 75 nmi. downrange from the preflight predicted impact point.

SPACE SHUTTLE MAIN ENGINES

The prelaunch operation for the Space Shuttle main engines (SSME's) was satisfactory. The SSME's performed satisfactorily throughout ascent with no in-flight anomalies identified from the data. SSME 2 was the first Block II engine to be flown in the Space Shuttle Program. The Block II engine performed as expected.

The flight-derived specific impulse (I_{sp}) was approximately 452.99 seconds based on trajectory data.

A review of ascent data showed that the Space Shuttle main engine (SSME) -2 liquid hydrogen (LH_2) inlet pressure after main engine cutoff (MECO) was higher than normal. This performance can be attributed to extra heat being transferred into the system by the Block II SSME. This was the first flight of a Block II SSME, and the extra heat that was put into the system by the engine is being investigated. A more complete discussion of this problem is contained in the Main Propulsion System section of this report.

Main engine cutoff (MECO) occurred 498.827 seconds after SRB ignition. The commanded maximum dynamic pressure ($Max Q\alpha$) throttle-down was in a single throttle step to 72 percent.

SHUTTLE RANGE SAFETY SYSTEM

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

The right SRB range safety system (RSS) system A signal strength exceeded the range safety minimum requirement of -85 dBm for one data sample at approximately 102 seconds after liftoff. The lowest observed signal strength was -85.1 dBm. The observed signal strength did not exceed the command sensitivity of the system Interface Requirements Document. This is not a problem as the low signal strength is an expected condition that occurs on high-inclination flights and is caused by plume attenuation and right SRB shading. This condition did not impact flight operations.

ORBITER SUBSYSTEMS PERFORMANCE

Main Propulsion Subsystem

The main propulsion system (MPS) operated satisfactorily, and no LCC or OMRSD violations occurred during the launch countdown and flight. The initial flight of a Block II SSME was experienced, and it performed satisfactorily. The overall prelaunch and ascent system performance was nominal, although one in-flight anomaly was identified.

Beginning at about the start of fast-fill during prelaunch operations, a leak indication was observed at the two liquid hydrogen (LH_2) T-0 umbilical sensors. The sensors are located inside the LH_2 tail service mast (TSM) and are used to monitor leak indications in the area of the LH_2 8-inch flexible line. The observed leak was confirmed to be a hydrogen leak and not helium corruption of the leak detectors. Historical values are in the 3,000 to 5,000 ppm range with the maximum value observed during this problem being 11,000 ppm. The hazardous limit for these two sensors is 44,000 ppm. Leakage at this location is influenced by flow-rate and pressure in the line. Leakage at the T-0 umbilical has always dissipated when the LH_2 tank is vented for topping, and this again occurred as it has in all previous cases. The leakage stabilized at approximately 1,000 ppm, and this area did not see any pressure developing as a result of propellant during the remainder of loading.

The liquid hydrogen (LH₂) loading operations were normal in all aspects. Based on the analysis of loading system data, the LH₂ load at the end of replenish was 231,689 lbm, which was a nominal 304 lbm over the planned load. This level was well within the required loading accuracy of ± 0.37 percent.

The liquid oxygen (LO₂) loading operations were nominal during all phases of the preparation for flight. Analysis of the loading data showed the LO₂ load to be 1,389,016 lbm, which was a nominal 60 lbm below the planned load. This level was well within the required loading accuracy of ± 0.43 percent.

The pre-pressurization operations for the LH₂ and LO₂ tanks were performed nominally, except the LO₂ SSME interface pressures violated the Interface Control Document (ICD) maximum of 111 psia at the initiation of engine start at T-9.5 seconds on all three SSMEs. The longitudinal-acceleration (POGO) valve opening at T-12.5 seconds caused this condition and it is being investigated.

During a review of MPS ascent data, it was found that the following main engine cutoff (MECO), the engine-2 inlet pressure was higher than normal. Following MECO, the liquid hydrogen (LH₂) pre valves close, and nominally the three engine-inlet pressures rise to between 60 and 65 psia before the pre valve relief valves open and relieve the pressure. Also, the LH₂ manifold pressure typically rises to just under 35 psia and then is relieved through the return to launch site (RTL) dump valves. During this mission, the engine-2 inlet pressure rose to 78 psia before falling off and following the other two engine-pressure readings. Also, with this extra rise in engine-2 inlet pressure, the LH₂ manifold pressure rose to 43 psia before the RTL dump valves opened. This performance was attributed to extra heat being transferred into the system by the Block II engine. This was the first flight of a Block II engine.

Modeling efforts completed by the Space Shuttle main engine (SSME) Project show that additional energy input to the system is to be expected from the Block II SSME. Further, the effects of this energy increase were not detected during SSME testing due to ground plumbing and valve sequencing differences. Actions were assigned to create models, which will be used to bound the worst-case effects of this added energy input. The resolution of this anomaly may not support using three Block II SSMEs on the STS-108 mission; consequently, an evaluation of alternate engines for that mission is in progress.

No significant hazardous gas concentrations were detected prior to liftoff. The maximum hydrogen concentration level in the Orbiter aft compartment, with the normally elevated system backpressure used for fast-fill, was 172 ppm (corrected for mass spectrometer drift). This compares favorably with previous data for this vehicle.

The data evaluation showed that 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. The engine inlet net positive suction pressure requirements were met throughout the flight. The Helium system performance for the SSME and pneumatic Helium systems were nominal. Entry Helium usage was 59.8 lbm and that is within the specification limits.

Reaction Control Subsystem

The reaction control subsystem (RCS) performed satisfactorily throughout the mission. No in-flight anomalies were noted in the evaluation of the data.

A total of 4994.1 lbm propellants (3019.7 lbm - oxidizer, 1874.4 lbm - fuel) were used from the RCS during the rendezvous mission with the International Space Station. In addition, a total of 2349.6 lbm of the orbital maneuvering subsystem (OMS) propellants were used by the RCS during interconnect operations. The primary RCS thrusters had 5914 firings and a total firing time of approximately 1202.56 seconds. The vernier RCS thrusters had 9296 firings and a total firing time of 37488.04 seconds.

The RCS was used to perform a window-protect maneuver during ascent, five translation firings in support of the rendezvous with the ISS, three RCS reboost maneuvers and a final separation maneuver from the ISS. The overall altitude increase delivered during the three separate reboost maneuvers was approximately 8.2 nmi. The following table reflects the major RCS maneuvers performed during the mission.

RENDEZVOUS MANEUVERS

| Maneuver | Time, G.m.t./MET | ΔV , ft/sec | Firing time, sec | Orbit, nmi. |
|----------------------------|---------------------------------|---------------------|---------------------|------------------------------|
| Window Protect | 193:09:05:59.73 00:00:02:00 | N/A | 2.08 | During ascent (No affect) |
| ET Photo Maneuver | 193:09:12:55.7 00:00:08:55.7 | N/A | 11.5 | No change |
| NCC Maneuver | 194:23:35:35 01:14:31:36 | 2.1 | N/A | N/A |
| MC-1 (RCS) | 195:00:53:07 01:15:49:08 | 0.1 | 0.4 | 197.3 by 205.0 |
| Out of Plane Null (RCS) | 195:01:08:00 01:16:04:01 | - | - | - |
| MC-2 (RCS) | 195:01:23:12 01:16:19:13 | 0.2 | 1.0 | 197.3 by 205.0 |
| MC-3 (RCS) | 195:01:40:14 01:16:36:15 | 0.1 | 0.5 | 197.4 by 205.1 |
| MC-4 (RCS) | 195:01:50:11 01:16:46:12 | 2.7 | 11.6 | 198.5 by 205.2 |
| Reboost 1 | 197:01:18:12 03:16:14:13 | 6.8 | 1 hour | 207 by 201 |
| Reboost 2 | 199:09:59:11.7 06:00:55:12.7 | 6.89 | 1 hour | 207.8 by 203.7 |
| Reboost 3 | 200:07:39:00.0 06:22:35:01.0 | 14.9 | 1 hour | 211.1 by 208.6 |
| Final Separation | 203:06:15:35.7 09:21:11:36.7 | 3.0 | 11.53 | 211.2 by 208.4 |

The first ISS reboost maneuver used RCS primary thrusters L3A and R3A, and the RCS thruster pulse widths were 160 msec, and the firing period was 11.6 seconds from start of one pulse firing until the next firing. Eleven breaks for attitude maintenance limited the maneuver to 262 pulses. Attitude maintenance was performed with the vernier thrusters. The aft down-firing vernier thrusters had a typical duty cycle of 8.08 seconds on and 3.56 seconds off. The reboost maneuver was performed with the RCS in left orbital maneuvering subsystem (OMS) interconnect.

The ISS relinquished attitude control to the Orbiter at 198:00:59 G.m.t. (04:15:55 MET) in support of Detailed Test Objective (DTO) 261, ISS On-Orbit Loads Validation. The first of five primary RCS thruster pulses were initiated at 198:03:35:16 G.m.t.

(04:18:31:17 MET). The maneuver consisted of five primary thruster pulses with 200 seconds between each pulse. RCS performance was nominal. The ISS resumed attitude control at 198:04:07 G.m.t. (04:19:03 MET).

The second ISS reboost maneuver used primary RCS thrusters L3A and R3A. The primary RCS thruster pulse widths were 160 ms and the firing period was 11.6 seconds from start of one pulse firing until the next firing. Eight breaks for attitude maintenance limited the maneuver to 270 pulses. Attitude maintenance was performed with the vernier thrusters. The aft down-firing vernier thrusters had an average duty cycle of 8.08 seconds on and 3.52 seconds off. The maneuver was performed with the RCS in right OMS interconnect.

