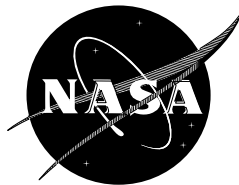


STS-132 SPACE SHUTTLE MISSION REPORT

November 2010



**National Aeronautics and
Space Administration**

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

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STS-132
SPACE SHUTTLE MISSION REPORT

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STS-132 SPACE SHUTTLE MISSION REPORT

INTRODUCTION

The Space Transportation System (STS) -132 Space Shuttle Mission Report presents a discussion of the Orbiter activities on the mission, as well as a summary of the External Tank (ET), the Reusable Solid Rocket Booster (RSRB), the Reusable Solid Rocket Motor (RSRM) and the Space Shuttle Main Engine (SSME) performance during the 132nd mission of the Space Shuttle Program. STS-132 was the 19th mission since the return to flight following the STS-107 mission, and the 34th mission to the International Space Station (ISS). STS-132 was also the 32nd flight of the Orbiter OV-104 vehicle.

The purposes of this mission were to deliver the Russian-built Mini Research Module-1 (MRM-1) that will provide additional storage space and a new docking port for Russian Soyuz and Progress spacecraft. MRM-1, also known as Rassvet, which means dawn in Russian, will be permanently attached to the bottom port of the ISS Zarya module. MRM-1 carried important hardware on its exterior including a radiator, airlock and a European robotic arm. Also the Integrated Cargo Carrier – Vertical Lightweight Deployable – 2 (ICC-VLD-2) was deployed and returned to the Payload Bay. Also, the crew performed three Extravehicular Activities (EVAs). The STS-132 mission, as of the writing of this report; was the final scheduled flight for Atlantis (104) vehicle.

The primary objectives of the STS-132 mission were as follows:

1. Rendezvous and dock with the ISS.
2. Activate, checkout and install the MRM-1 to the Zarya nadir interface.
3. Transfer mandatory quantities of water to the ISS.
4. Transfer critical items as defined in the Transfer Priority List (TPL).
5. Install the Space-to-Ground Antenna (SGANT) and the SGANT boom on the Z1 truss.
6. Install the Enhanced Orbital Replacement Unit (ORU) Temporary Platform (EOTP) on the Special Purpose Dexterous Manipulator.
7. Replace the six Port 6 (P6) batteries from the ICC-VLD-2 with new batteries and return the used batteries that were placed on the ICC-VLD-2 and returned to the Payload Bay for return to Earth.

The flight vehicle consisted of the OV-104 Orbiter; the ET, a Super Lightweight Tank (SLWT) designated ET-136; three Block II SSMEs that were designated as serial numbers (S/Ns) 2052, 2051, and 2047 in positions 1, 2 and 3, respectively; and two RSRBs that were designated BI-143. The two RSRMs were designated flight set RSRM-111. The individual RSRMs were S/N 360W111A (left) and S/N 360W11B (right). Launch pad 39A and Mobile Launch Platform (MLP) -3 were used as the platform for launch of the STS-132 mission.

All times during the flight are given in Greenwich Mean Time (GMT) and Mission Elapsed Time (MET). Appendix A contains the sequence of events. Appendix B provides a table containing all Orbiter, SRB, ET, and Integration In-Flight Anomalies (IFAs) and their status at the time of the publication of this report. Appendix C provides a list of sources of data, both formal and informal, that were used in the preparation of this report. Appendix D provides a list of acronyms, abbreviations and definitions as used throughout this report.

The six crewmembers that were on the STS-132 flight were Kenneth T. Ham, Captain, U. S. Navy, Commander; Dominic A. Antonelli, CDR, U.S. Navy, Pilot; Garrett E. Reisman, PhD, Civilian, NASA, Mission Specialist 1; Michael T. Good, Civilian, NASA, Mission Specialist 2; Stephen G. Bowen, Captain, U. S. Navy, Mission Specialist 3; and Piers J. Sellers, Civilian, NASA, Mission Specialist 4.

STS-132 was the third flight for the Mission Specialist 4, the second flight for the Commander, Pilot, Mission Specialist 1, Mission Specialist 2 and Mission Specialist 3.

MISSION SUMMARY

The objectives of the STS-132 mission included the installation, activation and checkout of the Mini-Research Module (MRM), deployment and return of the Integrated Cargo Carrier-Vertical Lightweight Deployable-2 (ICC-VLD-2), transferring the mandatory quantities of water and performing three Extravehicular Activities (EVAs).

Pre-Launch Up to 134/18:20:08.991

During the closeout inspection prior to the final closing of the Payload Bay Doors (PLBD), a ball bearing was found on a 1307 bulkhead blanket. The bearing was approximately 0.125 in. in diameter and weighed less than a tenth of a gram. No source was initially identified. Approximately 2 hr before launch, a pip-pin used to hold one of four payload bay cameras to the shelf was identified as a possible source. There are three pins on each of the two aft cameras and four pins on each of the two forward cameras. A review of the failure history, installation verification, and design tolerances was performed to determine the likelihood of one of these pins losing a ball bearing. While the likelihood was determined to be very low, the team further evaluated the ability of the pin to engage its locking feature with one ball bearing missing. This analysis confirmed good locking function.

Thirty seconds prior to the launch, a Multifunction Display Unit (MDU) in Cathode Ray Tube (CRT) 1 slot reported a CRT 1 Built-In Test Equipment (BITE) Fail with a detailed error of "Luminance Control Loop Fail". The error cleared 7 min 51sec later. The error repeated two additional times. Setting the brightness to the maximum condition can cause the error as backlight bulb luminance output reduces due to unit age. In this case, the error will clear once the MDU brightness is manually decreased by the user.

Flight Day 1 134/18:20:08.991 - 135/08:20

The STS-132 mission was launched at 134/18:20:08.991 Greenwich Mean Time (GMT) on May 14, 2010, and it was the 34th Space Shuttle Program (SSP) mission to the International Space Station (ISS). No problems or issues were noted during the ascent phase. This was the 132nd flight of the Space Shuttle Program and the 32nd flight of Atlantis. The launch occurred on the first launch attempt.

The Reusable Solid Rocket Booster (RSRB) shutdown occurred at 134/18:22:09 GMT [00/00:02:06 Mission Elapsed Time (MET)] and the separation was visible. A nominal Orbital Maneuvering System (OMS) assist maneuver was performed following RSRB separation. Ignition occurred at 134/18:22:24.3 GMT (00/00:02:16 MET) and the maneuver was 90.2 sec in duration.

Main Engine Cutoff (MECO) occurred at 134/18:28:34 GMT (00/00:08:32 MET). The External Tank (ET) separated from the Orbiter at 134/18:28:56 GMT (00/00:08:47 MET).

A nominal OMS-2 maneuver was performed at 134/18:58:24.1 GMT (00/0038:16.2 MET). The maneuver was 63.0 sec in duration with a Differential Velocity (ΔV) of 96.5 ft/sec. The achieved orbit was 85.1 by 124.7 nmi.

The payload bay doors were opened at 134/19:52:09 GMT (00/01:34:00 MET). The Ku-Band antenna was deployed and the self-test was completed with satisfactory results.

The Shuttle Remote Manipulator System (SRMS) On-Orbit Initialization was completed at 134/21:20 GMT (00/03:00 MET). The SRMS power-on was completed at 134/21:42 GMT (00/03:22 MET). SRMS checkout was completed at 134/22:48 GMT (00/04:28 MET). After a brief survey of the payload bay, the SRMS was returned to the Pre-Cradle Position at 134/23:02 GMT (00/04:42 MET). All SRMS activities were nominal.

The Orbital OMS-3 Nominal Correction (NC) 1 maneuver was an OMS two-engine, straight-feed firing performed at 134/21:54:58.9 GMT (00/03:34:50 MET). The firing was 26.2 sec in duration with a ΔV of 40.4 ft/sec. The resulting orbit was 107.9 by 124.7 nmi. OMS performance was nominal.

All Wing Leading Edge (WLE) Impact Detection System (IDS) ascent summary data was successfully downlinked. One indication on the Starboard wing exceeded the 1 Grms reporting criteria. The magnitude observed was 1.65 Grms on panel 6, which has a low-damage category.

Flight Day 2 135/08:20 – 136/07:20

The main activities for Flight Day (FD) 2 included the NC2 and NC3 maneuvers, the Orbiter Boom Sensor System (OBSS) surveys of the Reinforced Carbon-Carbon (RCC), and Orbiter Docking System (ODS) ring extension.

The OMS-4 NC2 maneuver was a dual-engine straight-feed OMS firing that occurred at 135/11:33:02.7 GMT (00/17:12:53.7 MET). The firing time was 10.4 sec with a ΔV of 7.9 ft/sec. The resulting orbit was 109.5 by 126.6 nmi. Engine performance was nominal.

The SRMS maneuver for OBSS grapple started at 135/11:48 GMT (00/17:28 MET), with grapple completed at 135/11:52 GMT (00/17:32 MET). The Starboard RCC survey began with the Flat Field Survey at 135/13:18 GMT (00/18:48 MET). However, after the completion of the Flat Field Survey, the Starboard T0 Umbilical Survey, and the OMS Starboard Pod Survey, the crew had issues setting up the sensor package for the Starboard RCC Survey. It was determined that a cable became pinched while the sensor package was commanded to tilt up, thus limiting the amount of travel (IFA STS-132-V-01). As a result, only the Integrated Sensor Inspection System (ISIS) Digital Camera (IDC) was used during the remaining surveys. The IDC, however, only provided limited coverage of the RCC and tile that is normally imaged during the FD 2 surveys. The Starboard RCC survey was ultimately completed at 135/16:51 GMT (00/22:31 MET). The Nose RCC surveys were completed at 135/18:07 GMT (00/23:47

MET). The Port RCC survey was completed at 135/19:25 GMT (01/04:51 MET). The OBSS was berthed on the starboard sill at 135/20:06 GMT (01/01:46 MET).

The first on-orbit fuel cell purge was a manual purge beginning at 135/14:35 GMT (00/20:15 MET).

The ODS ring extension was completed at 135/18:12:51 GMT (00/23:52:42 MET). No anomalies were noted during the ring extension. The ring extension was performed with nominal dual-motor drive to the initial position of 76.8% ring extension.

The Rendezvous Tools checkout was performed and all systems were nominal. The Trajectory Control Sensor (TCS) was powered on at approximately 135/20:38 GMT (01/02:18 MET) and was powered off at approximately 135/20:48 GMT (01/02:28 MET).

The NC3 maneuver was a Reaction Control System (RCS) -X firing occurring at 135/21:36:22 GMT (01/03:16:13 MET). The firing time was 6.880 sec with a ΔV of 1.7 ft/sec. The resulting orbit was 110.6 by 126.4 nmi.

Both the fuel and oxidizer injector temperatures for the L3D thruster reached 59 °F and 60 °F, respectively, with no indication of thruster heater activation (IFA STS-132-V-02). The adjacent thrusters, L2D and L4D, both indicated nominal thruster heater activation when their injector temperatures reached approximately 75 °F. Both of those thrusters exhibited the distinct signature of 4-5 heater cycles while the injector temperatures of L3D only declined. During the NC3 maneuver, the L3D thruster fired twice. The subsequent soak-back resulted in the thruster temperatures climbing to 72 °F. Given the observed rate of temperature decline of approximately 1 deg/hr, the thruster temperatures were not expected to decline low enough to be a significant issue. Thus, no vehicle attitude or procedural changes were expected to be required.

The crew reported that the ground-initiated printing of the summary timeline message only printed on half of the page before the printer ejected the page and continued printing the remainder of the timeline on the next page. Similar print problems were observed on subsequent flight days. Troubleshooting was not consistently successful, so the crew was asked to manually print the messages onboard.

Flight Day 3 136/07:20 – 137/07:20

The main activities on FD 3 were rendezvous and docking with the ISS.

The first maneuver of the day was the OMS-5 Nominal Height (NH) using both engines. The time of ignition was 136/09:21:56 GMT (01/15:01:47 MET) with the cutoff 84.4 sec later. The maneuver had a ΔV of 132.3 ft/sec, and the resulting orbit was 126.5 by 185.0 nmi. Engine performance was nominal. However, the Left Helium A-Regulator performance was off nominal during pre-maneuver preparation.

During Helium system configuration prior to the NH maneuver, the A-regulator configuration was taken to open and the B-regulator configuration was taken to General Purpose Computer (GPC) control. The initial pressure was low due to previous interconnect operations. Upon repressurization, the oxidizer tank pressure settled to 276.8 psia and the fuel tank pressure settled to 264.8 psia. Using the NC1 maneuver data as a comparison, the pre-maneuver activation oxidizer pressure was 272.8 psia and fuel pressure was 258.4 psia. As a result of the higher pressure on the A-regulator, the ground had the crew close the A regulator and open the B-regulator for the NH maneuver. The B-regulator performed as expected. For the subsequent rendezvous maneuvers, the B-regulator was used while the A-regulator remained closed. Considerations will be made to check out the A-regulator prior to the de-orbit maneuver.

The second maneuver of the day was the OMS-6 NC4, which was a dual-engine firing. The time of ignition was 136/10:08:11 GMT (01/15:48:02 MET) with the cutoff 63.2 sec later. The maneuver had a ΔV of 100.1 ft/sec, and the resulting orbit was 182.4 by 186.4 nmi. Engine performance was nominal.

The Nominal Corrective Combination (NCC) maneuver was a -X RCS firing using the F2F and F3F primary thrusters. The time of ignition was 136/10:42:28 GMT (01/16:22:19 MET). The ΔV delivered was 0.4 ft/sec and the resulting orbit was 181.6 by 185.5 nmi.

As the crew was setting-up for rendezvous and installing the Crew Optical Alignment Sight (COAS), the COAS did not power up after three attempts. The ground controllers verified that there was power when the switch was placed in the on-position. The crew replaced the light-bulb to the COAS and the COAS performance was nominal for the rendezvous.