The third ISS reboost maneuver used vernier RCS thrusters F5L and F5R were fired. There was no predefined duty cycle and the thrusters were turned off as necessary to maintain the required attitude within the 5-degree deadband. The maneuver was performed with the RCS in straight feed with the B regulators operating under general-purpose computer (GPC) control. The RCS performed nominally throughout the maneuver.

Following FCS checkout, the RCS hot-fire was performed nominally. The hot-fire began at 204:01:24:58 G.m.t. (10:16:20:59 MET) and ended at 204:01:31:46 G.m.t. (10:16:27:47 MET). A review of thruster chamber-pressure data confirmed that all of the firings were satisfactory, with each thruster performing at least two pulses of 320-millisecond duration. The RCS performed satisfactorily during the hot-fire.

Initial ISS separation was initiated with a +Z pulse of primary RCS thrusters L4U, R4U, and F3U at 203:04:54:17 G.m.t. (09:19:50:18 MET). The ISS flyaround was performed nominally.

Final separation from the ISS was accomplished with a 11.53 second +X pulse of primary RCS thrusters L3A and R3A at 203:06:15:36 G.m.t. (09:21:11:37 MET). The ΔV was 3.0 ft/sec and the resulting orbit was 211.2 by 208.4 nmi.

Orbital Maneuvering Subsystem

The orbital maneuvering subsystem (OMS) performed satisfactorily throughout the mission. No in-flight anomalies were identified from the analysis of the data.

A total of 20819 lbm (12,997 lbm - oxidizer and 7822 lbm - fuel) of OMS propellants were consumed during the mission. Of this total, the OMS provided 2349.6 lbm of propellants to the RCS during interconnect operations, and this represents 18.124 percent of the OMS propellants used during the mission. The table on the following page shows the OMS maneuvers performed to rendezvous and dock with the International Space Station (ISS).

The OMS assist maneuver was performed following SRB separation. The OMS 2 maneuver was performed at 193:09:42:31.6 G.m.t. (00:00:38:32.6 MET) and was 64.0 seconds in duration. The differential velocity (ΔV) was 96.8 ft/sec, and the orbit was 85.1 by 127.0 nautical miles (nmi.) following the maneuver. The OMS performed satisfactorily throughout the maneuver.

OMS RENDEZVOUS MANEUVERS

| Maneuver | Time, G.m.t./MET | ΔV , ft/sec | Firing time, sec | Orbit, nmi. |
|--------------------------------|---------------------------------|---------------------|---------------------|----------------|
| NC-1 (OMS 3) (Dual engine) | 193:12:39:00 00:03:35:01 | 141.8 | 92.6 | 126.2 by 165.1 |
| NC-2 (OMS 4) (Right engine) | 194:00:15:11.8 00:15:11:12.8 | 7.9 | 10.4 | 128.7 by 166.4 |
| NC-3 (OMS 5) (Dual engine) | 194:10:12:50.3 01:01:08:51.3 | 121.3 | 77.7 | 158.0 by 204.2 |
| NC-4 (OMS 6) (Dual engine) | 194:23:01:22.4 01:13:57:23.4 | 58.2 | 37.2 | 191.6 by 204.5 |
| TI (OMS-7) (Left engine) | 195:00:33:18.4 01:15:29:19.4 | 10.3 | 12.8 | 197.4 by 205.0 |

The deorbit maneuver for the first KSC landing opportunity on the first extension day was a dual-engine straight-feed firing. The maneuver was performed on orbit 200 at 206:02:31:35.2 G.m.t. (12:17:27:36.2 MET). The maneuver was 190.0 seconds in duration with a ΔV of 347.0 ft/sec.

Power Reactant Storage and Distribution Subsystem

The power reactant storage and distribution (PRSD) subsystem performance was nominal throughout the STS-104 mission. No LCC or OMRSD violations occurred during the countdown and mission, and no in-flight anomalies were noted during the analysis of the data. The PRSD subsystem supplied the fuel cells with 2908 lbm of oxygen and 366 lbm of hydrogen for the production of 4249 kW of electrical energy. In addition, the environmental control and life support system (ECLSS) was supplied 157 lbm of oxygen for life support.

PRSD tanks 4 and 5 were depleted to residual quantities during the mission. The Orbiter landed with 850 lbm of oxygen and 90 lbm of hydrogen remaining in the PRSD subsystem. A 61-hour mission extension capability existed at landing, based on the PRSD oxygen (limiting reactant) tank landing quantities and an average power level of 13.9 kW. At an extension-day power level of 12.3 kW, a 68-hour mission extension capability was available.

Fuel Cell Powerplant Subsystem

The overall performance of the fuel cell powerplant (FCP) subsystem was nominal during the mission. There were no OMRSD or LCC violations, nor were any in-flight anomalies found during the analysis of the data. The average power level and load was 13.9 kW and 450 amperes. The fuel cells produced 3274 lbm of potable water and 4249 kWh of electrical energy while using 2908 lbm of oxygen and 366 lbm of hydrogen.

Five 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 V above the predicted for fuel cell 1, 0.15V above predicted for fuel cell 2, and 0.15 V above the predicted for fuel cell 3. The voltage margin above the minimum performance curve at 200 amperes at

the end of the mission was 0.9 V for fuel cell 1, 0.9 V for fuel cell 2, and 1.2 V for fuel cell 3.

The overall thermal performance of the fuel cell water relief, water line, and reactant purge heater systems was normal. System A was used during the countdown, ascent and through 4.8 days of the mission. The B system was selected at that time and it operated for the remainder of the mission.

The fuel cell monitoring system (FCMS) was used to monitor individual cell voltages during prelaunch, on-orbit and postlanding operations. Inaccurate or erratic individual cell voltage readings from the FCMS were expected from the unsoldered voltage pins on fuel cells 1 and 2. Since the voltage pins on fuel cell 3 are soldered, the inaccurate readings on cells 3 and 4 during prelaunch operations were a first-time occurrence for a fuel cell with soldered pins. This condition did not affect the satisfactory operation of that fuel cell.

On-orbit fuel cell data were taken from the FCMS for 15 minutes. The data did not indicate any off-nominal fuel cell operation with the exception of pin-sharing on fuel cell 1, cells 21 and 22 and 45 and 46. These conditions did not affect fuel cell performance.

Auxiliary Power Unit Subsystem

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

APU RUN TIMES AND FUEL CONSUMPTION

| Flight phase | APU 1 (S/N 207) (a) (b) | | APU 2 (S/N 203) (a) | | APU 3 (S/N 401) (a) | |
|--------------------|----------------------------|----------------------|------------------------|----------------------|------------------------|----------------------|
| | Time, Min:sec | Fuel consumption, lb | Time, Min:sec | Fuel consumption, lb | Time, min:sec | Fuel consumption, lb |
| Ascent | 21:34 | 49 | 21:49 | 52 | 21:57 | 56 |
| FCS checkout | 6:22 | 17 | | | | |
| Entry ^a | 63:24 | 114 | 91:35 | 160 | 63:36 | 127 |
| Total | 91:20 | 180 | 113:24 | 212 | 85:33 | 183 |

^a APUs were shut down 18 minutes 8 seconds after landing.

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

After APU 2 shutdown following landing, the gearbox gaseous nitrogen (GN₂) pressure and gas generator bed temperature dropped out when the controller switch was turned off. These measurements are powered from the controller power switch as well as from the gas generator/fuel pump heater switch, and these measurements should have continued to be active until the heater switch was turned off. Postlanding testing will be performed to determine the cause of the loss of these measurements.

Hydraulic/Water Spray Boiler Subsystem

The hydraulics/WSB subsystem performed satisfactorily throughout the mission. There were no OMRSD or LCC violations, nor were any in-flight anomalies found during the analysis of the data.

STS-104 was the eighth flight in which the new WSB water additive [Propylene Glycol Monomethyl Ether (PGME)] was used to preclude ascent freeze-ups. The STS-104 mission was the third flight in which the additive was loaded into all three WSB system cores during the turnaround flow at KSC to preclude ascent under-cooling conditions from occurring.

Hydraulic performance during ascent, FCS checkout and entry was nominal. There were no unexpected decreases in reservoir quantities, indicating no gross leaks in the systems. Priority-valve cracks at APU activation were all within the 1-second specification limit, and reseats on systems 1 and 3 at APU shutdown were also within the specification limit (>2675 psia). Following APU shutdown after ascent, the hydraulic system-2 priority valve reseat pressure was approximately 2642 psia. Similar performance has been noted during the three previous missions of this vehicle.

Electrical Power Distribution and Control Subsystem

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

During entry when the Orbiter vent doors were opened, the left-hand vent door 8 and 9 closed indications went off and the motor open indication came on, all of which were expected. However, the motor 2 open-indication failed off and the motor continued to run. After driving for 10 seconds, the motor shut down because the software removed the open command. The motor 2 open indication came on approximately 1 minute 45 seconds later. The failure did not impact entry or landing operations.

Orbiter Docking System

During installation and checkout of the centerline camera at a 10-degree zoom position, the crew reported that the green crosshairs on the monitor were not within the target ring. The crew used both the prime and secondary cameras. The Orbiter Docking System (ODS) camera misalignment workaround procedure corrected the camera misalignment. The system provided accurate video throughout the final rendezvous and docking sequence.

The ISS contact and capture occurred at approximately 195:03:05 G.m.t. (01:18:01 MET). A successful ring-in and hard mating was subsequently performed. The alignment was temporarily lost during the drive-in of the ring, apparently the result of dampers 1 and 2 being stuck. The drive-in was temporarily stopped and the ring realigned without further action. This phenomenon has been observed in several past missions.

During docking hook closure, the Androgynous Peripheral Docking System (APDS) hook 8 closed indication was intermittent. At 195:03:23:03 G.m.t. (01:18:19:04 MET), the closed indication for hook 8 came on as expected. However, the indication was lost 3 seconds later and remained off for 109 seconds before returning to the closed state. The indication appeared after the hook group had reached the fully closed position. The

hook 8 closed indication also toggled off just prior to the hooks opening during undocking. Toggling of this type has not been observed previously. However, there was no mission impact as the toggling had no impact on ODS operations or capabilities.

The ODS valves were used during the docked operation and for EVAs. The Orbiter was docked to the ISS pressurized mating adapter and the vestibule was pressurized from the ISS. The post-docking vestibule leak check was nominal. The active system monitor parameters indicated normal output throughout the duration of the flight.

The Orbiter assumed attitude control of the mated stack in preparation for undocking from the ISS. Successful undocking from the ISS was completed at 203:04:54 G.m.t. (09:19:50 MET). The vestibule depressurization valves were used to depressurize the vestibule to vacuum before undocking, and the post-undocking vestibule leak check was nominal.

Atmospheric Revitalization Pressure Control Subsystem

The atmospheric revitalization pressure control subsystem (ARPCS) performed normally throughout the duration of the flight. Prior to docking, the ARPCS was configured to system 2. The Shuttle cabin pressure was equalized with the ISS at a resulting pressure of 14.2 psia and the hatches between the ISS and the Shuttle were opened at 19:14:03 G.m.t. (01:04:59 MET).

The first depressurization to support the first EVA was initiated at 195:09:54 G.m.t. (02:00:50 MET) and cabin pressure was initially reduced to 10.4 psia. Pressure was maintained at 10.2 psia until after the EVA crewmembers had ingress the cabin at the end of the EVA. After the first EVA, cabin pressure was returned to 14.7 psia and that pressure was maintained manually. The Orbiter cabin pressure was equalized with the ISS and the hatches were opened for the transfer of equipment at 196:10:52 G.m.t. (03:01:48 MET).

The hatches that provided access to the ISS were closed, and a depressurization to support the second EVA was performed at 198:12:04 G.m.t. (05:03:00 MET). Pressure was returned at 14.7 psia after the airlock repressurization, and pressure control was maintained manually. The Orbiter cabin pressure was equalized with the ISS and the hatches were opened. The prebreathing for the third EVA was performed onboard the ISS with the ODS hatch open.

At 202:00:20 G.m.t. (08:15:20 MET), nitrogen was used to repressurize the Orbiter/ISS vehicle to 14.7 psia through the 14.7 psia regulator. Because the oxygen partial pressure was near the ISS limits, a repressurization to 14.9 psia of the Orbiter/ISS vehicle was performed through the vent line of the nitrogen-transfer panel. Hatches that are common with the ISS were closed in preparation for undocking. Following the undocking, ARPCS system 2 was placed in Auto, and normal operation of the ARPCS system was used for the remainder of the mission. The full switchover on ARPCS 2 was observed. After wave-off of the first landing opportunity, ARPCS 1 was utilized; however, switchover was not observed on PCS 2.

Atmospheric Revitalization Subsystem

All atmospheric revitalization subsystem (ARS) systems performed nominally on STS-104.

At 194:06:45 G.m.t. (00:21:41 MET), the crew was preparing to remove a lithium hydroxide (LiOH) canister from EMU 3 when the crew reported that they found a white pasty material on the top of the EMU battery. A 2-inch blob of the white pasty material was measured. Downlinked photographs showed a white contaminate on top of one side of the battery, a white streak running up the LiOH canister and a small amount of white contaminate on top of one side of the portable life support system (PLSS) about 1 inch away from the LiOH outlet port. At approximately 194:09:10 G.m.t. (01:00:06 MET), the cabin fan, inertial measurement unit (IMU) fan and airlock booster fans were powered down as part of the hazardous spill response. The white pasty material was identified as potassium hydroxide (KOH), which is the EMU battery electrolyte. The LiOH cartridge and battery were individually bagged in plastic and stowed in the volume F wet trash for the remainder of the flight.

While the Orbiter was rendezvousing with the ISS at approximately 195:02:02 G.m.t. (01:16:58 MET), the water coolant loop (WCL)1 floodlight coldplate temperature reached 35.1 °F. This occurred during normal WCL 1 cycling every 4 hours for 6 minutes under general purpose computer (GPC) control. Analysis of the attitude timeline identified periods of cold attitudes where the nominal 4-hour cycle time was inadequate. As a result, a recommendation was made to the Operations personnel to cycle the WCL 1 every hour during those attitudes where cold temperatures were either expected or for the mission duration. Operations opted to increase the GPC cycle-frequency to hourly cycling. The mission continued with the one-hour cycling of WCL 1 and after undocking a low temperature of 40.67 °F was recorded on the WCL floodlight coldplate at 203:10:17 G.m.t. (10:01:13 MET) during a -ZLV -XVV attitude. The data review indicated that the low temperature occurred on previous flights of the OV-104 vehicle since the sensor installation during the vehicle Orbiter Major Modification (OMM) activities. The same temperature measurements on the OV-103 and OV-105 vehicles have averaged temperatures above 60 °F for all vehicle attitudes.

The postflight investigation identified a section of the return-line tubing that was not wrapped with the aluminized tape. The tape wraps the on-orbit active loop 2 with the passive loop 1. The tape provides the necessary transfer of heat to prevent loop 1 from freezing.

The booster fan was powered up following the first EVA at an airlock pressure of 9.43 psia. The fan continued to operate for over 21 minutes while the pressure climbed to 10.0 psia. The vendor was contacted about the occurrence and the response was that operating the fan at this pressure for the short duration would not have a permanent impact to the fans operation.

During the launch phase, the crew compartment temperature was 73.02 °F and climbed to 74.79 °F at approximately 52 minutes and 53 seconds after liftoff, and the temperature remained constant. Cabin humidity peaked to 42.4-percent 4 minutes and 26 seconds after launch. The heat exchanger outlet air temperature peaked to 70.98 °F approximately 3 minutes 15 seconds into the flight. Cabin Humidity averaged 33.0 percent for the flight, with a peak of 53 percent during the crew-awake activity period of flight day 12.

The partial pressure of carbon dioxide (ppCO₂) peaked to 6.93 mmHg at 14.7-psia cabin pressure. During 10.2-psia cabin pressure operations, the ppCO₂ was maintained below the flight rule limit for acceptable carbon dioxide (CO₂) concentration, peaking to an indicated ppCO₂ of 2.0 mmHg.

During the landing phase of the flight, the heat-exchanger outlet temperature peaked to 57.37 °F 7 minutes and 27 seconds after wheel stop, with the cabin air temperature peaking to 72.68 °F 19 minutes and 24 seconds after wheel stop. The cabin humidity peaked near 52 percent approximately 9 minutes after wheel stop.

Active Thermal Control Subsystem

The active thermal control subsystem performed nominally throughout the mission. One in-flight anomaly was identified and it is discussed in a later paragraph.

Approximately 7 minutes into the flight and prior to activation of the flash evaporator system (FES) activation, pre-evaporative cooling of 15 °F magnitude was observed by the general purpose computer (GPC). These data indicate a significant amount of condensate in the cores; however, it is within the historical database for the FES. The most pre-evaporative cooling that was observed in any Space Shuttle flight was approximately 20 to 25 °F.

About 1 hour and 30 minutes after liftoff, a FES rate shutdown occurred under primary B command control. The FES was being configured to the primary B controller to allow accumulation of water in tanks A and B for contingency water container (CWC) transfer to the ISS. A successful restart under primary B control was performed about 2 minutes and 26 seconds later. It is highly likely that the temperature transient resulting from the change in radiator configuration from bypass to flow coincided with the FES outlet temperature downward movement that follows the FES primary B startup. The radiator bypass valve changed from bypass to flow about 1.5 minutes before the FES was configured to primary B command. The FES was not able to compensate for the sudden change in heat load while it was in the process of bringing its outlet temperatures into the control band. There were no irregular FES duct temperatures at that time, thus indicating no excess carryover. The gaseous nitrogen (GN₂) pressure transients in tanks C and D that were caused by the tank A repressurization a few seconds before the shutdown may also have been a factor in hampering the FES controller's capability to adjust pulse rates and compensate for the FES inlet-temperature transients. It is difficult to determine conclusively how much of a factor the tank pressure transients may have been to the shutdown. The shutdown is not an indication of hardware failure and postflight troubleshooting was not necessary.

About 5 minutes after the primary B restart, FES outlet temperature transients with peaks of 52 °F and 50 °F were observed. At this time, the payload bay doors had not been opened and that accounted for the gradually warming radiator temperatures. The FES outlet temperature transients were normal because they resulted from the primary B controller switching the high load core in and out of standby to compensate for the gradually increasing heat loads. This signature was observed in STS-98, the previous OV-104 flight, under very similar conditions. No other notable FES behavior was observed for the remainder of the flight.

At approximately 196:22:34 G.m.t. (03:13:30 MET), the flash evaporator system (FES) high-load and accumulator feedline A system 1 heater failed to cycle on when expected (Flight Problem STS-104-V-02). Flight data from the accumulator line temperature sensor, which is located near the thermostat, typically indicates no-less-than 64 °F prior to the heater cycling on. The high-load line temperature sensor, which is also heated by this heater, typically indicates no-less-than 120 °F, dropped to 89 °F prior to selection of the system-2 heater. The accumulator- line temperature dropped to 53 °F at which time the system 2 heater was selected and nominal heater cycling was observed.