The Ku-Band antenna was taken to the RADAR mode at 136/10:58:08 GMT (01/16:37:59 MET) and detected the ISS within 7 sec at a range of 132,000 ft. The system began tracking the ISS at 136/10:58:44 GMT (01/16:38:35 MET) at a range of 130,000 ft. The RADAR mode operated as expected and the Communications (COMM) mode was reselected at 136/13:41:25 GMT (01/19:21:16 MET).

The OMS-7 Terminal Initiation (TI) maneuver was a straight-feed, left OMS engine firing. Ignition was at 136/11:40:09 GMT (01/17:20:00 MET) with the cutoff 12.2 sec later. The ΔV delivered was 9.3 ft/sec, and the resulting orbit was 184.2 by 189.6 nmi. Engine performance was nominal.

The Midcourse Correction (MC) 1 maneuver was initiated at 136/12:00:13 GMT (01/17:40:04 MET) and was completed 0.4 sec later. The ΔV delivered was 0.1 ft/sec. The MC2 maneuver was initiated at 136/12:37:06 GMT (01/18:16:57 MET) and was completed 6.8 sec later. The ΔV delivered was 1.6 ft/sec. The MC3 maneuver was performed at 136/12:54:04 GMT (01/18:33:55 MET) and was completed 7.6 sec later. The ΔV delivered was 1.8 ft/sec. The MC4 maneuver was initiated at 136/13:04:04 GMT (01/18:43:55 MET). The maneuver was completed 1.7 sec later. The ΔV

delivered was 0.4 ft/sec. The orbit at the completion of the MC maneuvers was 184.8 by 190.3 nmi.

The TCS began tracking the ISS at a distance of approximately 6129 ft at 136/12:49 GMT (01/18:29 MET). There were several instances of a brief loss of signal from the TCS that averaged approximately 4 sec. The TCS switched back and forth between the Pulse and Continuous Wave (CW) laser beginning at a range of 940 ft. At a range of 523 ft, the CW laser locked on to the ISS and was steady until docking.

The R-bar Pitch Maneuver (RPM) started at 136/13:27:09 GMT (01/19:07:00 MET) and ended at 136/13:35:09 GMT (01/19:15:00 MET). The peak pitch-rate during the maneuver reached approximately 0.7 deg/sec. The maximum attitude excursion was in roll and reached approximately 0.6 deg. Performance was nominal.

The ODS was activated at 136/13:55:07 GMT (01/19:34:58 MET). The Shuttle captured the ISS at 136/14:28:26 GMT (01/20:08:17 MET), and the Post-Contact Thrust (PCT) firing sequence was performed nominally. Ring retraction using dual motors was started at 136/14:35:14 GMT (01/20:15:05 MET) and the retraction was completed without incident. The hooks were driven closed nominally and final ring extension was performed, releasing the capture latches with the ring final-position being acquired at 136/14:43:21 GMT (01/20:23:12 MET).

Handover of attitude control to the ISS occurred at 136/16:05:00 GMT (01/21:44:51 MET).

Hatch opening took place around 136/16:21 GMT (01/22:01 MET).

The SRMS was maneuvered to the Integrated Cargo Carrier Vertical Lightweight Deployable-2 (ICC-VLD-2) Unberth-Viewing position at 136/17:25 GMT (01/23:05 MET). The Space Station Remote Manipulator System (SSRMS) unberthed the ICC from the payload bay at 136/18:53 GMT (02/00:33 MET) and the Mobile Base System (MBS) Payload and Orbital Replaceable Unit (ORU) Accommodation (POA) grappled the ICC at 136/21:08 GMT (02/02:48 MET).

Nitrogen (N₂) transfer was initiated at 136/18:51 GMT (02/00:31 MET).

Following the review of the FD 2 ISIS IDC and FD 3 RPM imagery, and based on data available, the Damage Assessment Team (DAT) determined that there were no requirements for a focused inspection. Options were still being evaluated to provide coverage for areas which were not imaged as a result of the cable issue on the Orbiter OBSS Pan and Tilt Unit (PTU).

Flight Day 4 137/07:20 – 138/06:50

The main activity on FD 4 was the first EVA.

In support of EVA activities, the SRMS was maneuvered to the Space-to-Ground Ku-band Antenna (SGANT) and Enhanced ORU Temporary Platform (EOTP) Viewing position at 137/08:47 GMT (02/14:27 MET).

The second on-orbit fuel cell purge was performed at 137/12:06 GMT (02/17:46 MET). During the 45.5-hour purge interval, the approximate performance decay was 0.2 Vdc for fuel cell 1, 0.2 Vdc for fuel cell 2, and 0.18 Vdc for fuel cell 3.

The first Contingency Water Container-Iodine (CWC-I) was filled at 137/13:01 GMT (02/18:41 MET) with 43.4 lbm. The second CWC-I was filled at 137/13:13 GMT (02/18:53 MET) with 39.9 lbm. The third CWC-I was filled at 137/13:26 GMT (02/19:06 MET) with 40.8 lbm. The fourth CWC-I was filled at 137/15:14 GMT (02/20:54 MET) with 40.6 lbm. The fifth CWC-I was filled at 137/16:06 GMT (02/21:46 MET) with 39.4 lbm. The sixth CWC-I was filled at 137/16:47 GMT (02/22:27 MET) with 40.8 lbm. The total water transferred to the ISS was 244.9 lbm.

The first EVA started at 137/11:54:49 GMT (02/17:34:40 MET) and was completed at 137/19:20 GMT (03/01:00 MET) for an EVA duration of 7 hr and 25 min. The tasks accomplished during the EVA included installation of the SGANT Boom onto Z1 truss, installation of the Dish onto the Boom, installation of the heat shield, and Battery preparation for the second and third EVA. The bolts securing the Dish to the Boom were torqued but had a gap between the dish and boom, and the crew installed two tie-down adjustable tethers to secure the dish.

After the completion of the EVA, the SRMS was maneuvered to grapple the MRM-1 starting at 137/18:05 GMT (02/23:46 MET). MRM-1 grapple was completed at 137/18:23 GMT (03/00:03 MET).

The Nitrogen (N₂) transfer was terminated at 137/22:31 GMT (03/04:11 MET). A total of 10.5 lbm was transferred to the ISS.

The DAT presented a summary of the three regions, for which imagery was not obtained or lacked sufficient resolution, during the FD 2 survey and FD 3 RPM because of the OBSS pan/tilt unit cable problem (IFA STS-132-V-03). A potential SRMS End Effector (EE) camera survey on FD 5 was discussed as a means to obtain imagery of the three areas which included the Port-tile chine, the Port RCC panels 1 through 17, and the Starboard RCC panels 1 through 9.

The Mission Management Team (MMT) decided not to perform the EE camera survey on FD 5 to allow the team time to further assess risks involved in conducting the survey and the impacts to the late inspection. Subsequent to the MMT, the DAT learned that digital imagery of the Port Chine and RCC area was obtained during the first EVA, and began their assessment of the imagery.

Flight Day 5 138/06:50 – 139/06:20

The main activities on FD 5 were the MRM -1 SRMS unberthing and handoff to the SSRMS for installation to the ISS, SSRMS OBSS unberthing and hand-off to the SRMS, and preparations for the second EVA.

The seventh CWC-I was filled at 138/09:41 GMT (03/15:21 MET) with 39.0 lbm. The eighth CWC-I was filled at 138/09:56 GMT (03/15:36 MET) with 40.6 lbm. The ninth CWC-I was filled at 138/10:11 GMT (03/15:51 MET) with 39.6 lbm. The tenth CWC-I was filled at 138/12:47 GMT (03/18:27 MET) with 40.0 lbm. The eleventh CWC-I was filled at 138/12:59 GMT (03/18:39 MET) with 40.5 lbm. With eleven CWC-Is filled, the total iodinated water transferred to the ISS was 444.6 lbm.

The unberthing of MRM-1 began at 138/09:48 GMT (03/15:28 MET). The MRM-1 was maneuvered to the handoff position at 138/10:01 GMT (03/15:41 MET). The MRM-1 was grappled by the SSRMS at 138/10:15 GMT (03/15:55 MET). The SRMS released the MRM-1 at 138/10:36 GMT (03/16:16 MET) and the SRMS was maneuvered to the MRM-1 Dock Viewing position at 138/11:24 GMT (03/17:04 MET). The MRM-1 was successfully installed on the ISS at 138/12:40 GMT (03/18:20 MET). The SRMS was then maneuvered to the OBSS Handoff Pre-grapple position at 138/13:32 GMT (03/19:12 MET).

The OBSS was grappled by the SSRMS at 138/13:52 GMT (03/19:32 MET). The unberthing of the OBSS began at 138/14:04 GMT (03/19:44 MET). The OBSS was maneuvered to the handoff position at 138/14:24 GMT (03/20:04 MET). The SRMS grappled the OBSS at 138/15:08 GMT (03/20:48 MET). The SSRMS ungrappled the OBSS at 138/15:22 GMT (03/21:02 MET). The OBSS was then maneuvered to the Battery Remove and Replace (R&R) Viewing position at 138/18:06 GMT (03/23:46 MET).

The DAT completed their review of the images taken of the Thermal Protection System (TPS) and the RCC during the first EVA. As a result of the additional images, the DAT recommended clearing all the tile and blankets for entry and the MMT concurred. The RCC coverage was improved with the additional images, but resolution was still less than optimal in some areas. The options for obtaining additional RCC imagery were still being evaluated.

Flight Day 6 139/06:20 – 140/06:00

The main activity for FD 6 was the second EVA.

An additional six CWC-I's were filled in parallel with the EVA activities on FD 6. The twelfth CWC-I was filled at 139/12:50 GMT (04/18:29 MET) with 42.4 lbm. The thirteenth CWC-I was filled at 139/13:03 GMT (04/18:42 MET) with 40.9 lbm. The fourteenth CWC-I was filled at 139/13:12 GMT (04/18:51 MET) with 38.3 lbm. The fifteenth CWC-I was filled at 139/15:42 GMT (04/21:22 MET) with 40.3 lbm. The

sixteenth CWC-I was filled at 139/15:55 GMT (04/21:35 MET) with 44.1 lbm. The seventeenth CWC-I was filled at 139/16:24 GMT (04/21:05 MET) with 40.1 lbm. The seventeenth CWC-I was filled at 139/16:12 GMT (04/21:52 MET) the total iodinated water transferred to the ISS was 690.7 lbm.

The PRCS L3D thruster temperature was up to approximately 72°F and slowly warming due to the attitude and beta angle. Work continues on refining the thruster temperature predictions for the post-undocked period. Alternate sleep-period attitudes are being analyzed.

The SRMS/OBSS was maneuvered to a series of positions in support of the EVA. The initial position was the Ingress-Clear position at 139/10:00 GMT (04/15:39 MET), followed by a maneuver to the Cable-Repair position at 139/11:06 GMT (04/16:45 MET), then to the Egress-Clear position at 139/11:30 GMT (04/17:09 MET), and to the Battery Remove and Replace (R&R) Viewing position at 139/11:53 GMT (04/17:32 MET).

The second EVA started at 139/10:38 GMT (04/16:17 MET) and was completed at 139/17:47 GMT (04/23:26 MET) for an EVA duration of 7 hr and 9 min. The major tasks accomplished during the EVA included OBSS Laser Dynamic Range Imager (LDRI) PTU cable-snag repair, P6 Battery removal and replacement, and a get-ahead task for SGANT troubleshooting.

The first task of the EVA was to tie the cable on the PTU to allow the proper tilting of the OBSS LDRI. Subsequent checkout of the PTU after the repair confirmed that the full range of motion was now available in the pan and tilt axes (IFA STS-132-V-01). The OBSS LDRI PTU was considered fully functional to support Late Inspection surveys.

The third on-orbit fuel cell purge was performed at 139/18:34 GMT (05/00:13 MET). During the 54.5 hour purge interval, the approximate performance decay was 0.22 Vdc for fuel cell 1, 0.21 Vdc for fuel cell 2, and 0.21 Vdc for fuel cell 3.

Discussions continued regarding whether to wait until the post-undocking Late Inspection to obtain imagery of the starboard and port RCC areas that were missed during the FD 2 OBSS inspection due to the LDRI PTU cable snag. Discussions also continued on whether to transfer the RCC plug repair hardware from the ISS to the Orbiter to protect for a repair in the unlikely event that ascent damage was detected during the Late Inspection in the above mentioned areas.

Flight Day 7 140/06:00 – 141/05:50

The main activities on FD 7 were the MRM -1 leak check, a Public Affairs Officer (PAO) event, crew off-duty, and preparations for the third EVA.

The eighteenth CWC-I was filled at 140/08:23 GMT (05/14:03 MET) with 40.0 lbm. The first Contingency Water Container (CWC) was filled at 140/10:00 GMT (05/15:39 MET) with 94.5 lbm. The total water transferred to the ISS was 825.2 lbm.

The Payload Retention Latch Assemblies (PRLAs) for the MRM-1 were closed at 140/08:50 GMT (05/14:30 MET).

The TCS team presented results of the assessment of the data dropouts observed during the FD 3 rendezvous. The dropouts were determined to be caused by sunlight into the sensor. This is a known limitation of the system, and no issues are expected for undocking.

Discussions continued on whether to perform dedicated surveys to obtain imagery of the starboard and port RCC areas that were missed during the FD 2 OBSS inspection due to the LDRI PTU cable snag. The remaining available data suggests that it is highly unlikely that ascent damage requiring repair has occurred. Imagery review indicated no anomalies, also the WLE IDS had no significant indications, and the analysis of known debris releases indicated that critical damage was highly unlikely. The missed areas will be imaged as part of the Late Inspection which was performed post-undocking on FD 11.

The MMT decided that additional docked surveys were not required. The MMT also determined that proactive transfer of the RCC plug repair kit from the ISS to the Orbiter was not required.