The FES was under primary B command from 193:10:33 G.m.t. (00:01:29 MET) through 199:11:02 G.m.t. (06:01:58 MET). At the later time, the FES was switched from primary B to primary A command because the filling of CWCs for transfer to ISS had been completed. A total of three FES water dumps were performed, one under primary B command controller and two under primary A command controller. At the scheduled end-of-mission (EOM) deorbit day, the radiator bypass/FES checkout was successfully completed. At the EOM + 1 deorbit day, the radiator bypass/FES checkout was also completed successfully. Approximately 13 minutes before landing, the radiators were switched from bypass to flow mode. At 6 minutes after landing, the ABS system B secondary controller was enabled to initiate ammonia flow. System B loss of cooling capability started to occur 45 minutes after landing and system A secondary was enabled. The system A secondary controller was powered off at the start of ground support equipment (GSE) cooling.

Supply and Waste Water Subsystem

The Supply Water and Waste Management Systems performed nominally throughout the mission and all of the scheduled in-flight checkout requirements were satisfied. Supply water was managed through the use of the FES, water transfer to the ISS and the overboard nozzle-dump system. Five supply-water nozzle dumps were performed at a nominal dump rate of 1.6 percent per minute (2.64 lb/min). The line heater maintained the supply water dump line temperature between 75 °F and 92 °F throughout the mission.

Six wastewater nozzle dumps at an average rate of 2.0 percent per minute (3.3 lb/min) were performed. The ISS requested that the first wastewater nozzle dump be video taped and monitored to confirm that the dump spray pattern was not directed at the ISS and thus would not contaminate the ISS solar arrays.

After the completion of the sixth wastewater nozzle dump, the waste dump isolation valve was closed and a CWC containing ISS Laboratory condensate (~ 77 lbm) was connected to the waste cross-tie quick-disconnect (QD) and dumped through the waste dump nozzle. The wastewater dump line temperature was maintained between 58.7 °F and 74 °F throughout the mission.

Nine CWCs were filled with supply water for a total of 881 lb and transferred to the ISS. Six of the CWCs transferred contained potable water and three contained technical water. The calculated average fill-rate was 109 lb/hr. Additionally, seven potable water reservoirs (PWRs), were filled with iodinated water from the galley for a total of 140 lb. The PWRs are used for the ISS EMU water recharge.

The supply water tank C quantity transducer exhibited quantity measurement dropouts at approximately 194:08:25 G.m.t. (00:23:21 MET). The dropouts occurred at a tank quantity of approximately 65 percent and lasted for about 15 seconds. This problem is believed to be associated with minor contamination of the quantity gage potentiometer and does not impact supply water tank usage.

The vacuum vent line temperature was maintained between 58.3 °F and 75 °F.

Waste Collection Subsystem

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

Airlock Support Subsystem

The airlock support system provided all of the support required for the EVA activities in a satisfactory manner.

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 (FCS) performance was nominal throughout the mission with no in-flight anomalies noted in the data review and analysis.

The entry inertial guidance, navigation and control (GNC) performance was nominal. The navigation sensors (drag, TACAN, ADTA, and MLS) data were incorporated into the onboard navigation state vectors at their expected region of operations with no navigation editing observed.

During entry, the miniature air-to-ground receiver-Shuttle (MAGR-S) global positioning system (GPS) receiver reported higher figure of merit (FOM)/geometric dilution of precision (GDOP) values than expected for the post-blackout region of entry. A review of the downlisted data indicated that the cause of this behavior was that the receiver firmware had experienced a channel management task collision, which prevented it from processing ionospheric measurements properly at that region of entry. A fix for this known condition is included in the next receiver firmware update release.

Flight Software

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

Flight Control Subsystem

The flight control subsystem performance was nominal throughout the mission. No in-flight anomalies were noted in the analysis of the data.

Displays and Control Subsystem

The displays and controls subsystem performed nominally.

Communications and Tracking Subsystem

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

At 193:10:47 G.m.t. (00:01:43 MET), the crew reported that a hand-held microphone (HHM) was "cutting in and out" resulting in unreliable voice communications. The crew confirmed that the switch configuration was correct. The HHM was changed out with a spare and the failed HHM was tagged and stowed.

The crew experienced a loss of video downlink at 197:23:14 G.m.t. (04:14:10 MET). This loss was caused by a known problem with the interface between the PD100 camcorder video output connector and the cable. The problem occurred on both dedicated video recorders. The crew was briefed prior to the flight on this condition, and as a result was able to regain a good video-downlink signal.

When the sequential still video (SSV) was checked out, it appeared to function nominally upon activation. However, when its use was attempted during rendezvous and docking on flight day (FD) 3, it did not operate. The crew reported that there were no light emitting diodes (LEDs) lit and that the compression encoder box was hot. The ground controllers asked the crew to reseat the cable connectors, but the SSV was not recovered. On FD 5, it was reported that the crew completed a change-out of the compression encoder box internal 2-ampere fuse (as per the SSV malfunction procedure in the Photo/TV Checklist), cycled the power to the encoder box, and reseated the cable connectors. The SSV was recovered and functioned nominally.

On orbit 127 at acquisition of signal (AOS) of the Tracking and Data Relay Satellite (TDRS), the Ku-band system was powered up from standby and acquired the forward link as indicated by a strong automatic gain control (AGC) signal of -90 dBm. However, the electronic assembly 1 did not indicate either "detect" or "track" (Flight Problem STS-104-V-03). After unsuccessful attempts to recover normal operations by commanding different antenna steering modes, the ground controller of the system had the crew cycle the Ku-band circuit breakers. The crew then powered the system back on and normal operations were recovered.

Two additional occurrences of the Ku-band system failing to detect and track the forward link were noted. The events occurred on orbit 148 while on the West TDRS satellite and on orbit 153 on the East TDRS satellite. The Ku-band system recovered normal operation from both events without power cycling the system. During the 24 hours prior to stowing the Ku-band antenna, several additional occurrences of the Ku-band system failing to detect and track the forward link were noted. In each instance, the Ku-band system recovered normal operation. Postflight testing of the Ku-band system will be performed in an effort to isolate the cause of this problem.

Operational Instrumentation/Modular Auxiliary Data System

The operational instrumentation (OI) and modular auxiliary data system (MADS) performed satisfactorily throughout the mission. No in-flight anomalies were identified from the data evaluation.

Structures and Mechanical Subsystems

The structures and mechanical subsystems performed satisfactorily throughout the mission with one in-flight anomaly identified from the review of the data. This anomaly discussed in a following paragraph. The following table presents the landing and braking parameters for the flight.

LANDING AND BRAKING PARAMETERS

| Parameter | From Threshold, Ft | Speed, Keas | Sink rate, ft/sec | Pitch rate, deg/sec |
|---------------------------|---------------------|---------------------|-----------------------------|---------------------|
| Main gear touchdown | 2273.2 | 198.1 | -0.55 | N/A |
| Nose gear touchdown | 5463.8 | 148.3 | N/A | -4.9 |
| Brake initiation speed | | N/A | | |
| Brake-on time | | 52.91 seconds | | |
| Rollout distance | | 13127.3 feet | | |
| Rollout time | | 97.95 seconds | | |
| Runway | | 15 (Concrete) KSC | | |
| Orbiter weight at landing | | 210,020.7 lb | | |
| Brake sensor Location | Peak Pressure, Psia | Brake assembly | Gross energy, million ft-lb | |
| Left-hand inboard 1 | 779.4 | Left-hand inboard | 6.64 | |
| Left-hand inboard 3 | 779.4 | | | |
| Left-hand outboard 2 | 622.5 | Left-hand outboard | 3.71 | |
| Left-hand outboard 4 | 622.5 | | | |
| Right-hand inboard 1 | 779.4 | Right-hand inboard | 4.39 | |
| Right-hand inboard 3 | 779.4 | | | |
| Right-hand outboard 2 | 720.6 | Right-hand outboard | 4.73 | |
| Right-hand outboard 4 | 720.6 | | | |

The payload bay doors were opened at 193:10:45:12 G.m.t. (00:01:41:13 MET). All voltages were nominal and the motors opened the doors in nominal dual-motor time.

The payload bay doors were closed and latched for the nominal end-of-mission Kennedy Space Center (KSC) landing opportunities at 205:00:54:40 G.m.t. (11:15:50:41 MET). Both KSC landing opportunities on the planned landing day was waived because of unacceptable weather conditions. The payload bay doors were reopened. The payload bay doors were closed and latched on the first extension day at 206:00:01:09 G.m.t. (12:14:57:10 MET) in preparation for landing on the first KSC opportunity.

During entry when the Orbiter vent doors were opened, the left-hand vent door 8 and 9 closed indications went off and the motor 1 open indication came on as expected. However, the motor 2 open-indication failed off and the motor continued to run (Flight Problem STS-104-V-04). After driving for 10 seconds, the motor was shut down by the software. The motor 2 open-indication came on approximately 1 minute and 45 seconds later.

Integrated Aerodynamics, Heating and Thermal Interfaces

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

Thermal Control Subsystem

The heater system performance and purge air maintained hardware within acceptable limits during the prelaunch period. The thermal control subsystem (TCS) performed within satisfactory limits throughout the mission. One in-flight anomaly was identified and it is discussed in the following paragraph.

The temperature of the coldplate return line for the forward bulkhead floodlight reached 36 °F during rendezvous and docking (Flight Problem STS-104-V-01). Previous OV-104 flight data shows significantly colder temperatures on this line than on other vehicles. Flight data from OV-103 and OV-105 show temperatures above 60 °F. The data indicates that OV-104 may have a configuration problem with the water-loop insulation being incorrectly installed and/or the sensor being incorrectly located. The line needs to be maintained above 32°F to avoid freezing the water. A plan was implemented to increase water coolant loop 1 pump cycles from 1 cycle every four hours to one cycle every hour for the remainder of the flight.

The FES feedline system A (port side of vehicle) string 1 heater failed after docking. The heaters were switched to string 2 and these heaters operated properly for the remainder of the mission.

The entry interface (EI) temperatures and main landing gear tire pressures were maintained within acceptable limits.

Aerothermodynamics

Structural thermocouple temperature data, aileron deflection data, and yaw thruster firings all indicated a normal symmetric boundary layer transition. The surface data on the centerline location indicates transition from laminar flow to turbulent flow occurred at Mach 7.0 (1287 seconds after entry interface). All centerline fuselage thermocouples recorded similar onset times. The acreage heating data indicate that the vehicle experienced normal entry heating. Local heating was also normal.

Thermal Protections Subsystem and Windows

The thermal protection subsystem (TPS) performed satisfactorily. Both the total number of Orbiter TPS damage sites and the number of damage sites one-inch or larger were well within the established family of experience.

Entry heating was normal based on lower-surface structural temperature response data. Boundary layer transition from laminar flow to turbulent flow was nominal and occurred at Mach 7.0 or 1287 seconds after entry interface (EI).

The postlanding inspection of the Orbiter TPS identified a total of 126 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 the flame arrestment sparkler system, SSME vibration/acoustics and exhaust plume recirculation. 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 | 24 | 108 |
| Upper Surface | 0 | 0 |
| Window Area | 0 | 14 |
| Right Side | 0 | 0 |
| Left Side | 0 | 0 |
| Right OMS Pod | 0 | 0 |
| Left OMS Pod | 2 | 4 |
| Total | 26 | 126 |

The Orbiter lower surface sustained 108 hits of which 24 had a major dimension of 1-inch or larger. Approximately 39 damage sites (8 larger than 1-inch in length) were located in the area from the nose gear to the main landing gear wheel wells. More damage occurred on the right-hand side than on the left-hand side. Damage sites in this area were most likely caused by ice/frost from the LO₂ feedline or foam debris. ET thermal protection subsystem (TPS) venting modifications continue to have a reducing effect on the quantity and size of the damage sites.

The largest lower-surface tile damage site was located inboard of the liquid hydrogen (LH₂) umbilical area where 42 damage sites were found. The damage site measured 4 ½ inches in length by ¾ inch in width by 0.250 inch in depth.

Typical amounts of tile damage occurred on the base heat shield. All SSME dome heat shield closeout blankets were in good condition although some small torn places in the material were noted.

The tiles on the OMS pods and vertical stabilizer had a typical amount of damage. A four-inch long segment of gap filler material was protruding approximately 0.5 inch from the left-hand OMS pod tiles.

Two pieces of Ames gap filler, were found on the runway under the nose landing gear wheel. Each piece was approximately 5 inches in length and 1 inch in width. There was no indication of entry heating or tile damage.

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 -96 | STS -93 | STS -103 | STS -101 | STS -92 | STS -97 | STS -98 | STS- 102 | STS- 100 | STS- 104 |
|--------------------------------|------------|------------|-------------|-------------|------------|------------|------------|-------------|-------------|-------------|
| Lower surface Total hits | 160 | 161 | 84 | 70 | 86 | 78 | 73 | 44 | 42 | 108 |
| Lower surface Hits > 1 in. | 66 | 42 | 13 | 19 | 14 | 10 | 8 | 10 | 4 | 24 |
| Longest damage Site, in. | 4.0 | 6.0 | 1.5 | 8 | 2 | 3 | 3 | 1 | 2.5 | 4.5 |
| Deepest damage Site, in. | 0.5 | 0.5 | 0.25 | 0.75 | 0.75 | 0.5 | 0.5 | 0.125 | 0.125 | 0.250 |

Gas Sample Analysis

The STS-104 mission was a successful flight for the gas sample bottles. The hardware provided five excellent gas samples. The sixth sample, bottle 3 right, had 4.14 percent hydrogen. This level is still within the nominal range over the history of all vehicles: however, it is the highest reading obtained from this vehicle. The data from the last four flights of this vehicle have shown an increasing trend in hydrogen in the last sample. The bottle-pressures were in the expected range. The oxygen data were within the bands of error as determined by the argon measurement, and the amount detected can be attributed to air.

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

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

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

EXTRAVEHICULAR ACTIVITY

Three extravehicular activities (EVAs) were successfully performed with all tasks being completed plus a number of get-ahead tasks in preparation for the following flights.

During the extravehicular mobility unit (EMU) checkout, when the crew began removing the lithium hydroxide (LiOH) canister from EMU 3, a white pasty substance was found between the battery and the portable life support system (PLSS). The photographs downlinked were consistent with a potassium hydroxide (KOH) leak from the battery stored in this EMU. The crew performed a cleanup of the EMU, double-bagged the battery that had leaked and stowed the battery in the wet trash. Evaluations of the potential mission impacts that may result from the leaking potassium hydroxide (KOH) electrolyte from the battery were made. Each of the remaining batteries in EMUs 1 and 2, as well as the stowed batteries, was inspected and no signs of leaking electrolyte were found. It was concluded that with the exception of the EMU 3 battery that had leaked, all of the remaining EMU batteries were acceptable for use. In addition, the decision was made to not perform any cleaning of EMU 3. The EMU was not transferred to the International Space Station (ISS) and was instead returned on this mission.

FIRST EXTRAVEHICULAR ACTIVITY

The first extravehicular activity (EVA) was successfully completed with the airlock being installed on the ISS. Both EMUs performed nominally during the 5-hour 59-minute EVA. The ISS airlock was unberthed from the Orbiter payload bay and installed onto Node 1. The other planned tasks completed were airlock passive common berthing mechanism (PCBM) cover removal, towel bar installation, launch-to-activation jumper cable removal, starboard CBM inspection, airlock-to-node jumper cable mating, setup of oxygen and nitrogen tank orbital replacement unit (ONTO) worksite, and payload bay cleanup. In addition four get-ahead tasks were attempted, three of which were successful. These tasks included an inspection and photography of pressurized mating adapter 2 and reattachment of loose Velcro, opening of the Node nadir CBM window cover, and evaluation the P601 connector soft-dock configuration. The attempt to remove the P608 connector cap was unsuccessful.

During the EVA, the crew reported that the handhold that was to be attached to the seat track on the airlock could not be attached properly as only one bolt could be secured. The bolthole for the second bolt did not align properly. The handhold was brought into the crew cabin for troubleshooting. The crew inspection showed that the spring detent on the handhold shoe was not functioning properly (failed in extended position) and this prevented the handhold from moving into the soft-dock position on the seat track. The handhold was stowed for return in the same location as it was stowed for launch.

On the day following the first EVA, EMU 2 was transferred to the ISS airlock for checkout.

SECOND EXTRAVEHICULAR ACTIVITY

The second EVA of the mission was completed satisfactorily. All EMU hardware and tools performed nominally during the 6-hour 29-minute EVA. Two high-pressure gas tanks (oxygen) were installed on the airlock as planned. Since adequate EVA time remained; the crew performed a task planned for the third EVA by installing a third high-

pressure gas tank (nitrogen). In addition, a flight-releasable grapple fixture (FRGF) was installed, and three of four trunnion covers were installed.

THIRD EXTRAVEHICULAR ACTIVITY

The Mission Management team approved a recommendation to extend the mission one day to provide an additional docked day prior to performing the third EVA.

EMU 1 was transferred to the airlock in preparation for the third EVA. A depressurization and repressurization cycle of the equipment lock was satisfactorily completed. Also a leak check of the crew lock was successfully performed.

The third EVA of the mission, and the first conducted out of the ISS airlock, was satisfactorily completed. Both EMUs performed nominally during the 4 hour 1 minute EVA. The fourth high-pressure gas tank was installed on the airlock during the EVA. Also, an inspection of the bearing motor roll-ring module (BMRRM) and the FPP LED were performed. The Unity emblem label was photographed and the super bolt cover on the FRGF was closed. The fourth trunnion-cover and the fourth HPGT FRGF cover were installed

After the EMU power transfer from battery to the servicing and cooling umbilical (SCU) following the return to the airlock, the EMU 2 display and control module (DCM) display appeared blank and would not respond. The crewmember continued to receive the expected alert tones during the repressurization. A warm restart of the EMU was performed during the post-EVA operations and the DCM display problem cleared. This is a known condition and has occurred during previous flights, and a workaround procedure is in place to correct the problem.

REMOTE MANIPULATOR SYSTEM

The remote manipulator system (RMS) performed satisfactorily during the mission and was used to support all three extravehicular activities (EVA). STS-104 was the sixty-second flight of the Shuttle RMS and the seventh flight of arm 202.

The RMS was powered on flight day (FD) 2 at 194:01:59 G.m.t. (00:16:55 MET) to perform the RMS checkout. The checkout was temporarily suspended while a payload bay survey and wastewater dump survey were performed. Following completion of the surveys and a successful checkout, the RMS was powered down.

Following docking with the International Space Station (ISS), the arm was powered to participate in an Airlock trajectory dry run. The dry run was satisfactory.

The arm supported the first EVA on flight day 4. During the EVA, two joint slips were detected. The first slip was detected when a crewmember was ingressing the articulating portable foot restraint (APFR) in preparing the Airlock for unberthing from the payload bay. The second joint slip was detected when that same crewmember egressed the APFR. This type of error is displayed when joint angle changes greater than 0.5 degree are observed while the brakes are on. The shoulder pitch joint brake slip was approximately 0.52 degree and the elbow joint brake slip was approximately 0.64 degree. This error is not unexpected during these types of EVA operations, as errors of this type have been seen on nine previous missions. The RMS arm brakes are designed to slip before any loads could damage the arm, and the brake slip is not indicative of RMS brake degradation.