Flight Day 8 141/05:50 – 142/05:20

The main activities on FD 8 were the third EVA, and potable water-fill and transfer.

The third EVA was started at 141/10:27 GMT (06/16:06 MET) and was completed at 141/17:13 GMT (06/22:52 MET) for an EVA duration of 6 hrs and 46 min. All scheduled tasks were accomplished which included the Ammonia (NH₃) jumper installation, two battery removals and replacements, and retrieval of the Power and Data Grapple Fixture (PDGF) from the payload bay. A get-ahead task to stow tools in the Zenith (Z) 1 truss port and starboard tool boxes was also performed.

The first Potable Water Reservoir (PWR) was filled at 141/11:15 GMT (06/16:55 MET) with 15.2 lb. The second PWR was filled at 141/11:51 GMT (06/17:30 MET) with 19.9 lb. The third PWR was filled at 141/12:13 GMT (06/17:32 MET) with 19.2 lb. The second CWC was filled at 141/12:13 GMT (06/17:53 MET) with 93.3 lb. The total water transferred to the ISS is 972.8 lb.

The fourth on-orbit fuel cell purge was performed at 141/18:47 GMT (07/00:26 MET). During the 48-hour purge interval, the approximate voltage decay was 0.21 Vdc in fuel cell 1, 0.19 Vdc in fuel cell 2, and 0.20 Vdc in fuel cell 3.

The crew reported that the screen on the Rendezvous/Proximity Operators Program (RPOP) Payload General Support Computer (PGSC) Lexan® screen was cracked, but intact. A new configuration was defined to use the RPOP2 PGSC as primary in its place.

Flight Day 9 142/05:20 – 143/04:50

The main activities on FD 9 were SSRMS berth of the ICC into the payload bay, CWC fills, Oxygen (O₂) transfer initialization, and crew off-duty time.

The third CWC was filled at 142/06:44 GMT (07/12:24 MET) with 103.3 lb. The fourth CWC was filled at 142/07:41 GMT (07/13:21 MET) with 99.3 lb. The total water transferred to the ISS is 1172.1 lb.

The SSRMS berthed the ICC in the payload bay at 142/09:45 GMT (07/15:24 MET). After ungrapple of the ICC, the SSRMS was maneuvered to the Undock position.

The O₂ transfer was initiated at 142/10:48:55 GMT (07/16:28:46 MET). The O₂ transfer was tank-to-tank and the estimated total O₂ to be transferred to ISS is 47 lb.

The SRMS was maneuvered to the OBSS Undock position at 142/11:14 GMT (07/16:54 MET).

Flight Day 10 143/04:50 – 144/04:50

The main activities on FD 10 were completion of the O₂ transfer, final transfers, hatch closure, undock, and fly around.

At approximately 143/05:29 GMT (08/11:08 MET), a decrease of approximately 2 lb/hr was observed in Power Reactant Storage and Distribution (PRSD) Hydrogen (H₂) tank 3. The crew was instructed to activate both tank heaters and the response allowed the ground to confirm that the signature was due to de-stratification.

The O₂ tank-to-tank transfer and teardown was completed at 143/07:13 GMT (08/12:52:51 MET). The estimated total O₂ transferred to ISS was 47 lbm. A total of 70 lbm, which also includes O₂ for ISS repressurizations, was transferred during this mission.

The fifth CWC was filled at 143/06:07 GMT (08/11:47 MET) with 95.0 lbm. The total water transferred to the ISS is 1266.6 lbm, which also included 54.3 lbm of iodinated water transferred in the PWRs.

The hatch between the ISS and the Orbiter was closed at 143/12:40:09 GMT (08/18:20 MET), and the vestibule was leak-checked successfully.

During the setup for undocking, the crew reported that the ODS vestibule lights were not working. Troubleshooting to regain the lighting was unsuccessful. As a workaround,

the crew positioned Light-Emitting-Diode (LED) flashlights in the vestibule as a substitute for the failed lighting.

The Orbiter resumed attitude control with the Digital Autopilot (DAP) in the automatic-mode at 143/12:33:45 GMT (08/18:13:36 MET) and the maneuver to the undocking attitude was initiated at 143/14:11:08 GMT (08/19:50:59 MET). The maneuver was completed satisfactorily in approximately 33 min. The DAP was commanded to Free Drift at 143/15:19:08 GMT (08/20:58:59 MET) for the undocking.

The command to undock from the ISS was initiated at 143/15:19:49 GMT (08/20:59:40 MET). The total drive time was approximately 2 min and 15 sec and the Hook Groups 1 and 2 operated nominally. The ODS performed nominally for undocking. Physical separation occurred at 143/15:22:10 GMT (08/21:02:01 MET).

The fly-around the ISS was initiated with RCS +X pulses of the L1A and R1A thrusters at 143/15:48:51 GMT (08/21:28:42 MET). The operation of the TCS for undocking and fly-around activities was nominal. No dropouts occurred as were observed during rendezvous on FD 3.

Prior to the separation 1 maneuver, the Ku-Band was taken to the RADAR mode at 143/16:31:13 GMT (08/22:11:04 MET) and locked on to the ISS at an approximate range of 651 ft. The Ku-Band was configured back to the COMM mode at 143/17:07:51 GMT (08/22:47:42 MET) at a range of approximately 6620 ft.

The separation 1 maneuver was initiated with RCS +X pulses for 6.0 sec using thrusters L1A and R1A at 143/16:36:53 GMT (08/22:16:44 MET). The separation 2 maneuver was performed at 143/17:04:53 GMT (08/22:44:44 MET). This was a 5.84 sec RCS -X maneuver using thrusters F2F and F3F.

The fuel cell water relief and water line heaters were switched from the A system to the B system at 143/17:30 GMT (08/23:09 MET).

Flight Day 11 144/04:50 – 145/04:20

The main activities on FD 11 were waste and water dumps, the Late Inspection of the RCC surfaces, the OBSS berthing, and the SRMS power-down.

The fifth on-orbit fuel cell purge was performed, beginning at 144/05:30 GMT (09/11:09 MET). During the 59-hour purge interval, the approximate voltage decay was 0.23 Vdc for fuel cell 1, 0.18 Vdc for fuel cell 2, and 0.22 Vdc for fuel cell 3.

A simultaneous waste dump and a supply and condensate CWC dump were performed. The waste dump was completed in two nozzle-temperature cycles with the first waste-valve opening at 144/05:13 GMT (09/10:52 MET) and closing at 144/05:54 GMT (9/11:33 MET). After the nozzle bakeout, the waste dump was re-initiated at 144/06:04 GMT (09/11:43 MET) and terminated at 144/06:20 GMT (09/11:59 MET). Both the

supply and condensate dumps were done in one nozzle-temperature cycle, with the supply valve opening at 144/05:14 GMT (09/10:53 MET) and the condensate dump initiating at 144/06:31 GMT (09/12:10 MET) and terminating at 144/06:45 GMT (09/12:24 MET).

The Starboard RCC survey began at 144/08:29 GMT (09/14:08 MET) and was completed at 144/09:49 GMT (09/15:28 MET). The Nose RCC was surveyed from 144/10:18 GMT (09/14:57 MET) to 144/10:51 GMT (09/16:30 MET). The Port RCC was surveyed from 144/11:20 GMT (09/16:59 MET) to 144/11:17 GMT (09/16:56 MET).

The OBSS was berthed by the SRMS at 144/12:48:48 GMT (09/18:28:39 MET). The SRMS was cradled at 144/13:11:26 GMT (09/18:51:17 MET). The SRMS was powered down and the Port Manipulator Positioning Mechanism (MPM) was stowed at 144/15:14:08 GMT (09/18:53:59 MET). The Starboard MPM was stowed at 144/13:16:08 GMT (09/18:55:59 MET),

The Orbiter Boom Sensor System (OBSS) aft pedestal Manipulator Retention Latch (MRL) System 2 latch indication did not come on during both OBSS berthing operation. This is an explained condition caused by a flight rule that opens the circuit breakers, for safety reasons, that inhibit one of the motors.

Flight Day 12 145/04:20 – 146/04:20

The STS-132 mission is progressing satisfactorily. The main activities on FD 12 were the Flight Control System (FCS) checkout and the RCS Hot-Fire.

The FCS checkout was initiated at 145/07:30 GMT [10/13:09 MET). APU 1 was started at 145/07:42:03 GMT (10/13:21:54 MET) and ran for 3 min 18 sec, and used 12 lb of fuel. The APU and the Hydraulic/Water Spray Boiler (HYD/WSB) systems operated nominally throughout the FCS checkout. The FCS checkout procedure was completed nominally and all flight-control surfaces responded as expected.

The RCS Hot-Fire was initiated at 145/08:22:02 GMT (10/14:01:53 MET) and terminated at 145/08:29:06 GMT (10/14:08:57 MET). A total of 36 of the 38 thrusters were fired for at least 0.240 sec. The Hot-Fire was modified to prevent the L3D thruster from firing as the temperature was below the 59 °F threshold. The RCS operation was nominal.

The OMS-8 Shuttle Ionospheric Modification with Pulsed Local Exhaust (SIMPLEX) maneuver was initiated at 145/15:23:20 GMT (10/21:03:11MET) and ended at 145/15:23:30 GMT (10/21:03:21 MET). The firing duration was 9.8 sec with a ΔV of 17.2 ft/sec. The resulting orbit was 181.9 by 194.3 nmi. Engine performance was nominal.

All of the Late Inspection data for the RCC were downlinked and analyzed. The RCC DAT reported that no anomalous conditions were identified and that the vehicle was

ready for entry. The Mission Management Team (MMT) accepted the report and cleared the vehicle for entry.

Flight Day 13 and Entry and Landing 146/04:20 – 146/13:00

The main activity for FD 13 will be deorbit preparation, the deorbit maneuver, entry, and landing at Kennedy Space Center (KSC).

Both Payload Bay Doors (PLBDs) were closed nominally by 146/03:49:08GMT (11/09:28:59 MET) in preparation for landing.

During the PLBD closing, the starboard PLBD system 1 close indication came on approximately 13 sec later than the system 2 close indication. There has been a long history of PLBD close (and open) indication problems in the history of the program. Similar delay times have occurred in the past, and this event is not considered an issue.

The Flash Evaporator System (FES) shutdown in the topping mode while operating on primary B controller during the deorbit preparations (IFA STS-132-V-04). The shutdown occurred 46 min into the radiator cold-soak. The crew restarted the FES topper using the primary B controller. This resulted in a shutdown with the FES Freon outlet temperature failing to reach the control band. Subsequently, the crew restarted the FES using the primary A controller resulting in a successful 7-min operation. A contingency procedure using a modified radiator bypass/FES checkout with a core flush (on secondary controller) followed the primary A operation. In the contingency procedure, the FES operated in the secondary high-load mode, followed by a core flush and then concluded with secondary topping operation. Ice and excess carryover were observed in the FES topping duct during the core flush. The core-flush stage of the procedure was performed twice because the initial core flush produced duct temperatures that indicated ice had not been completely flushed from the core. After completion of the contingency procedure, the FES configuration was switched to the primary A controller in the full-up mode which prepares the Orbiter for the deorbit and entry operations.

The deorbit maneuver for the first landing opportunity at KSC, a dual-engine straight-feed firing, was started on orbit 186 at 146/11:41:59.2 GMT (11/17:21:51.2 MET) with shutdown at 146/11:45:05 GMT (11:17:24:57 MET). The burn was 185.6 sec in duration with a ΔV of 333.6 ft/sec. The resulting orbit was 195.7 by 24.0 nmi.

Entry interface occurred at 146/12:16:35 GMT (11/17:56:26 MET).

The main landing gear touchdown occurred at KSC on runway 33 at 146/12:48:08 GMT (11/18:37:59 MET) on May 26, 2010. The drag chute was deployed at 146/12:48:10.5 GMT. The nose gear touchdown occurred at 146/12:48:19 GMT. Drag chute jettison occurred at 146/12:48:47.1 GMT. Wheels stop occurred at 146/12:49:28 GMT. The rollout was normal in all respects.

The flight duration was 11 days 18 hr 37 min 59 sec. The last APU was shut-down 19 min 28 sec after landing. At the time this report was written, this was the last planned mission of the Atlantis vehicle.

PAYLOADS AND EXPERIMENTS

LAUNCH PACKAGE OVERVIEW

The Utilization Flight (UF) 4 Launch Package consisted of two cargo elements in the payload bay and utilization payloads and crew resupply items stowed in the Middeck. The primary purpose of the mission was to deliver and robotically install the Russian-built Mini Research Module1 (MRM1) to the International Space Station (ISS) Functional Cargo Block (FCB) nadir port. In addition to the MRM1, the second-set of major objectives for the mission included the delivery of an Integrated Cargo Carrier-Vertical Light Deployable (ICC-VLD) with six batteries and three Orbital Replacement Units (ORUs), which were the Enhanced ORU Temporary Platform (EOTP), the Space-to-Ground Ku-Band Antenna (SGANT), and the SGANT boom.

The MRM1, also called Rassvet, meaning dawn in Russian, carried 3,086 lb (1400 kg) of U. S. logistics cargo within the pressurized module. Externally mounted ORUs on the MRM1 included a spare elbow joint for the European Robotic Arm (ERA) and outfitting equipment for the Russian Multi-Purpose Laboratory Module (MLM) which is scheduled to launch on a Russian rocket in 2012. The outfitting equipment includes a radiator, airlock for payloads, and a Portable Work Platform (PWP) that will provide a spacewalk worksite for ERA activation, checkout, and operations.