On FD 7, the arm was powered to support the second EVA. During this EVA, the arm supported the installation of the three high-pressure gas tanks (HPGTs). The RMS was cradled approximately 8 hours 30 minutes after the power was applied.

On FD10, the arm was powered to support the third EVA, which was performed from the new ISS joint Airlock. The final HPGT was installed on the Airlock. The arm was cradled and powered down after approximately 4 hours of operation.

The arm was stowed on flight day 11 as no more RMS activities were planned for the STS-104 mission.

GOVERNMENT FURNISHED EQUIPMENT/FLIGHT CREW EQUIPMENT

The Government furnished equipment (GFE) and flight crew equipment (FCE) performed nominally throughout the mission. Minor problems were noted, but no in-flight anomalies were identified from the data.

The Orbiter space vision system (OSVS) checkout was performed and during the checkout, the liquid crystal display monitor went blank. The crew cycled the power and regained the OSVS.

The trajectory control system (TCS) performance during the rendezvous and docking operations with the ISS was nominal. The TCS was energized at a range of 2.5 miles and provided accurate range and range-rate data throughout its operational period. The trajectory control system (TCS) was used following undocking and performed nominally. The TCS provided valid data throughout the flyaround activities and out to a range of 463 ft. At that range, the TCS lost track and was deactivated.

When the sequential still video (SSV) was checked out, it appeared to function nominally upon activation. However, when its use was attempted during rendezvous and docking on flight day (FD) 3, it did not operate. The crew reported that there were no light emitting diodes (LEDs) lit and that the compression encoder box was hot. The ground controllers asked the crew to reseal the cable connectors, but the SSV was not recovered. On FD 5, it was reported that the crew completed a change-out of the compression encoder box internal 2-ampere fuse (as per the SSV malfunction procedure in the Photo/TV Checklist), cycled the power to the encoder box, and reseated the cable connectors. The SSV was recovered and functioned nominally. In flight day 5 it was reported that the crew had completed a change-out of the compression encoder box internal fuse, power cycled the box and reseated cable connectors. The SSV was recovered and functioned properly for the remainder of the flight.

The crew experienced a loss of video downlink caused by a known problem with the interface of the PD100 camcorder video output connector and cable. This problem occurred on both the Public Affairs and the International Space Station (ISS) dedicated camcorders. During the preflight preparations, the crew was briefed to wiggle the video cable until a good signal was achieved and then the cable was to be taped in place.

SPACE-TO-SPACE COMMUNICATIONS SYSTEM

The Space-to-Space Communications System (SSCS) performed very well during the three extravehicular activities (EVAs). No anomalies were noted in the course of the three EVAs.

The operation of the SSCS was verified with all three extravehicular mobility units (EMUs). The crew was very pleased with the quality of the communications using these units.

The first operational use of the SSCS was during the pre-docking and docking activities. The radios were powered in the ISS and the Orbiter when the Orbiter was about 32 kilometers from the ISS. At approximately 10 kilometers distance between the Orbiter and ISS, the radios locked on to each other, a condition that was maintained without a break throughout the remainder of the closure and docking activities.

A configuration problem with the ISS audio caused an echo during the pre-EVA communications checkout for the second EVA. The ISS radio was powered while the Shuttle-ISS audio hard-line was still enabled. As a consequence, the communications checkout audio was fed through both paths (hard-line and RF) causing an echo. Just prior to egress for the EVA, the hard-line link was disabled and the SSSR was configured to provide audio between the Shuttle and ISS. The SSCS radios operated nominally during the EVA with no lost audio and a solid frame synchronization throughout the EVA. As a result, the EVA communications configuration documentation will be updated to ensure that the Shuttle to Space Station radio (SSSR) audio is not enabled while the Shuttle-ISS hard-line link is still in use.

POSTLAUNCH LAUNCH PAD INSPECTION

The postlaunch inspection of the mobile launch platform (MLP) -2, Launch Pad B, Fixed Service Structure (FSS) and Rotating Service Structure (RSS) was successfully completed approximately 4 hours after the launch. No flight hardware was found.

The Orbiter liftoff lateral acceleration data to predict stud hang-ups indicated that no hang-up had occurred. Erosion was typical for the north posts. North holddown post blast covers and the T-0 umbilical exhibited typical exhaust plume damage. Both SRB aft skirt gaseous nitrogen purge lines were intact, with no protective tape layering evident.

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

The GH₂ vent line latched in the fourth of eight teeth of the latching mechanism. The ground umbilical carrier plate (GUCP) 7-inch quick disconnect (QD) sealing surface exhibited no damage. A 4-inch section of the peripheral seal was missing from the aft (bottom) location. The deceleration cable was in the nominal configuration, and the vent line blanket was sooted, but in generally good condition.

The Orbiter Access Arm (OAA) was intact with no evidence of plume impingement. All slide-wire baskets were secured in place.

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

Overall, the damage to the FSS/RSS and MLP appeared to be minimal. Minimal debris was noted of the pad apron and FSS.

DEVELOPMENT TEST OBJECTIVES/DETAILED SUPPLEMENTARY OBJECTIVES

DEVELOPMENT TEST OBJECTIVES

DTO 261 - International Space Station On-Orbit Validation – The Orbiter reaction control subsystem (RCS) thrusters were fired to complete the requirements of development test objective (DTO) 261 in support of the International Space Station (ISS). The ISS relinquished attitude control to the Orbiter at 198:00:59 G.m.t. (04:15:55 MET) in support of this DTO. Five primary RCS thruster pulses were performed with 200 seconds between each pulse. The ISS resumed attitude control at 198:04:07 G.m.t. (04:19:03 MET). Structural dynamic data acquired by the Orbiter inertial measurement unit (IMU) was downlinked, processed and provided to the ISS evaluation personnel. The structural dynamic properties recovered from the flight data indicate that the results are similar to the results measured during the STS-102 mission.

DTO 262 - On-Orbit Bicycle Ergometer Loads Measurement - This DTO was performed successfully by an Orbiter crewmember pedaling the Shuttle ergometer at a varying frequency with simultaneous video taping of the exercise. ISS data system data recovery was not successful during the test and this condition was caused by an unsuccessful partial reboot of the data system. This DTO will be rescheduled for a later flight.

DTO 700-14 - Single String Global Positioning System - This miniature air-to-ground receiver (MAGR) DTO was successfully performed in the option where no payload and ground support computer (PGSC) is attached. MAGR performance was nominal throughout ascent, as well as during orbit and docked operations. Ground personnel continually monitored the MAGR performance. The scheduled operations 2 test scheduled for flight day 11 was not performed because of crew workload. Since past flights have shown this test to be nominal and as expected, the data loss for this flight was minimal.

The MAGR commanded self-test was performed as planned on flight day 12 during the flight control subsystem (FCS) checkout. The MAGR returned a warning bit at the conclusion of the self-test. However, this same indication has been seen on previous flights and had no impact on the DTO or on MAGR performance.

MAGR performance during entry was acceptable, although the receiver appeared to have suffered from earlier plasma blackout effects. A detailed review of the downlisted data is in progress to determine the actual results of entry operations.

DTO 805 - Crosswind Landing Performance - DTO 805, (a DTO of Opportunity) was not performed because the crosswind conditions did not meet the minimum criteria for this DTO.

DETAILED SUPPLEMENTARY OBJECTIVES

DSO 493 - Monitoring Latent Virus Reactivation and Shedding in Astronauts - Samples were acquired during flight and will be assessed during postflight analysis. The results will be reported following the completion of analysis of the samples.

DSO 496 - Individual Susceptibility to Postflight Orthostatic Intolerance - Data were taken during the preflight and postflight periods as planned. The results of the analysis of these samples will be reported following completion of the analysis of the samples.

DSO 498 - Spaceflight and Immune Function - Samples were taken from the crewmembers during the preflight and postflight periods. The results will be reported following completion of the analysis of the samples.

DSO 634 - Sleep-Wake Actigraphy and Light Exposure During Spaceflight - Data were acquired during flight and will be assessed during postflight analysis. The results will be reported following the completion of analysis of the samples.

DSO 635 - Spatial Reorientation Following Spaceflight - Samples were taken from the crewmembers during the preflight and postflight periods. The results will be reported following completion of the analysis of the samples.

HUMAN EXPLORATION AND DEVELOPMENT OF SPACE TECHNOLOGY DEMONSTRATION

HDT 1403 - Micro-Wireless Instrumentation System - The Micro-WIS sensors/recorders were successfully used to collect thermal data on the Airlock and HPGTs for real-time thermal environment analysis.

PHOTOGRAPHY AND TELEVISION ANALYSIS

The launch photography and video (23 videos and 20 films) were reviewed. The only significant item noted in the film review is discussed in the following paragraph.

Two cameras that were located in the External Tank/Orbiter (EO) umbilical well provided onboard photography of the vehicle during the ascent phase. The crew also photographed the External Tank (ET) after separation. No anomalies or significant missing tile were detected and the ET appeared to be in excellent condition.

The on-orbit photography (13 frames) and video of the External Tank (ET) was reviewed. No anomalous conditions were noted from these data.

The landing video was also reviewed and no anomalous conditions were noted in the review.