The ICC-VLD carried six battery ORUs for the Port 6 (P6) Integrated Equipment Assembly (IEA) which were exchanged with six old batteries for return. The SGANT, SGANT Boom and an EOTP were also installed onto the ICC-VLD. The SGANT will provide a hot backup KU-band communication system and was mounted on the top of the Zenith 1 (Z1) truss. The SGANT Boom Assembly provides power, data, and structural support to the new SGANT. The EOTP was installed on the Special Purpose Dexterous Manipulator (SPDM) and will provide power to the ORU temporary stowage platform.

CREW ACTIVITY SUMMARY

On Flight Day (FD) 3, the Atlantis' docking to the ISS occurred at 9:29 am CDT; 01/20:20 MET. The hatch was opened at approximately 01:22:01 MET, and transfer activities were started after the crew welcome and safety briefings were completed.

The ICC-VLD was robotically transferred to the ISS using the Space Station Remote Manipulator System (SSRMS) and installed on the Payload and On-orbit Replacement Units (ORU) Accommodation (POA) on the Mobile Remote Servicer Base System (MBS). Robotic ground controllers then reconfigured the MBS to provide power to the ICC-VLD via the POA. Overnight, ISS ground controllers released the SSRMS from the ICC-VLD, translated the Mobile Transporter (MT) from Worksite (WS) 4 to WS 6, and walked the SSRMS off onto the MBS Power and Date Grapple Fixture no. 3 to support the first EVA on the next-day.

On FD 4, the first EVA was completed satisfactorily in 7 hr 25 min. The crew completed all of the planned tasks plus two get-ahead tasks.

On FD 5, the Russian Mini-Research Module 1 (MRM1) was successfully installed on the Russian segment FGB.nadir port. In addition transfer of items from the middeck progressed satisfactorily.

On FD 6, the second EVA of the mission was performed and the EVA was successfully completed in 7 hr 9 min. The Orbital Boom Sensor Subsystem (OBSS) Intensified (black and white) Television Camera (ITVC) Pan/Tilt Unit (PTU) cable was re-positioned and tie-wrapped, and the ground verified full functionality of the OBSS/ITVC system was restored. In addition, four of the six batteries on the B side of the P6 Solar Array (SA) were replaced. Three of the old batteries were stowed on the ICC VLD-2 for return. In addition, two get-ahead tasks were completed.

On FD 7, the ISS Commander (CDR) and Flight Engineer (FE)-1 ingress the MRM-1 and completed the Functional Cargo Block (FGB)-Pressurized Adapter [ΓA] to MRM-1 interface leak checks. Prior to initiating MRM-1 atmosphere scrubbing, FE-1 collected Carbon Monoxide (CO), and Formaldehyde samples. The CDR and FE-1 then initiated the MRM-1 Ingress activities.

On FD 8, the third EVA of the mission was performed successfully and the EVA was completed in 6 hr 46 min. The EVA crewmembers completed the planned tasks as well as four get-ahead tasks. The removal and replacement of the remaining two batteries and the stowing of the last three batteries completed the final preparations for returning the batteries to Earth.

On FD 9, the crew continued the transferring of equipment and experiments from the Shuttle middeck to the ISS.

On FD 10, the crew completed all of the transfer activities from the middeck as well as the transfer activities to the middeck for return to Earth. The undocking from the ISS was completed successfully as well as the fly-around of the ISS.

On FD 11, the crew completed the Late Inspection of the RCC, and the stowing of the SRMS.

TRANSFER WEIGHT SUMMARY

All of the transfers were successfully accomplished during the mission. The following table and discussion provides an overview of the total transfers.

TOTAL WEIGHT TRANSFERRED DURING THE MISSION

Parameter	To ISS, lb _m	From ISS, lb _m
Cargo Bay	25,256	6,495
Middeck	1,591	1,439
Totals	26,847	7,934

1. **Water** – A total of 1267.6 lb_m of water was transferred.
2. **Oxygen** – A total of 74 lb_m of oxygen was transferred. A total of 44 lb_m was transferred to the Airlock High Pressure Gas Tank, and 30 lb_m was used for ISS cabin repressurization.
3. **Nitrogen** – A total of 88 lb_m was transferred and used. A total of 11 lb_m was transferred to the Airlock tanks, and 77 lb_m was used to repressurize the ISS stack.
4. **Lithium Hydroxide** – A total of 12 unused LiOH canisters were transferred to the ISS, and 5 unused canisters were transferred to the Orbiter.
5. **Food** – A total of 109 (Russian Crew Preference) via the MRM 1.

SIGNIFICANT FIRSTS

The significant firsts for the STS-132 mission were as follows:

1. Last planned flight of OV-104/Atlantis
2. Russian module berthing with the active side of the berthing mechanism commanded through the Space Station Remote Manipulator System (SSRMS)

SIGNIFICANT ISS ANOMALIES

During the first EVA, while installing the SGANT, the crew demated two connectors (J254 and J253) on the Z1 patch panel in accordance with the procedures. The connectors un-terminated the ISS data bus and resulted in the Primary Command and Control (C&C) Multiplexer/Demultiplexer (MDM) transitioning to the FAILED state. The SSRMS robotic activities were halted temporarily while the backup C&C-2 MDM transitioned to prime. The impact of the transition was the loss of the prime C&C MDM during a robotics-supported EVA while a EVA crewmember was on the SSRMS. This anomaly resulted in a delay to the first EVA timeline.

MAJOR ISS MISSION PRIORITIES AND END-OF-MISSION STATUS

The following table provides the status of the mission priorities at the end of the mission.

ISS MISSION PRIORITIES COMPLETION STATUS

	Task	Flight Day Task Completed
	Category 1 Tasks	
1	Rendezvous and dock Orbiter to Space Station PMA2 during a direct crew handover period (six ISS crew) and perform mandatory crew safety briefing for all crewmembers.	FD3
2	Activate and check out MRM1 in Shuttle Payload Bay (PLB).	FD1
3	Support Dual Docked Operations (if required)	Not required
4	Perform robotic installation of the MRM1 to the FGB Nadir port. a. Closure of a minimum of one set of hooks in the MRM1/FGB Nadir interface b. Confirmation of electrical connectivity through the MRM1/FGB interface. c. Perform assembly of TV transmission setup via KU-band for MRM1 docking. d. Perform MRM1 hatch opening and atmosphere purification. e. Perform MRM1 docking mechanism disassembly. f. Perform screw clamps installation on MRM1 hatch.	FD 5
5	Transfer mandatory quantities of water from Orbiter to ISS per ULF4 Transfer Priority List (TPL).	Not required
6	Transfer all critical cargo per ULF4 TPL.	FD 10
7	Deploy ICC-VLD2 with ORUs from the PLB and stow it on the MT POA structure.	FD 3
	Category 2 Tasks	
8	Install the SGANT and SGANT Boom on Z1. a. Remove redundant SGANT gimbal locks.	FD 4 FD 6
9	Install the EOTP on the SPDM.	FD 4
10	Replace the six P6 Channel 4B batteries currently on-orbit with new batteries on ICC-VLD2 and return the old batteries on the ICC-VLD2. a. Perform P6 battery preparatory tasks, including ICC-VLD battery torque release, P6 battery torque release, and gap spanner/Articulating Portable Foot Restraint (APFR) relocation.	FD 6 and FD 8 FD 4
11	Return ICC-VLD2 with old batteries to the Payload Bay	FD 9
12	Remove the PDGF from the sidewall carrier and transfer to ISS.	FD 8
13	Transfer mission success items per the ULF4 TPL.	FD 10
	Category 3 Tasks	
14	Perform the following IVA tasks to allow for return of on-orbit hardware: None identified	Not required
15	Perform daily ISS payload status checks as required.	Daily

ISS MISSION PRIORITIES COMPLETION STATUS (Continued)

	Task	Flight Day Task Completed
16	Perform critical non-recoverable Utilization activities (not listed in priority order): <ul style="list-style-type: none"> a. Bisphosphonates b. Double Coldbag Packing. c. Waiving and Cooling of Arabidopsis Roots at Different G-levels (WAICO)-2/ESA Conditioning Container (ECCO) Bag Packing. d. General Laboratory Active Cryogenic ISS Experiment Refrigerator (GLACIER). e. Micro2 f. Myco- 2G g. National Laboratory Pathfinder (NLP) Cells-4 h. NLP Vaccine – 9 i. Spinal Long (ISS USOS Crew) and Spinal Short (STS-Crew) j. Fish Scales (UROKO) k. Hydro Tropi MELFI insertion l. Double Coldbag Unpacking 	FD 9 FD 9 FD 9 FD 6 and FD10 FD 9 FD 9 Transfer only FD 2 FD 11 FD 9 FD 7 and FD 10 FD 4 FD 4
17	Transfer additional quantities of water from Orbiter to ISS per Flight ULF4 TPL.	FD 9
18	Transfer remaining cargo per Flight ULF4 TPL	FD 10
19	The following EVA tasks are deemed to fit within the existing EVA timelines; however, may be deferred if the EVA is behind schedule. The EVA will not be extended to complete these tasks. <ul style="list-style-type: none"> a. Remove redundant SGANT Space-to-Ground Transmitter Receiver Controller (SGTRC) Multi-layer Insulation (MLI) b. Install redundant SGANT Antenna Group Interface Tube (AGIT) heat shield. 	
20	Perform daily middeck activities to support payloads (includes cases where Shuttle crew also performs payloads on ISS) per SSP 54023_54023-ANX 5	Daily
21	Perform OGA Water ORU s/n 00001 R&R with ORU s/n 0002 and perform post installation leak checks	FD 6
22	Perform remaining ISS Payload research operations tasks per SSP 54023 54024-ANX 5. <ul style="list-style-type: none"> a. Short Duration Bioastronautics Investigation (SDBI) 1634 Sleep Wake Actigraphy and Light Exposure during Spaceflight ('SLEEP SHORT') 	Daily
23	Perform Russian ISS Payload experiments: <ul style="list-style-type: none"> a. IZGIB with Dragon-M Hardware b. Matryoshka-P with Bubble dosimeters c. Pneumocard d. Sonocard e. Vzaimodejstvie f. Membrana g. Bar h. Caskad i. Pilot 	Performed

ISS MISSION PRIORITIES COMPLETION STATUS (Continued)

	Task	Flight Day Task Completed
24	<p>Perform Russian Resupply</p> <ul style="list-style-type: none"> a. Operations for integrating MRM1 into the ISS RS b. Upgrading onboard simulator software on Progress vehicle remote Teleoperator Control Mode and Soyuz TMA relocation due to the ISS configuration change c. ISS-23 crew preparations for departure d. Collecting samples from FGB surfaces for return on Soyuz e. Leak checks of ISS-23 crew Sokol spacesuits before undocking and deorbit. f. Update Navigation Computer Module (HBM) software using Laptop 3 (to increase the accuracy of the relative navigation during ATV2 rendezvous with ISS). g. Perform remote station Laptop relocation from RS ISS central post into Cupola and to perform test prior to MRM1 docking to FGB h. Perform 37P partial cargo unloading and reflect the status in the IMS database i. Perform symbolic activity per Roscosmos program j. Perform photo and video imagery of flight chronicle for ISS-23 k. Perform installation of AOK ГАНК delivered on Progress 37P. l. Unpack MRM1 - Pending IMMT direction –deferred m. Perform SM, DC1, FGB and MRM2 ventilation system prophylactic maintenance n. Perform БКО CPBK changeout o. Perform sampling of humidity condensate ([KAB]) upstream gas/liquid mixture filter (ФГС) for samples return on Soyuz. p. Perform sampling of humidity condensate ([KAB]) upstream purification column unit (БКО) prior to БКО change out for samples return on Soyuz 	Performed
	Category 4 Tasks	
25	Transfer N ₂ from the Orbiter to the ISS airlock HPGT's	FD 4 – FD 5
26	Transfer O ₂ from the Orbiter to the ISS Airlock HPGT's as consumables allow.	FD 9- FD 10
27	Perform imagery survey of the ISS exterior during Orbiter flyaround after undock.	FD 10
28	Perform photo survey of TMA-18 (22S)	FD 10
29	Perform ISS reboost with the Orbiter if mission resources allow and are consistent with ISS trajectory analysis and planning.	Not Performed

ISS MISSION PRIORITIES COMPLETION STATUS (Concluded)

	Task	Flight Day Task Completed
30	<p>Perform program-approved EVA get-ahead tasks. The following EVA get-ahead tasks do not fit in the existing EVA timelines; however, the EVA team will be trained and ready to perform should the opportunity arise.</p> <ul style="list-style-type: none"> a. Install EOTP input drive mechanism and two fuse ORU's b. Cleanup P6 battery R&R worksite (includes gap spanner retrieval and APFR relocation). c. Retrieve P6 PDGF (Only if time does not permit the retrieval of the PDGF from the Shuttle Sidewall Carrier) d. Connect P4/P5 NH₃ jumper for Port NH₃ refill. e. Install P3 Crew Equipment Translation Aid (CETA) light. f. EOTP Maintenance Tether Installation g. EVA Tool Relocation to External Tool Boxes 	<p>FD 4 FD8</p> <p>Not required</p> <p>FD 8 Not performed FD 4 FD 8</p>
31	<p>Perform program-approved IVA get-ahead tasks. The following IVA get-ahead tasks do not fit in the existing IVA timelines; however, the IVA team will be trained and ready to perform should the opportunity arise.</p> <ul style="list-style-type: none"> a. Ingress MRM1 b. Install Carbon Dioxide Removal Assembly (CDRA) bed c. Perform Potable Water Dispenser (PWD) troubleshooting 	<p>FD 7 FD7 FD 8</p>
32	Perform SDTO 13005-U ISS Structural Life Validation and Extension during MRM1 installation.	FD 5
33	Perform SDTO 13005-U, ISS Structural Life Validation and Extension, during Shuttle mated Reboost.	Not performed
34	Perform SDTO 13005-U, ISS Structural Life Validation and Extension, during ULF4 Orbiter docking (ISS Wireless Instrumentation System (IWIS) required).	FD 3
35	Perform SDTO 13005-U, ISS Structural Life Validation and Extension, during ULF4 Orbiter undocking (IWIS highly desired, but not required).	FD 10
36	Perform Payloads of Opportunity operations to support MAUI, SEITE, SIMPLEX, and RAMBO-2.	FD 12 SIMPLEX
	Tasks Added in Real Time During Mission	
	<ul style="list-style-type: none"> 1. Potable Water Dispenser troubleshooting 2. Photographic survey of TMA-18 3. Oxygen Generation Assembly Water ORU Removed and Replaced and post-installation leak checks were performed. 	<p>Completed Completed Completed</p>

DEVELOPMENT TEST OBJECTIVES

DEVELOPMENT TEST OBJECTIVE 805 CROSSWIND LANDING PERFORMANCE

This Development Test Objective (DTO) of opportunity was not performed during landing because of the crosswind conditions being less than the minimum standards set for this DTO.

DEVELOPMENT TEST OBJECTIVE 900 SHUTTLE RSRB CHAMBER PRESSURE, STRAIN GAGE AND ACCELERATION RATES DATA COLLECTION

This DTO collects higher-fidelity data to contribute additional knowledge of Solid Rocket Motor (SRM) flight characteristics for RSRB analysts. It is assumed that data collection was acquired during ascent. No subsequent assessment of the data is available at this time.

DEPARTMENT OF DEFENSE PAYLOADS OF OPPORTUNITY

MAUI ANALYSIS OF UPPER-ATMOSPHERIC INJECTIONS

The MAUI payload experiment matrix involves dedicated Orbital Maneuvering System (OMS), Primary Reaction Control System (PRCS) and Vernier RCS thruster firings. Observations of firings in the vicinity of the International Space Station (ISS), particularly the ISS reboost firings, are done passively. Shuttle engine exhaust plumes are observed utilizing optical telescope sensors and the all-sky imagers at the Air Force Maui Optical and Supercomputing Site (AMOS) at Maui, Hawaii. Shuttle thruster firings and attitude maneuvers were to be conducted during night passes over AMOS. This is an observational payload of opportunity that contains no flight hardware.

SHUTTLE EXHAUST ON TURBULENCE EXPERIMENTS

The Shuttle Exhaust on Turbulence Experiments (SEITE) utilized the Space Shuttle to investigate plasma turbulence caused by the OMS engine exhaust in the Ionosphere using space-based sensors. Data are collected by flying satellites through the plasma turbulence during a conjunction with the Space Shuttle. Observations of density and electric field disturbances are used to develop quantitative models of plasma turbulence that affects tracking and imaging radars. This is an observational payload of opportunity that contains no flight hardware.

No SEITE observation opportunities occurred during this mission.

RAM BURN OBSERVATION -2

The objective of the Ram Burn Observation (RAMBO) -2 activity is to use the Space Shuttle to acquire data for developing a method to decipher satellite maneuvers from plume observations and to characterize monopropellant plume radiance. Ram Burn Observations-2 (RAMBO-2) used two Space Tracking Surveillance System (STSS) satellites to make observations of the PRCS plumes.

No RAMBO-2 observations were made on this flight as the satellites were not ready to acquire data for the RAMBO-2 experiment, and no observation opportunities occurred during this mission.

VEHICLE PERFORMANCE

NATURAL ENVIRONMENTS

The T-0 (instantaneous) surface conditions (based on measurements at the 60-ft level of Camera Site 3) were as follows; wind speed was 9.4 knots, wind direction was 81 deg, temperature was 79 °F, humidity was 72% and ambient pressure was 30.24 in Hg.

The I-loads were designed with the Launch (L) -4:50 Jimsphere data. An analysis based on the L-2:20 Day of Launch I-Load Update (DOLILU) assessment profile, identified no exceedances of the May 90th percentile database limits for the in-plane or out-of-plane components. The maximum measured wind velocity was 67.2 ft/sec at 47,700 ft and 280 deg. There were no wind-shear exceedances.

There were no violations of the in-plane or out-of-plane wind change redlines from the L-4:50 DOLILU I-Load design-wind profile to the final assessments based on the L-2:20 Jimsphere balloon and the 1800 Universal Time Code (UTC) 50 MHz Doppler Radar Wind Profiler (DRWP).

The L-1:08 Jimsphere balloon was used to clear the roll-maneuver region and was validated with the 1701 UTC False Cape 915 MHz profiler. The maximum measured wind velocity in the roll maneuver region was 33.1 ft/sec at 7200 ft and 119 deg.

FINAL INSPECTION

The Final Inspection Team (FIT) reported light condensate on the Liquid Hydrogen (LH₂) tank and the +Z side of the Liquid Oxygen (LO₂) tank, with dry surfaces on the Intertank and -Z LO₂ tank. Surface temperatures ranged from 58 °F to 74°F. Two typical cracks were observed in the intertank stringer valleys. The LO₂ feedline-brackets exhibited typical ice/frost formations at the bracket base-to-tank-fitting interface. The Ice/Frost Ramps (IFRs) looked clean; no observations were recorded. Typical ice/frost was noted on the aft interface hardware. A typical crack with no offset (7-in. by 0.25-in.) was observed on the -Y side of the vertical strut. A thick-shell ice-ball, which was approximately 1.25-in. long by 0.5-in. wide by 0.25-in. deep, was formed at the LH₂ feedline inboard closeout near the Liquid Hydrogen (LH₂) tank aft-dome-acreage interface, and was acceptable per the ice-ball table in NSTS documentation.

All observations were acceptable per NSTS document that was entitled Ice/Debris Inspection Criteria except for one stress relief crack (3.5-in. by 1/16-in. with no offset) that was located at the diagonal strut-fitting closeout and inboard near the interface to the tank.

REUSABLE SOLID ROCKET BOOSTERS

All Reusable Solid Rocket Booster (RSRB) systems performed as expected during the launch- countdown and ascent of the STS-132 mission.

No RSRB Launch Commit Criteria (LCC) or Operations and Maintenance Requirements and Specifications Document (OMRSD) violations occurred. No RSRB related Interim Problem Reports (IPRs) occurred during the countdown and launch.

All RSRB systems performed as expected during launch countdown and ascent. The RSRB pre-launch countdown was nominal and one RSRB In-Flight Anomaly (IFA) has been identified.

There was no indication of hold-down stud hang-up based on analysis.

Both RSRBs were successfully separated from the ET and reports indicate that the deceleration subsystem performed as designed. Recovery ships returned the RSRBs to Kennedy Space Center (KSC) for the inspection, and disassembly. The inspection and disassembly identified one RSRB anomaly

The Left-Hand (LH) RSRB Frustum Upper Right Booster Separation Motor (BSM) Room Temperature Vulcanizing (RTV)-133 material is missing with darkened substrate that measures 5 ft long. The fracture surface is heat affected (IFA STS-B-001). Time of occurrence has not been determined, with possibility for ascent libration. The Microscopy inspection showed heat effects and soot on Hypalon surfaces of the missing RTV-133 area less than full-flight exposure, but greater than an adjacent area with intact RTV-133. Microscopy analysis is inconclusive as to time of occurrence.

REUSABLE SOLID ROCKET MOTORS

The STS-132 Reusable Solid Rocket Motor (RSRM) set performed within established and predicted limits (nominal). Based upon data analysis, the RSRM ballistic performance was nominal. No RSRM LCC or OMRSD violations occurred.

No RSRM-related Interim Problem Reports (IPRs) occurred during the countdown and launch

Power up and operation of all igniter and field joint heaters was accomplished routinely. All RSRM temperatures were maintained within acceptable limits throughout the countdown. The heated, ground supplied, aft skirt purges maintained the nozzle/case joint and flex bearing temperatures within the required LCC ranges.

The post-flight inspection did not show any IFAs.

EXTERNAL TANK

The External Tank (ET) performed as designed throughout the ascent operations. Two IFAs were identified and are discussed in later paragraphs.

No ET OMRSD violations occurred. All other ET systems performed as expected during launch countdown and ascent. The ET pre-launch countdown was nominal.

There was one Interim Problem Report (IPR) identified during the launch countdown for a LH₂ diagonal-strut base-fitting Thermal Protection System (TPS) crack. This IPR resulted in an LCC ICE-01 constraint and required a waiver to the LCC. Analysis determined this is a possible condition as the predicted outer fiber strain exceeds the minimum design value of the BX-265 foam. Similar stress relief cracks formed by joint movement during the cryogen loading have been previously documented in other locations. NSTS 08303 was updated post-flight to include this condition.

All ET objectives and requirements associated with propellant loading and flight operations were met. No significant oxygen or hydrogen concentrations were detected in the Intertank or at the Ground Umbilical Carrier Plate (GUCP). All electrical equipment and instrumentation operated satisfactorily. Purge and heater operations were monitored and performed properly. Liquid level and Engine Cut-off (ECO) sensors performed as designed.

ET separation was nominal. Main Engine Cut-Off (MECO) occurred nominally, and impact occurred at the latitude of 35.906 deg South and longitude of 157.809 deg West.

During the pre-launch countdown, a 3.5 in. by 0.062 in. crack with no off-set was observed on the outboard face of the Diagonal Strut Base Closeout in the crotch area between the Diagonal Strut and the LH₂ Aft Dome (IFA STS-132-T-001). This condition violated the LCC.

The post-flight photographic film reviews identified on foam loss on the +Z side of the intertank (IFA STS-132-T-002). The loss is located at approximately STA 1102; Panel 2, Stringer 18 which is forward and outboard of the Y-Bipod. The approximate dimensions of this loss were 9.31 in. by 2.19 in. by 0.58 in., with an estimated mass of 0.016 lb_m. Time of the loss occurred at approximately 129 seconds MET. The failure mode was weak bond-adhesion attributed to this Intertank. Acreage loss is not specifically covered in NSTS 60559. The most probable contributor to these Intertank acreage losses as determined by the Intertank Loss Team is potential contamination.

SPACE SHUTTLE MAIN ENGINES

All Space Shuttle Main Engine (SSME) systems performed as expected during the launch countdown and ascent performance was typical of previous flights. The SSME pre-launch countdown was nominal. No SSME LCC or OMRSD violations occurred.

No SSME Failure Identifiers (FIDs) occurred during the countdown and launch. The post-flight inspection identified one IFA, which is discussed in a later paragraph.

Engine "Ready" was achieved at the proper time and the thrust build-up was nominal. Preliminary flight data indicates nominal SSME performance during startup, mainstage, throttling, and shutdown.

The predicted average SSME Specific Impulse (ISP) tag value (using the ground-based tag value method) was 452.05 seconds at 104.5% Rated Power Level (RPL). Indications are that the delivered ISP will be within the expected range. A waiver was generated to address this condition.

The High Pressure Oxidizer Turbo Pump (HPOTP) and High Pressure Fuel Turbo Pump (HPFTP) temperatures were well within specifications throughout the engine operation.

The commanded Max Q (Maximum Dynamic Pressure) throttle down was a single-step throttle bucket to 72% Rated Power Level (RPL).

Propellant dump operations data identified nominal conditions and the MECO time was Engine Start + 512 sec.

The review of the Advanced Health Monitoring System (AHMS) vibration measurements indicates nominal performance. All accelerometer measurements were healthy.

Detailed vibration-data review occurred after return of the on-board Modular Auxiliary Data System (MADS) recorder during post-landing activities in the Orbiter Processing Facility.

The nozzle Flow Recirculation Inhibitor (FRI) showed degradation approximately in line with the Nozzle tubes, and this condition violated the OMRSD (IFA STS-132-E-001). This is the first flight for this FRI. The fraying of this material into the flow path is different from other insulation. During the pre-launch countdown, a 3.5 in. by 0.062 in. crack with no off-set was observed on the outboard face of the Diagonal Strut Base Closeout in the crotch area between the Diagonal Strut and the LH2 Aft Dome. This condition violated Launch Commit Criteria (LCC).

SHUTTLE RANGE SAFETY SYSTEM

The Shuttle Range Safety System (SRSS) closed-loop testing was completed as scheduled during the launch countdown. There were no OMRSD or LCC violations.

All SRSS Safe and Arm (S&A) devices were armed and system inhibits turned off at the appropriate times. As planned, the RSRB S&A devices were safed and RSRB system power was turned off prior to RSRB separation.

ORBITER SYSTEMS

Main Propulsion System

All Main Propulsion System (MPS) systems performed as expected during the launch-countdown and ascent. No MPS LCC or OMRSD violations occurred.

The maximum hydrogen concentration level in the Orbiter aft compartment, with the normally elevated system backpressure used for fastfill, was 140.0 ppm (System A was used to determine the maximum concentration). This compares favorably with previous data for this vehicle.

Data indicate that the MPS performed in a nominal manner. All Liquid Hydrogen (LH₂) and Liquid Oxygen (LO₂) loading parameters were nominal. All LO₂ and LH₂ fill and drain valves performed nominally. The LO₂ and LH₂ Engine Cutoff (ECO) sensors passed all pre-flight checkouts and operated nominally through ascent.

The LH₂ pre-pressurization cycle count was 10 cycles; 14 cycles or more violates the LCC criteria. Engine inlet net positive suction pressure requirements were met throughout the flight. Pressurization performance was nominal indicating proper operation of the Flow Control Valve (FCV) hardware.

The Gaseous Hydrogen (GH₂) system in-flight performance was nominal. Flow control valves performed nominally with 7 cycles for FCV no. 1, 16 cycles for FCV no. 2, and 14 cycles for FCV no. 3.

The Gaseous Oxygen (GOX) fixed-orifice pressurization system performed as predicted. Reconstructed data from engine and MPS parameters closely matched the actual ET ullage pressure measurements.

Hazardous Gas Concentrations

The aft hazardous gas concentrations during loading were nominal. The Hazard Gas Detection System (HGDS) system A was primary. The aft Hydrogen peaked at 140 ppm during fast fill and returned to approximately 10 ppm. The aft Oxygen peaked at 13 ppm during loading and returned to 9 ppm after loading. The Helium peaked at approximately 10,000 ppm during initial LH₂ ET loading. The following table summarizes the results.