TABLE I.- STS-104 SEQUENCE OF EVENTS

| Event | Description | Actual time, G.m.t. |
|---|--|--|
| APU Activation | APU-1 GG chamber pressure APU-2 GG chamber pressure APU-3 GG chamber pressure | 193:08:59:10.583 193:08:59:11.748 193:08:59:12.592 |
| SRB HPU Activation ^a | LH HPU System A start command LH HPU System B start command RH HPU System A start command RH HPU System B start command | 193:09:03:30.961 193:09:03:31.081 193:09:03:31.241 193:09:03:31.401 |
| Main Propulsion System Start ^a | ME-3 Start command accepted ME-2 Start command accepted ME-1 Start command accepted | 193:08:03:52.442 193:09:03:52.562 193:08:03:52.671 |
| SRB Ignition Command (Liftoff) | Calculated SRB ignition command | 193:09:03:59.991 |
| Throttle up to 104.5 Percent Thrust ^a | ME-1 Command accepted ME-2 Command accepted ME-3 Command accepted | 193:09:04:02.651 193:09:04:02.682 193:09:04:02.682 |
| Throttle down to 72 Percent Thrust ^a | ME-1 Command accepted ME-2 Command accepted ME-3 Command accepted | 193:09:04:32.731 193:09:04:32.762 193:09:04:32.762 |
| Maximum Dynamic Pressure (q) | Derived ascent dynamic pressure | 193:09:04:48 |
| Throttle up to 104.5 Percent Thrust ^a | ME-1 Command accepted ME-2 Command accepted ME-3 Command accepted | 193:09:04:55.772 193:09:04:55.802 193:09:04:55.803 |
| Both RSRM's Chamber Pressure at 50 psi ^a | RH SRM chamber pressure mid-range select LH SRM chamber pressure mid-range select | 193:09:05:55.31 193:09:05:56.23 |
| End RSRM ^a Action ^a Time | RH SRM chamber pressure mid-range select LRH SRM chamber pressure mid-range select | 193:09:05:58.07 193:09:05:58.07 |
| SRB Physical Separation ^a | LH rate APU turbine speed - LOS | 193:09:06:00.67 |
| SRB Separation Command | SRB separation command flag | 193:09:06:02 |
| Throttle Down for 3g Acceleration ^a | ME-1 command accepted ME-3 command accepted ME-2 command accepted | 193:09:11:23.459 193:09:11:23.486 193:09:11:23.491 |
| 3g Acceleration | Total load factor | 193:09:11:31 |
| Throttle Down to 72 Percent Thrust ^a | ME-1 command accepted ME-3 command accepted ME-2 command accepted | 193:09:12:17.860 193:09:12:17.887 193:09:12:17.892 |
| SSME Shutdown ^a | ME-1 command accepted ME-3 command accepted ME-2 command accepted | 193:09:12:24.340 193:09:12:24.367 193:09:12:24.372 |
| MECO | MECO command flag MECO confirm flag | 193:09:12:25 193:09:12:25 |
| ET Separation | ET separation command flag | 193:09:12:44 |
| APU Deactivation | APU-1 GG chamber pressure APU 2 GG chamber pressure APU 3 GG chamber pressure | 193:09:20:42.311 193:09:20:57.468 193:09:21:05.872 |

^aMSFC supplied data

**TABLE I.- STS-104 SEQUENCE OF EVENTS
(Continued)**

| Event | Description | Actual time, G.m.t. |
|---|---|---|
| OMS-1 Ignition | Left engine bi-prop valve position Right engine bi-prop valve position | Not performed - direct insertion trajectory flown |
| OMS-1 Cutoff | Left engine bi-prop valve position Right engine bi-prop valve position | Not performed |
| OMS-2 Ignition | Left engine bi-prop valve position Right engine bi-prop valve position | 193:09:42:31.6 193:09:42:31.7 |
| OMS-2 Cutoff | Right engine bi-prop valve position Left engine bi-prop valve position | 193:09:43:35.8 193:09:43:35.9 |
| Payload Bay Doors (PLBDs) Open | PLBD right open 1 PLBD left open 1 | 193:10:43:55 193:10:45:13 |
| OMS-3 Ignition | Left engine bi-prop valve position Right engine bi-prop valve position | 193:12:38:59.9 193:12:39:00.0 |
| OMS-3 Cutoff | Right engine bi-prop valve position Left engine bi-prop valve position | 193:12:40:32.6 193:12:40:32.7 |
| OMS-4 Ignition | Left engine bi-prop valve position Right engine bi-prop valve position | N/A 194:00:15:01.8 |
| OMS-4 Cutoff | Left engine bi-prop valve position Right engine bi-prop valve position | N/A 194:00:15:12.4 |
| OMS-5 Ignition | Right engine bi-prop valve position Left engine bi-prop valve position | 194:10:12:50.2 194:10:12:50.3 |
| OMS-5 Cutoff | Left engine bi-prop valve position Right engine bi-prop valve position | 194:10:14:08.3 194:10:14:08.4 |
| OMS-6 Ignition | Left engine bi-prop valve position Right engine bi-prop valve position | 194:23:01:22.4 194:23:01:22.4 |
| OMS-6 Cutoff | Right engine bi-prop valve position Left engine bi-prop valve position | 194:23:01:59.8 194:23:01:59.8 |
| OMS-7 Ignition | Left engine bi-prop valve position Right engine bi-prop valve position | 195:00:33:18.4 N/A |
| OMS-7 Cutoff | Left engine bi-prop valve position Right engine bi-prop valve position | 195:00:33:31.6 N/A |
| Initial ISS Contact | Initial contact | 195:03:08:03 |
| Docking with ISS | Docking ring final position | 195:03:23:34 |
| Airlock Depressurization (end) | Airlock differential pressure no. 1 | 196:03:07:06 |
| Begin First Extravehicular Activity | Airlock differential pressure no. 1 | 196:03:07:06 |
| Airlock Repressurization (start) | Airlock differential pressure no. 1 | 196:09:09:03 |
| Cabin Repressurization (start) | Cabin pressure | 196:09:44:19 |
| First Reboost Maneuver (start) | As reported | 197:01:18:12 |
| Cabin Depressurization (end) | Cabin pressure | 198:12:17:42 |
| Cabin Repressurization (start) | Cabin pressure | 199:03:02:20 |
| Begin Second Extravehicular Activity | Airlock differential pressure no. 1 | 199:03:02:20 |
| End Second Extravehicular Activity | Airlock differential pressure no. 1 | 199:09:33:40 |
| Airlock Repressurization (start) | Airlock differential pressure no. 1 | 199:09:33:40 |
| Cabin Depressurization (end) | Cabin pressure | 199:10:20:39 |
| Second Reboost Maneuver (start) | As reported | 199:09:59:12 |

**TABLE I.- STS-104 SEQUENCE OF EVENTS
(Continued)**

| Event | Description | Actual time, G.m.t. |
|---------------------------------------|---|--|
| Third Reboost Maneuver (start) | As reported | 200:07:39:00.0 |
| Undocking from ISS | Undock complete | 203:04:54:00 |
| ISS Separation Maneuver (RCS) | As reported | 203:06:15:35.7 |
| Flight Control System Checkout | | |
| APU Start | APU 1 GG chamber pressure | 204:00:31:02.401 |
| APU Stop | APU 1 GG chamber pressure | 204:00:37:21.794 |
| Payload Bay Doors Close | PLBD left close 1 PLBD right close 1 | 205:23:58:32 206:00:00:11 |
| APU Activation for Entry | APU-2 GG chamber pressure APU-1 GG chamber pressure APU-3 GG chamber pressure | 206:02:25:21.176 205:02:53:24.582 205:02:53:25.969 |
| Deorbit Burn Ignition | Left engine bi-prop valve position Right engine bi-prop valve position | 206:02:31:35.2 206:02:31:35.3 |
| Deorbit Burn Cutoff | Left engine bi-prop valve position Right engine bi-prop valve position | 206:02:34:45.6 206:02:34:45.7 |
| Entry Interface (400K feet) | Current orbital altitude above | 206:03:07:09 |
| Blackout end | Data locked (high sample rate) | No blackout |
| Terminal Area Energy Management | Major mode change (305) | 206:03:32:25 |
| Main Landing Gear Contact | LH main landing gear tire pressure 1 RH main landing gear tire pressure 2 | 206:03:38:55 206:03:38:55 |
| Main Landing Gear Weight on Wheels | LH MLG weight on wheels RH MLG weight on wheels | 206:03:38:55 206:03:38:56 |
| Drag Chute Deployment | Drag chute jettison 1 CP Volts | 206:03:38:57.7 |
| Nose Landing Gear Contact | NLG LH tire pressure 1 | 206:03:39:06 |
| Nose Landing Gear Weight On Wheels | NLG weight on wheels 1 | 206:03:39:06 |
| Drag Chute Jettison | Drag chute jettison 1 CP Volts | 206:03:39:38.6 |
| Wheel Stop | Velocity with respect to runway | 206:03:40:36 |
| APU Deactivation | APU-1 GG chamber pressure APU-2 GG chamber pressure APU-3 GG chamber pressure | 206:03 56:45.614 206:03:56:53.667 206:03:57:01.442 |