HAZARDOUS GAS CONCENTRATIONS AT LAUNCH

Parameter	Peak, ppm	Steady State, ppm
Helium	10,000	7200
Hydrogen	140	10
Oxygen	13	9
LD54/55	0	0

Gas Sample Analysis

The measured sample bottle pressures indicate the redesigned Orbiter aft fuselage gas sampler system.

SUMMARY OF BOTTLE PRESSURES AND GAS CONCENTRATION

Bottle No.	Position	Pressure, psia	Helium, %	Measured Oxygen, %	Hydrogen, %
1	RH 1	3.11	0.39	3.07	0.00
2	LH 1	1.42	0.26	3.05	0.01
3	RH 2	1.43	0.27	3.17	0.01
4	LH 2	0.83	0.52	3.57	0.02
5	LH 3	0.19	1.38	2.26	0.15
6	RH 3	0.07	4.12	1.46	0.29

The Ascent Hazard Analysis indicates the maximum hydrogen firing leak rate

HYDROGEN FIRING LEAK RATES

Bottle no.	Position	Hydrogen Firing Leak Rate, scim
1	RH 1	0
2	LH 1	255
3	RH 2	255
4	LH 2	350
5	LH 3	730
6	RH 3	575

Aft Fuselage Gas Sample Analysis

Five of the six measured sample bottle pressures were within the allowable range. The first bottle in the sequence, right-hand no. 1, had a reported pressure that was approximately 1 torr below the minimum acceptable value. This phenomenon has also been observed on STS-112, 117, 118 and 125. The constituents of the sample appeared valid so it was included in the analysis.

Hydrogen concentrations were well below the flammability limit in each bottle. The highest estimated leak rate was 730 SCIM from the left-hand no. 3 bottle.

The oxygen concentrations were nominal and below the flammability limit. The highest concentration was 3.57% in the left-hand no. 2 bottle. Argon indicates air as the major source of the oxygen in all six bottles and not Orbiter system leakage.

The highest helium concentration was 4.12% in right-hand no. 3 bottle. Due to the low pressure at the time the last bottle acquired its sample and the lack of a diluting atmosphere, the last bottle typically has the most variation in helium concentration.

The complete results of the gas chemical analysis, provided by Kennedy Space Center, are shown in the following table.

AFT SAMPLE BOTTLE ANALYSIS DATA

S/N	Position	Actual pressure, torr	Ar, %	Air from Ar, %	He, %	CO, %	CH ₄ , %	CO ₂ , %	O ₂ from air, %	O ₂ found, %	H ₂ , %	H ₂ pyro corrected, %
1132 FLT-2	RH1	161.0	0.13	13.92	0.39	<0.01	<0.01	<0.01	2.92	3.07	<0.01	0.00
1121 FLT-2	LH1	73.5	0.14	14.99	0.26	<0.01	0.02	0.01	3.15	3.05	0.01	0.01
1135 FLT-2	RH2	73.7	0.15	15.74	0.27	<0.01	0.03	0.01	3.31	3.17	0.01	0.01
1125 FLT-2	LH2	43.0	0.16	17.56	0.52	<0.01	0.03	<0.01	3.69	3.57	0.02	0.02
1129 FLT-2	LH3	9.65	0.12	12.74	1.38	0.03	<0.01	0.01	2.68	2.26	0.17	0.15
1136 FLT-2	RH3	3.61	0.11	11.56	4.12	0.64	<0.01	0.02	2.43	1.46	0.64	0.29

Purge, Vent, and Drain System

The Purge, Vent and Drain (PV&D) system performed nominally. Purge flow rates and temperatures and hazardous gas detection system readings were nominal.

The landing purge was initiated within 30 min (approximately 21 min) of the upper aft safety assessments. The purge was initiated approximately 52 min after touchdown, exceeding the 45-min limit. This condition did not impact the safing of the vehicle.

Reaction Control System

The Reaction Control System (RCS) performed all functions required for successful completion of the mission. One In-Flight Anomaly (IFA) was identified and is discussed later in this section of the report.

The propellant loading for the mission is shown in the following table.

PROPELLANT LOADING

Parameter	Forward RCS		Left RCS		Right RCS	
	Oxidizer	Fuel	Oxidizer	Fuel	Oxidizer	Fuel
Target, %	82.67	81.53	100.48	100.76	100.48	100.76
Target, lbs	1343	832	1523.0	962.0	1523.0	962.0
Calculated, %	83.14	79.75	100.73	100.76	100.66	100.69
Advertised, %	1349.4	816.9	1526.3	962.0	1524.4	961.4

PROPELLANT LOADING (Concluded)

Parameter	Forward RCS		Left RCS		Right RCS	
	Oxidizer	Fuel	Oxidizer	Fuel	Oxidizer	Fuel
PASS WHI ^a	4.3793	4.3369	4.3609	4.2683	4.3758	4.2539
BFS WHI ^b	4.3872	4.3437	4.3622	4.2869	4.3934	4.2703

Notes:

^a PASS WHI – Primary Avionics Software System Initial Weight of Helium Load

^b BFS WHI – Backup Flight System Initial Weight of Helium Load

All Tyvek covers released at nominal speeds. Tyvek cover release speeds and vehicle alpha/beta angles at cover release are given in the table below:

TYVEK COVER RELEASE TIMES, VELOCITIES AND ALPHA/BETA ANGLES

Cover	MET (sec)	Velocity (mph)	Alpha (deg)	Beta (deg)
F1D	4.8	59	5	13
F3D	5.7	70	5	11
F2D	5.9	74	5	11
F4D	6.7	85	4	9
F1U	7.4	95	4	8
F1L	7.5	96	4	9
F3F	7.7	100	4	9
F3L	8.5	112	4	8
F4R	8.8	117	4	7
F2R	8.8	117	4	7
F2U	9.3	124	3	6
F1F	10.0	135	1	5
F3U	10.0	135	0	5
F2F	10.6	145	0	4

The RCS window-protect firing of thrusters F1U, F2U and F3U was initiated at 134/18:22:13 GMT for total duration of 2.08 sec. Forward Reaction Control System (FRCS) performance was nominal. The window-protect firing provides a means to deflect exhaust from the RSRB separation motors away from windows during RSRB separation.

The maneuvers performed using the RCS thrusters and the firing data are shown in the following table.

RCS MANEUVERS AND FIRING DATA

Maneuver/Firing	Engine/System	Time of Ignition, GMT	ΔV , ft/sec	Duration, sec
RCS Window Protect	RCS	134/18:22:13	N/A	2.08
ET Separation	RCS	134/18:28:55	N/A	7
ET Photo +X	RCS	134/18:29:04	N/A	10.4
ET Photo Pitch	RCS	134/18:31:41	N/A	N/A
NC3	RCS	135/21:36:22	1.7	6.88
NCC	RCS	136/10:42:28	0.1	N/A
MC1	RCS	136/12:00:13	0.1	0.4
Out of Plane Null	RCS	136/12:18:15	N/A	N/A
MC2	RCS	136/12:37:06	1.6	6.88
MC3	RCS	136/12:54:04	1.8	7.6
MC4	RCS	136/13:04:04	0.4	1.68
Separation 1	RCS	143/16:36:53.6	N/A	6.00
Separation 2	RCS	143/17:04:53	N/A	5.84
RCS Hotfire	RCS	145/08:22:02	N/A	N/A
Forward Reaction Control System Dump	RCS	146/11:58:35.5	N/A	57.6

The residual propellants at the end of the mission are shown in the following table.

RCS RESIDUAL PROPELLANTS

Parameter	Mission Operations Calculation		PASS Model Calculation ^s	
	%	lbs	%	lbs
Forward Oxidizer	4.4	59.4	2.90	39.1
Forward Fuel	0.0	0	-0.59	-5.0
Left Oxidizer	51.2	691.2	50.70	684.4
Left Fuel	53.0	450.5	53.21	452.2
Right Oxidizer	50.4	680.4	49.48	667.9
Right Fuel	49.4	419.9	49.44	420.2

Note:

^a The official JSC Engineering RCS propellant residuals are those listed under the PASS model

The Aft RCS propellant usage is shown in the following table.

RCS PROPELLANT CONSUMPTION

Parameter	Oxidizer, lb	Fuel, lb	Mixture ratio, Oxidizer/Fuel
Forward RCS	1083.3	682.9	1.59
Left RCS	675.4	404.3	1.67
Right RCS	691.0	435.7	1.59

The attitude control responsibilities between the ISS and the Orbiter are shown in the following table.

CONTROL RESPONSIBILITIES BETWEEN ISS AND SHUTTLE

Control Responsibility	Control Start, GMT	Orbiter DAP Mode	Comments
	136/14:28:26	DAP FREE	Docking/ISS Capture
Orbiter	136/14:48:28	DAP VERN	
	136/14:54:07	DAP FREE	
Orbiter	136/14:54:14	DAP AUTO	TEA Maneuver
	136/15:29:21	DAP FREE	Set Contraction
Orbiter	136/15:33:11	DAP AUTO	
Orbiter	136/15:50:32	DAP B	Collapse Dead band
	136/16:01:53	DAP FREE	
Orbiter	143/14:11:09	DAP AUTO	Maneuver to Undock Attitude
	143/15:07:54	DAP FREE	Logic Configuration
Orbiter	143/15:08:59	AUTO	
	143/15:19:08	DAP FREE	Driver Configuration
Orbiter	143/15:19:46	DAP B/ALT No Low Z	
	143/15:22:03		Undock

As part of the undocking preparations, forward thrusters were reselected at 143/14:43:54 GMT (08/20:23:45 MET), except for thrusters F1F and F2F. Undocking was initiated with a +Z pulse at 143/15:22:11 GMT (08/21:02:02 MET). The undocking from the ISS was nominal. The F1F and F2F thrusters were reselected at 143/15:27:35 GMT (08/21:07:26 MET) following undocking. The Fly Around (full maneuver) was initiated with a +X pulse of thrusters L1A and R1A at 143/15:48:51 GMT (08/22:53:26 MET).

At approximately 90 sec MET, the Backup Flight System (BFS) Left propellant quantities increased over a 20-sec period from 100% to 106% fuel and 110% oxidizer remaining, respectively. The indicated quantities returned to nominal readings after about 5 min.

Both the fuel and oxidizer injector temperatures for thruster L3D went below thruster heater activation range with no sign of activation. The allowable heater turn-on temperature is between 60 °F and 80 °F (IFA STS-132-V-02).

The thermal predictions showed that the L3D thruster would be maintained within acceptable temperatures during the pre-dock and docked phases, but L3D valve temperatures could go below 50 °F after undocking. The ground controllers requested the post-undocking attitudes and durations that would protect L3D from potential leakage and allow L3D to be warmed back up to acceptable firing temperatures. The ground controllers also requested a post-chill recovery temperature that would maximize chances for continued successful firings of L3D should it be required following

failure of another thruster. The Mission Evaluation Room (MER) personnel recommended warming L3D to a minimum of 59 °F following an injector temperature drop below 47 °F without indicating failed leak for the STS-132 flight conditions.

The lowest injector temperatures observed during the entire mission were 45.2 °F for fuel and 47.7 °F for oxidizer. Since oxidizer and fuel injector temperatures did not fall below their respective limits of 30 °F and 20 °F, the thruster was not deselected as failed leak by the Redundancy Management (RM) system. However, thruster L3D was manually placed in third (last) priority after the flyaround at 143/17:19:04 GMT (08/22:58:55 MET) since injector temperatures were expected to fall below 50 °F. Also, the RCS Hot-fire Test procedure was modified to prevent L3D firing with injector temperatures below 59 °F and omitting the –Z pulses (F3D, F4D, L3D, R3D) in the third pulse sequence. Since L3D’s injector temperatures were below 59 °F prior to the deorbit maneuver, the L3D thruster was deselected prior to entry.

Orbital Maneuvering System

The Orbital Maneuvering System (OMS) performed satisfactorily and no IFAs were identified from the review and analysis of the flight data.

OMS CONFIGURATION

Vehicle/ equipment	Flight	Orbital Maneuvering Engine (OME)	Ancillary data
Left Pod (LP) 04	32 nd	L-OME S/N 108	6 th rebuilt flight - 30 th flight
Right Pod (RP) 01	39 th	R-OME S/N 109	11 th rebuilt flight - 28 rd flight

OMS MANEUVERS

Maneuver designation	Configuration	Time of ignition, GMT	Firing time, sec	ΔV, ft/sec/ interconnect usage, %
Assist	Dual Engine	134/18:22:24.2	90.2	N/A
OMS-2	Dual Engine	134/18:58:24.2	63.0	97.5
OMS-3 (NC1)	Dual Engine	134/21:54:58.8	26.3	40.4
OMS-4 (NC2)	Right Engine	135/11:33:02.7	10.4	7.9
OMS-5 (NH)	Dual Engine	136/09:23:20.7	84.4	132.3
OMS-6 (NC4)	Dual Engine	136/10:08:10.7	63.2	100.1
OMS-7 (TI)	Left Engine	136/11:40:09.3	12.2	9.3
OMS-8 (SIMPLEX)	Dual Engine	145/15:23:20.3	9.8	17.2
(Deorbit)	Dual Engine	146/11:41:59.2	185.6	333.6

The interconnect usage from the OMS to the RCS is shown in the following table.

INTERCONNECT USAGE, %/POUNDS

Parameter	Total, %	Total, lb
Left OMS	1.212	156.99
Right OMS	1.357	175.78

The following table presents the propellant loading and usage data for this mission.

PROPELLANT USAGE DATA

Parameters	Left OMS pod		Right OMS pod	
	Oxidizer	Fuel	Oxidizer	Fuel
Loaded, lbm	7050	4254	7051	4254
Residual, lbm (aft gage)	498	297	585	377
Residual, lbm (burn time integration)	623	352	628	294
Residual, lbm (SODB flow rate)	538	334	562	317

Auxiliary Power Unit System

The Auxiliary Power Unit (APU) system performance was nominal throughout the STS-132 mission. The bed heater lower set-point shift signature for the APU 1 Gas Generator (GG) repeated as expected on STS-132. There were no In-flight anomalies identified from the review and analysis of the flight data. The following tables show the run times and fuel consumption for each APU.

APU RUN TIMES

APU (S/N)	Ascent, hr:min:sec	FCS Checkout, hr:min:sec	Entry, hr:min:sec	Total time, hr:min:sec
APU 1 SN 409	00:19:16	00:03:18	1:02:52	1:25:26
APU 2 SN 410	00:19:38	00:00:00	1:30:04	1:49:42
APU 3 SN 204	00:19:57	00:00:00	1:03:43	1:23:40

APU FUEL CONSUMPTION

APU (S/N)	Ascent, lb	FCS Checkout, lb	Entry, lb	Total, lb
APU 1 SN 409	48	12	109	169
APU 2 SN 410	48	0	159	207
APU 3 SN 204	50	0	128	179

The APU 3 drain line “A” heater circuit was again noted to have a wide control band during the mission, even though the previous S132A thermostat had been Removed and Replaced (R&R'd) prior to flight; no post-flight action is planned.

Hydraulics and Water Spray Boiler

The Hydraulic /Water Spray Boiler (HYD/WSB) system performance was nominal during all phases of the mission. There were no HYD/WSB anomalies during the flight. The following tables present the ascent and entry performance.

All three WSB system cores were loaded with approximately 5.0 lb of the additive mixture (53% water; 47% PGME). The initial PGME/Water Tank loading for all WSBs was approximately 133.8 lbs. Nominal WSB performance was observed on all three systems during pre-launch and ascent.

A WSB “Ready” Signal was obtained on each of the three WSBs at beginning at 134:02:28:25 GMT (00/00:08:16 MET) when the Gaseous Nitrogen (GN₂) Isolation Valves were opened. The GN₂ Isolation Valves were closed at 134:02:29:07 GMT (00/00:08:58 MET).

The following tables show the WSB performance during ascent and entry.

WSB PERFORMANCE DATA DURING ASCENT

WSB	Spray Start Temperature (°F)	Time, GMT	Steady State Temperature (°F)	PGME/H2O Usage (lb)
System 1	255	134:18:29:44	252	3.1
System 2	269	134:18:30:47	253	1.4
System 3	261	134:18:28:19	254	4.5

WSB PERFORMANCE DATA DURING ENTRY

WSB	Spray Start Temp (°F)	Time, GMT	Steady State Temp (°F)	PGME/H2O Usage (lb)
System 1	253°F	146:12:12:03	146:12:12:03	17.1
System 2	259°F	146:11:45:35	146:11:45:35	40.9
System 3	259°F	146:12:10:49	146:12:10:49	31.8

Power Reactant Storage and Distribution System

The OV-104 Power Reactant Storage and Distribution (PRSD) system performance was nominal, and no IFAs were identified from the analysis of the data. The PRSD system supplied the fuel cells with 2673 lb_m of oxygen and 337 lb_m of hydrogen for the production of 3896 kWh of electrical energy. The average power level for the 282.49-hour mission was 13.8 kW. A 75-hr mission extension was possible at the average power level with the reactants remaining at touchdown. Oxygen Tanks 4 and 5 and Hydrogen Tanks 4 and 5 were depleted to residual quantities.

The total oxygen supplied to Shuttle Environment Control and Life Support System (ECLSS) and ISS was 234 lb_m of oxygen. A 42 lb_m tank-to-tank oxygen transfer from the Shuttle PRSD to ISS was performed.

The following table shows the tank quantities at loading, lift-off and landing.

PRSD TANK QUANTITIES

Oxygen

Oxygen	Tank 1, %	Tank 2, %	Tank 3, %	Tank 4, %	Tank 5, %	Total Mass, lb _m
Loaded	101.8	101.8	100.9	101.8	101.8	3968
Launch	100.5	100.5	100.1	100.5	100.5	3921
Landing	42.3	42.3	34.8	5.5	5.0	1015

Hydrogen

Hydrogen	Tank 1, %	Tank 2, %	Tank 3, %	Tank 4, %	Tank 5, %	Total Mass, lb _m
Loaded	101.9	101.5	102.3	103.7	102.8	471.2
Launch	99.3	98.4	99.3	100.6	99.7	457.5
Landing	38.2	43.5	45.3	1.5	2.9	120.9

Fuel Cell System

Fuel Cells

The overall performance of the OV-104 fuel cell system was nominal for STS-132. No IFAs were identified during the review and analysis of the flight data.

The average electrical power level and load was 13.8 kW and 449 Amperes (A). During the 282.49-hr mission, the fuel cells produced 3009 lb_m of potable water and 3896 kWh of electrical energy from 2673 lb_m of oxygen and 337 lb_m of hydrogen.

The fuel cell electrical power level averaged 13.8 kW and the total Orbiter load averaged 449 A. Six fuel-cell purges were performed, occurring at approximately 20, 66, 120, 168, 227, and 274 hours MET.

The actual fuel cell voltages (200 A load) at the end of the mission were 0.05 Volt (V) above predicted for fuel cell 1, 0.10 V above predicted for fuel cell 2, and 0.15 V above predicted for fuel cell 3. The voltage margins above the minimum performance curves at 200 A at the end of the mission were 0.74 V above minimum for fuel cell 1, 0.90 V above minimum for fuel cell 2, and 0.90 V above minimum for fuel cell 3.

The prelaunch baseline Cell Performance Monitor (CPM) values for fuel cell 1 were 2, 18, and 22 mV, for fuel cell 2 were 6, 2, and 64 mV, and for fuel cell 3 were 20, 12, and 60 mV. They were established at 134/11:30 GMT, approximately 4 hr and 43 min after the completion of the fuel-cell calibration requirement.

The Fuel Cell Monitoring System (FCMS) was used to monitor individual cell voltages prelaunch, on-orbit, and postlanding. The full-rate on-orbit data was recorded for 12 min beginning at 135/10:08:51 GMT (00/15:48:42 MET); there were no outliers.

Station-to-Shuttle Power Transfer System Operation

The OV-104 vehicle was not equipped with the Station-to-Shuttle Power Transfer System (SSPTS), no power was transferred to the Shuttle.

Electrical Power Distribution and Control System

The Electrical Power Distribution and Control (EPDC) system performed nominally during all mission phases. The data review and analysis of all available EPDC parameters was completed and no non-nominal conditions were identified.

Orbiter Docking System

The Orbiter Docking System (ODS) performed satisfactorily, and no IFAs were identified from the review and analysis of the data.

The initial application of power to the ODS and ring extension were performed nominally during Flight Day (FD) 2 and the ODS was activated for 9 min 17 sec, and the avionics hardware was powered for 5 min 35 sec. The system was ready for rendezvous and docking with the ISS.

The application of power for the docking activities was initiated at 136/13:55:07 GMT (01/19:34:59 MET), and the ODS was powered for 54 min 42 sec with power to the avionics hardware for 47 min 25 sec. The initial contact and capture of the ISS occurred at 136/14:28:26 GMT (01/20:08:18 MET). The initial damping was 1 min 34 sec and performance of the "Disable and Release Dampers" procedure was necessary to ensure that any stuck dampers were disengaged. The start of drive-in function began at 136/14:35:14 GMT (01/20:15:06 MET), and was completed in 3 min 16 sec. The drive- start time for the Hooks-Close function was 136/14:38:24 GMT (01/20:18:16 MET), and the capture latches were released in 2 sec, and docking was complete 14 min 54 sec later.

In preparation for undocking, the ODS was activated at 143/14:54:41 GMT (08/20:34:33 MET). During the setup for undocking, the crew reported that the ODS vestibule lights were not working. Troubleshooting to regain the lighting was unsuccessful. As a workaround, the crew positioned Light-Emitting-Diode (LED) flashlights in the vestibule as a substitute for the failed lighting.

The undocking and separation from the ISS was completed satisfactorily at 143/15:21:14 GMT (08/21:01:06 MET). The ODS was powered for 45 min 20 sec with power to the avionics hardware for 31 min 54 sec for the undocking operations.

Life Support Systems

Atmospheric Revitalization Pressure Control System

The Atmospheric Revitalization Pressure Control System (ARPCS) performed nominally throughout the mission and no IFAs were identified during the review and analysis of the flight data.

A tank-to-tank Nitrogen (N₂) transfer from the Orbiter to the ISS, was made and approximately 10.5 lb of N₂ was transferred. Also, an Oxygen (O₂) Orbiter-to-ISS tank-to-tank transfer was performed and approximately 44 lbm of O₂ was transferred. In addition, two Orbiter/ISS stack N₂ repressurizations were performed using the Orbiter Pressure Control System (PCS).

Airlock System

The Airlock Systems performed nominally throughout the mission. No Orbiter-based Extravehicular Activities (EVAs) were performed during this mission. All water line, vestibule, and structure heaters cycled on all systems.

Supply and Waste Water System

The Supply Water and Waste Management Systems (SWWMS) performed nominally throughout the mission and no IFAs were identified during the review and analysis of the flight data. The supply water was managed through the use of the Flash Evaporator System (FES), water transfer to the ISS and the dump nozzle. The supply water dump line temperature was maintained between 73 °F and 112 °F throughout the mission.

The Waste Water Management performed nominally through the mission. The waste management system performed three successful dumps. The first two dumps were performed as simultaneous dumps. The second dump was followed by a Contingency Water Container (CWC) dump. The dump rate for the three water dumps was a nominal average dump rate of 1.9 %/min (3.1 lb/min). The wastewater dump line temperature was maintained between 53 °F and 77 °F throughout the mission.

Eighteen (18) Contingency Water Containers –Iodine (CWC-Is) were filled, five CWCs and 3 Portable Water Reservoirs (PWR's) were filled with water and transferred to the ISS, for a total of 1212.3 lbm (730.7 lb_m from CWC-Is and 481.6 lbm from CWCs). The PWRs contained iodinated water for a total 54.3 lb_m were filled and transferred to ISS.

Two CWCs were used to collect condensate. Both CWCs were transferred to the ISS for processing in the Russian segment.

The quantity sensors in the supply water tanks A, C and D exhibited quantity dropouts throughout the mission. Such dropouts have been experienced in previous flights and the problem was caused by either contamination on the collector bar and/or surface defect on the collector bar of the potentiometer, which causes an intermittent break in continuity. These dropouts are understood problems.

The vacuum vent line temperature was maintained between 75°F and 58 °F. The thermostat low and high set points are 55 ± 5 to 75 ± 5 °F.

Smoke Detection and Fire Suppression System

The Smoke Detection and Fire Suppression (SDFS) system operated nominally with no issues. The smoke detector checkout was accomplished. All smoke detection A & B sensor circuits passed.

Use of the Fire Suppression system was not required.

Active Thermal Control System

The Active Thermal Control System (ATCS) performed all functions required for a successful mission. The radiators were not deployed this flight. One IFA was identified and this IFA is discussed in a later paragraph.

The crew compartment Partial Pressure Carbon Dioxide (PPCO₂) was managed to levels below 5.0 mmHg for the entire mission except for FD 8, and 10. The PPCO₂ peaked to 5.9 mmHg on FD 10.

The primary B controller shut-down the FES in the topping mode near the end of the radiator cold-soak for deorbit preparation (IFA STS-132-V-04). The crew executed a restart of the FES topper using the primary B controller. This restart failed to reach the proper temperature control band, causing a second shutdown of the primary B controller. The crew restarted the FES using the primary A controller and this resulted in a successful startup with proper temperature control. A contingency procedure for core-ice removal using a modified radiator bypass/FES checkout with core flush (on secondary controller) followed the primary A restart operation. Ice and excess carryover were observed in the FES topping ducts during this modified radiator bypass/FES checkout with core flush, so the core-flush stage of the procedure was performed once more. The second core flush produced duct temperature signatures that indicated a complete ice flush of the core. After completion of the contingency procedure, the FES configuration was switched to primary A controller in full up mode which prepared the Orbiter for deorbit.

The Ammonia Boiler System (ABS) A primary controller was activated at 146/12:56 GMT (011/18:36 MET). Continued ABS operation on system A was for 39 min, until the system was terminated because of ground-cooling activation. System B activation was not required because Ground Support Equipment (GSE) cooling was initiated.

Flight Software

The Primary Avionics Software System (PASS) and Backup Flight System (BFS) Flight Software (FSW) performed nominally. All mode operations were completed successfully. Normal explained errors occurred during the mission, none of which impacted the mission.

Data Processing System Hardware

The Data Processing System (DPS) performed satisfactorily, and the data review and analysis of DPS parameters identified no IFAs.

Multifunction Electronic Display System

The Multifunction Electronic Display System (MEDS) performed satisfactorily and no IFAs were identified during the review and analysis of the data.

The Multifunction Display Unit (MDU) Cathode Ray Tube (CRT) 1 reported "Power Supply/Lamp Fail" and "CRT1 Built In Test Equipment (BITE) Fail" with a detailed error of "Luminance Control Loop Fail" 29 sec prior to Launch (134/18:19:40 GMT). The error cleared after 7 min 51 sec. The error repeated two more times after launch. These errors are attributed to MEDS Hardware User Note. Neither MDU performance nor the quality of the display image were affected by this error condition.

The MDU Multifunction Display (MFD) 2 reported "Power Supply/Lamp Fail" and "MFD1 BITE Fail" with detailed error of "Luminance Control Loop Fail" during the Flight Control System (FCS) checkout. The error cleared one second later. The error repeated four additional times within the next 21 min, clearing within 10 sec each time. These errors are believed to be attributed to MEDS Hardware User Note. This condition did not impact the successful completion of the mission.