TABLE II- STS-104 SPACE SHUTTLE VEHICLE ENGINEERING OFFICE IN-FLIGHT ANOMALY LIST

| No. | Title | Reference | Comments |
|--------------|---|---|---|
| STS-104-V-01 | Forward Bulkhead Floodlight Coldplate Return Line Low Temperature | 195:00:32 G.m.t. 01:15:29 MET IPR 110V-0002 | <p>The temperature of the coldplate return line for the forward bulkhead floodlight reached 36 °F during rendezvous and docking. Previous OV-104 flight data shows significantly colder temperatures on this line than on other vehicles. Flight data from OV-103 and OV-105 show temperatures above 60 °F. The data indicates that OV-104 may have a configuration problem with the water-loop insulation being incorrectly installed and/or the sensor being incorrectly located. The line need to be maintained above 32 °F to avoid freezing the water. A plan was implemented to increase water coolant loop 1 pump cycles from one cycle every four hours to one cycle every hour to ensure that freezing does not occur.</p> <p>KSC: During KSC troubleshooting, blankets were removed and inspected. The inspection revealed a section of line approximately 10 inches long that was not wrapped with the LT-80 aluminum tape at the temperature sensor location.</p> |
| STS-104-V-02 | FES Hi-Load and Accumulator Feedline A System 1 Heater Failed Off | 196:22:34 G.m.t. 03:22:34 MET IPR 110V-0001 | <p>At approximately 196:22:34 G.m.t. (03:13:30 Met), the FES high-load and accumulator feedline A system 1 heater failed to cycle on when expected. The accumulator line temperature sensor, which is located near the thermostat, typically indicates no less than 64 °F prior to the heater cycling on. The accumulator line temperature dropped to 53 °F at which time the system 2 heater was selected and nominal heater cycling was observed. The high-load line temperature sensor, which typically indicates no less than 120 °F dropped to 89 °F prior to selection of the system 2 heater. There was no mission impact.</p> <p>KSC: Troubleshooting will be performed.</p> |

TABLE II- STS-104 SPACE SHUTTLE VEHICLE ENGINEERING OFFICE IN-FLIGHT ANOMALY LIST

| | | | |
|--------------|--|---|---|
| STS-104-V-03 | Loss of Ku-band Forward Link | 201:10:39 G.m.t. 08:01:35 MET | <p>On orbit 127 at acquisition of signal (AOS) of the Tracking and Data Relay (TDRS) West Satellite, the Ku-band system was powered up from standby and acquired the forward link as indicated by a strong automatic gain control (AGC) signal of -90 dBm. However, the electronic assembly 1 did not indicate either detect or track. After unsuccessful attempts to recover normal operations by commanding different antenna steering modes, the crew was requested to cycle the Ku-band ELEC and SIG PROC circuit breakers on panel R 14. The crew then powered the system back on and normal operations were recovered.</p> <p>Two additional occurrences of the Ku-band failing to detect and track the forward link occurred later in the flight. The events occurred on orbit 148 while on the West TDRS and on orbit 153 on the East TDRS satellite. The Ku-band system recovered normal operations from both events without power cycling the system. Subsequent to these occurrences, there were several additional failures of the system to detect and track the forward link on flight day 12.</p> <p>KSC: Troubleshooting will be performed.</p> |
| STS-104-V-04 | Left-Hand Vent Door 8 and 9 Motor 2 Open Indication Failed Off | 206:03:32 G.m.t. 12:18:28 MET IPR 110V-0007 | <p>After entry interface (EI) when the Orbiter vent doors were opened at 206:03:32:32 G.m.t. (12:18:28:33 MET, the left-hand vent door 8 and 9 closed indications went off and the motor 1 open indication came on as expected. However, the motor 2 open indication failed off and the motor continued to run. The software turned off the motor after driving for 10 seconds. The motor 2 open indication came on approximately 1 minute 45 seconds later.</p> <p>KSC: Troubleshooting was performed, and the data are under review.</p> |

DOCUMENT SOURCES

In an attempt to define the official as well as the unofficial sources of data for the STS-104 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-104 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.

| | |
|-----------------|--|
| ADTA | air data transducer assembly |
| AGC | automatic gain control |
| A/L | Airlock |
| AOS | acquisition of signal |
| APDS | Androgynous Peripheral Docking 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 |
| BBND | |
| BMRRM | bearing motor roll-ring module |
| CBC | C-band controller |
| CBM | common berthing mechanism |
| CEI | contract end item |
| CO ₂ | carbon dioxide |
| CSR | Customer Support Room |
| CWC | contingency water container |
| DAP | digital autopilot |
| dBm | decibel per meter |
| DCM | display and control module |
| DCSU | Direct current switching unit |
| DFRC | Dryden Flight Research Center |
| DSO | Detailed Supplementary Objective |
| DTO | Developmental Test Objective |
| ΔV | differential velocity |
| ECLSS | environmental control and life support system |
| e.d.t. | eastern daylight time |
| EI | entry interface |
| EMU | extravehicular mobility unit |
| EO | ET/Orbiter |
| EOM | end of mission |
| EPDC | electrical power distribution and control |
| ET | External Tank |
| EV1, EV2 | extravehicular crewmember designation |
| EVA | extravehicular activity |
| EVR | extravehicular robotics |
| FCMS | fuel cell monitoring system |
| FCP | fuel cell powerplant |
| FCS | flight control system/subsystem |
| FD | flight day |
| ES | flash evaporator system |
| FOM | figure of merit |
| FPP | Floating Potential Probe |

| | |
|--------------------|--|
| FSS | Fixed Service Structure |
| ft/sec | feet per second |
| GDOP | geometric dilution of precision |
| GEI | ground environmental instrumentation |
| GFE | Government furnished equipment |
| GH ₂ | gaseous hydrogen |
| G.m.t. | Greenwich mean time |
| GN ₂ | gaseous nitrogen |
| GNC | guidance navigation and control |
| GO ₂ | gaseous oxygen |
| GPC | general purpose computer |
| GPS | Global Positioning System |
| GSE | ground support equipment |
| GUCP | ground umbilical carrier plate |
| HHM | hand-held microphone |
| HPGT | high-pressure gas tank |
| IATCS | internal active thermal control system |
| ICBC3D | IMAX Cargo Bay Camera Three Dimension |
| IMAX3D | Three-Dimension Camera system |
| IMU | inertial measurement unit |
| IMV | inter-module ventilator |
| IREDD | ISS Resistive Exercise Device |
| I _{sp} | specific impulse |
| ISS | International Space Station |
| IV | intravehicular |
| IWIS | Internal Wireless Instrumentation System |
| JSC | Johnson Space Center |
| keas | knots estimated air speed |
| KOS | potassium hydroxide |
| KSC | Kennedy Space Center |
| kW | kilowatt |
| kWh | kilowatt/hour |
| lbm | pound mass |
| lb/min | pound per minute |
| LCC | Launch Commit Criteria |
| LED | light emitting diode |
| LH ₂ | liquid hydrogen |
| LiOH | lithium hydroxide |
| LMSO | Lockheed Martin Space Operations |
| LO ₂ | liquid oxygen |
| MADS | Modular Auxiliary Data System |
| MAGR | Miniature Air to Ground Receiver |
| Max q _α | maximum dynamic pressure |
| MC | midcourse correction (rendezvous maneuver) |
| MCIU | master control interface unit |
| MCC | Mission Control Center |
| MCOR | medium-rate communications outage records |
| MDM | multiplexer/demultiplexer |
| MECO | main engine cutoff |
| MER | Mission Evaluation Room |

| | |
|-------------------|---|
| MET | mission elapsed time |
| METOX | meta oxide |
| Micro-WIS | Micro-Wireless Instrumentation system |
| MILA | Merritt Island launch area |
| MLP | Mobile Launch Platform |
| MLS | microwave landing system |
| mmHg | millimeter mercury |
| MPEV | manual pressure equalization valve |
| MPLM | Multi-Purpose Logistics Module |
| MPS | main propulsion system\ |
| msec | millisecond |
| MSFC | Marshall Space Flight Center |
| NASA | National Aeronautics and Space Administration |
| NC, NC2, NCC | circularization maneuvers (rendezvous maneuver) |
| NC3, NC4 | circularization maneuvers (rendezvous maneuver) |
| nmi. | nautical mile |
| NPSP | net positive suction pressure |
| O ₂ | oxygen |
| OAA | Orbiter Access Arm |
| ODS | Orbiter Docking System |
| OI | operational instrumentation |
| OMRSD | Operations and Maintenance Requirements and Specifications Document |
| OMS | orbital maneuvering subsystem |
| ONTO | Orbital replacement unit |
| ORCA | oxygen recharge compressor assembly |
| OSVS | Orbiter Space Vision System |
| OV | Orbiter Vehicle |
| PCBM | passive common berthing mechanism |
| PCMCIA | |
| PDGF | power and data grapple fixture |
| PGME | Propylene Glycol Monomethyl Ether |
| PGSC | payload and ground support computer |
| PLSS | portable life support system |
| 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 |
| psia | pound per square inch absolute |
| psid | pound per square inch differential |
| PWR | payload water reservoir |
| QD | quick disconnect |
| RCS | reaction control subsystem |
| RF | radio frequency |
| RMS | Remote Manipulator System |
| RSRM | Reusable Solid Rocket Motor |
| RSS | rotating service structure/range safety system |
| RTLS | return to launch site (abort mode) |
| RTV | room temperature vulcanizing (material) |
| S&A | safe and arm |

| | |
|---------|--|
| SCU | service and cooling umbilical |
| SIGI | Space Integrated Global Positioning system Navigation System |
| SIMPLEX | Shuttle Ionospheric modification with pulsed local exhaust |
| SLF | Shuttle Landing Facility |
| SLWT | super lightweight tank |
| S/N | serial number |
| SRB | Solid Rocket Booster |
| SRSS | Shuttle range safety system |
| SSCS | Space-to-Space Communications System |
| SSME | Space Shuttle main engine |
| SSRMS | Space Station Remote Manipulator System |
| SSSR | Space-to-Space Station Radio |
| SSV | sequential still video |
| STS | Space Transportation System |
| SWAR | Sea water activated release |
| TACAN | Tactical Air Navigation |
| TCS | trajectory control sensor |
| TDRS | Tracking and Data Relay Satellite |
| TI | transfer injection |
| TPS | thermal protection system/subsystem |
| TSM | tail service mast |
| TVIS | treadmill vibration isolation system |
| V | Volts |
| VSC | video signal recorder |
| WCL | water coolant loop |
| WCS | waste collection system |
| WDVA | water dispenser valve assembly |
| WSB | water spray boiler |