Displays and Controls System

The Display and Controls (D&C) system performed satisfactorily and no IFAs were identified during the review and analysis of the data. One item of interest is discussed in the following paragraph.

During the set up of the vestibule lights prior to FD10 undocking, the crew reported the lights would not illuminate. The crew checked Panel A6L circuit breakers (MN A and MN B vest port/starboard) and verified they were closed (ON). It was assumed that the vestibule lighting operated nominally for FD 3 docking. The crew attached LED flashlights in the area and adequate illumination was provided.

Flight Control System

The Flight Controls System (FCS) performed nominally during the flight as well as during the post- landing operations.

The FCS hardware/effector systems performed nominally during ascent through APU shutdown. At all times, the SRB thrust vector controller (TVC), MPS TVC, and Aerosurface Actuators (ASAs) were positioned as commanded with normal driver currents, secondary differential pressures, and elevon primary differential pressures. The rate outputs of the four Orbiter Rate Gyro Assemblies (ORGAs) and four SRB Rate Gyro Assemblies (SRGAs) tracked one another normally, and no Spin Motor Rotation Detector (SMRD) dropouts. The outputs of the four Accelerometer Assemblies (AAs) also tracked one another normally. Reaction Jet Driver (RJD) operation was also normal with no thruster failures or other anomalies noted. The Device Driver Unit (DDU) and controller operations also were nominal. Both the Rotational Hand Controller (RHC) and the Translational Hand Controller (THC) were used and exhibited normal channel tracking.

The OMS TVC actuator rates were normal. Flight control actuator temperatures were also normal. Rudder/Speed Brake Power Drive Unit (RSB PDU) motor backdrive did not occur during the hydraulic system shutdown.

The FCS hardware checkout in the OPS-8 mode performance was nominal. No anomalies were found in aerosurface drive data, individual channel test data, ORGA and AA test data, nose-wheel steering test data, and DDU/controller data.

Entry performance was nominal from the deorbit maneuver through vehicle touchdown. The pre-ignition OMS gimbal profile was as expected with the OMS actuator active and standby channels reaching nominal drive rates. All ASAs performed normally. Secondary differential pressures for all actuators were well within the equalization threshold, and all actuator positions closely tracked General Purpose Computer (GPC) commands. Entry hydraulic system temperatures were comparable to previous flights with aerosurface actuator temperatures being within the normal limits. The MPS TVC actuator performance was normal, with secondary differential pressures within threshold and TVC actuator positions and GPC commands following each other closely.

Air Data Transducer Assembly

The Air Data Transducer Assemblies (ADTAs) performed nominally during all phases of the flight and during post-landing operations, and no IFAs were identified during the review and analysis of the data.

All four ADTAs functioned nominally from power-on until nominal data loss at the T-minus-20-min transition on launch day. The ADTA self-test performed shortly after power-on was nominal. There is no insight into ADTA performance during the ascent phase until after the elevons are parked during the post-insertion period. All ADTA mode/status words were nominal during elevon park.

ADTA OPS-8 mode FCS checkout performance was nominal. Power-on and self-tests were performed with no anomalies. All 16 transducer outputs showed nominal responses.

Entry performance was nominal from de-orbit through wheels-stop. All 16 transducers tracked during the pre-probe deployment phase of entry. Air data probes were deployed at approximately Mach 5.0, and deployment timing was within specification of less than 15 sec. ADTA data were incorporated into Guidance, Navigation, and Control (GN&C) at about Mach 3.0. No ADTA dilemmas or Redundancy Management (RM) failures occurred during deployment through wheels-stop.

Inertial Measurement Unit and Star Tracker System

The Inertial Measurement Unit (IMU) system performed nominally throughout the mission, and no IFAs were identified from the review and analysis of the flight data.

During on-orbit operations, one adjustment of the onboard IMU accelerometers compensations was performed on all three IMUs, and two adjustments of the IMU drift compensation values.

The -Y and -Z Star Trackers (STs) performed nominally throughout the mission and no IFAs were identified during the review and analysis of the data.

The -Y ST acquired a navigation-star 304 times during the mission. A total of 61% (477) of the navigation stars were missed. The missed stars result from Shuttle attitude, EVAs, docking orientation, Orbiter maneuvers and bright objects in the Field of View (FOV), which are considered normal.

The -Z ST acquired a navigation star 27 times and missed navigation stars 68.6% (59) times. Evaluation showed that 94.9% (56) of the missed stars occurred during docking operations. This operation is considered normal.

Global Positioning System Navigation

Overall, Global Positioning System (GPS) performance was nominal and no IFAs were identified during the review and analysis of the data.

The OV-104 was configured with the "1-String GPS" configuration. The GPS state vector was incorporated into both the PASS and BFS in Major Mode (MM) 304 after performance confirmation with high-speed C-band tracking. This occurred at approximately 153,000-ft altitude, and simultaneously with the call to incorporate Tactical Air Navigation (TACAN) systems. The effect was that the PASS and BFS navigation state vector residuals were reduced significantly, as expected. The PASS navigation state vector residuals remained consistently low from GPS incorporation down to MLS incorporation at approximately 16,000-ft altitude where the PASS automatically stops taking GPS updates per design. Likewise, the BFS navigation state vector residuals remained consistently low from GPS incorporation all the way through rollout as designed since the BFS does not process Microwave Landing data.

Communications and Tracking System and Navigation Aids

The Communications and Tracking systems performed nominally throughout the mission, and no IFAs were identified from the review and analysis of the data. One item of interest is discussed in a later paragraph. The S-Band system operated satisfactorily for over 24 hr, which fulfilled the mission requirements.

The Navigation Aids (NAV AIDS) system performed satisfactorily and no IFAs were identified during the review and analysis of the data.

The S-Band Lower-Right antenna path had intermittent noisy Automatic Gain Control (AGC) and forward link dropouts. During the mission, after several days of monitoring and data evaluation, both the S-band and Ant/Cable personnel concluded there was no failure present and no troubleshooting was required.

Operational Instrumentation/Modular Auxiliary Data System

The Operational Instrumentation (OI) and Modular Auxiliary Data System (MADS) performed nominally throughout the mission, and no IFAs were identified during the review and analysis of the flight data.

The Modular Auxiliary Data System (MADS) Pulse Code Modulation (PCM) ascent data was recorded on the Solid State Recorder (SSR) and dumped to the ground. The MADS PCM performed nominally with no problems identified in the review of the data.

Mechanical and Hatches System

All mechanical and hatch systems performed nominally and no IFAs were identified during the review and analysis of the data.

During the Payload Bay Door (PLBD) closing, the starboard PLBD system 1 close indication came on approximately 13 sec later than the system 2 close indication. There has been a long history of PLBD close (and open) indication problems in the history of the program. Similar delay times have occurred in the past, and this event is not considered an issue.

The Orbiter Boom Sensor System (OBSS) aft pedestal Manipulator Retention Latch (MRL) System 2 latch indication did not come on during both OBSS berthing operation. This is an explained condition caused by a flight rule that opens the circuit breakers, for safety reasons, that inhibit one of the motors.

Landing and Deceleration System

The Landing System performance at KSC was nominal. This assessment includes all events from landing gear deployment, main gear touchdown, nose gear touchdown, through roll out, and including drag chute deployment and brake/deceleration. It was

the first flight of the nose landing gear tires. They were in good condition and performed nominally. The main landing gear tires appeared nominal. The normal appearance of tread cord materials on areas of the tire's surface is a known and expected condition that is a characteristic of the new tire design. Parachute deployment and jettison occurred nominally. No unexpected affects of performance of the drag chute occurred.

LANDING PARAMETERS

Parameter	From threshold, ft	Time from MLG touchdown, sec	Speed, keas ^a	Speed, kgs	Sink rate, ft/sec	Pitch rate, deg/sec
Main Landing gear touchdown	2990.1	0.0	193.8	192.4	-1.93	
Drag Chute Deployment	3898.2	2.83	184.6	182.5		
Drag Chute Disreef	5299.6	7.80	163.9	158.1		
Nose Landing Gear Touchdown	6229.9	11.48	140.1	134.8		-5.0
Brakes On	9952.9	35.48	72.7	63.5		
Drag Chute Jettison	10349.5	39.44	OSL ^b	56.9		
Wheels Stop	12098.2	79.92	0.0	0.0		
Parameter			Data			
Brake Initiation Speed, keas			72.7			
Brake On Time, sec			44.44			
Rollout Distance, ft			12098.2			
Rollout Time, sec			79.92			
Runway Location, Surface and Degrees			KSC/33 Concrete			
Orbiter Weight at Landing, lb			210563			
Parameter		Maximum Brake Pressure, psia		Total Brake Energy, Mft/lb		
Left inboard		684		7.78		
Left outboard		552		6.46		
Right inboard		600		5.14		
Right outboard		588		5.86		

^aKnots equivalent air speed

^bOff scale low

Aerothermodynamics, Integrated Heating and Interfaces

The Orbiter Boundary Layer Transition (BLT) onset time was 1272 seconds after entry interface or Mach 6.8 based on the centerline location at X/L = 0.6. This transition time was based on the MADS data and the STS-132 best estimated trajectory (BET). All the windward fuselage surface thermal sensors plus two located at the forward wing area indicated the vehicle transition occurring around Mach 6.8 except four sensors at the wing area. The thermal sensors indicated at the right wing aft outboard the transition occurred around Mach 9.3, and at the left wing aft outboard occurred around Mach 8.0 and two wing aft inboard thermal sensors indicated the transition occurred around Mach

7.7. The thermal couple located at left fuselage at X/L = 0.68 indicated the transition occurred around Mach 13.8. This was caused by a protruding gap filler.

Post-landing measurement of the gap filler indicated maximum height of 0.3-in. tapering to 0 in. with a length of 5-in. An intermediate height measurement of 0.1-in. was noted approximately 3.5-in. from the end of the gap filler that was sticking up 0.3-in. The predicted transition Mach number is 15.2 based on BET.

The lower structural temperature data indicated normal entry heating and was within the range expected for this weight and inclination. The recorded temperatures were within the flight experience of the OV-104 vehicle. The following table shows the entry maximum temperature and temperature rise data.

ENTRY MAXIMUM TEMPERATURE AND MAXIMUM TEMPERATURE RISE DATA

Thermal Sensor Location	Maximum Temperature, °F	Maximum Temperature Rise, °F
Lower fuselage forward center (B1)	135.1	113.8
Lower fuselage forward left-hand (B2)	171.9	163.4
Lower fuselage forward mid left-hand (B3)	164	170.7
Lower fuselage mid center (B4)	145.6	144.7
Lower fuselage mid aft center (B5)	161.4	155.4
Lower fuselage aft center (B6)	177.2	148.2
Left-wing center (LW)	109	133.5
Right wing center (RW)	124.7	128.8
Port side FRCS forward (P1)	127.3	106
Port side fuselage forward center (P2)	83	97.4
Port side fuselage forward mid center (P3)	77.9	89.7
Port side fuselage mid aft center (P4)	64.9 ^a	84.4 ^a
Port side fuselage aft center (P5)	77.9	69.3
Starboard side FRCS Forward (S1)	148.2	101.3
Starboard side fuselage forward center (S2)	140.4	113.9
Starboard side fuselage forward mid center (S3)	116.8	82.7
Starboard side fuselage mid-aft center (S4)	80.5 ^a	61.7 ^a
Starboard side fuselage aft center (S5)	101.2	72.2
Left-hand OMS pod side forward (LP)	67.5 ^a	61.5 ^a
Right-hand OMS pod side forward (RP)	75.3 ^a	66.7 ^a
Lower body flap center	106.4 ^a	80.0 ^a
Right-hand OMS POD Side forward	75.3 ^a	66.7 ^a
Left-hand OMS POD Side forward	67.5 ^a	61.5 ^a
Right-hand PLBD forward	70.1 ^a	114.8 ^a
Left-hand PLBD forward	70.1	129.9
Right-hand PLBD aft	77.9 ^a	102.3 ^a
Left-hand PLBD aft	75.3 ^a	117.4 ^a
Right wing upper center	98.6	107.9
Left wing upper center	83.0 ^a	115.1 ^a

ENTRY MAXIMUM TEMPERATURE AND MAXIMUM TEMPERATURE RISE DATA (Concluded)

Thermal Sensor Location	Maximum Temperature, °F	Maximum Temperature Rise, °F
Forward RCS center	96.0 ^a	72.2 ^a
Forward Fuselage (Upper Center)	80.5	97.3

Notes

^a Maximum temperature occurred 30 min after wheel stop.

Thermal Control System

The Passive Thermal Control systems performed nominally, and one IFA was identified from the review and analysis of the data. This anomaly did not impact the successful completion of the planned mission.

On FD 2 before docking, at 1/03:21:39 MET, the L3D thruster heater was declared failed OFF when the Oxidizer and Fuel injector temperatures dropped to 57 °F (IFA STS-132-V-02). The previous flight of this vehicle showed the L3D heater turning ON at 84 °F. A low trending signature was noted on the last flight of OV-104 (STS-129) towards the end of the flight. The range apparently changed, but the heater was still cycling normally. This may have been an indication that the sensor for the controller was starting to act erratically, but it was still within an allowable temperature range. The R4D thruster heater also failed OFF during STS-5 with a thermally similar attitude. For STS-5, it failed OFF and then ON again. This was probably due to the controller sensor failing OSH and then OSL.

Thermal Protection System and Post-Landing Assessment

Post-Landing Assessment

The final debris-related tile damage numbers are shown in the following table.

SUMMARY OF IMPACT SITES FOR EACH ORBITER SURFACE

Orbiter Surface	Impacts greater than 1 in.	Total impacts
Lower surface	4	95
Upper Surface/Window	0	13
Right OMS pod	4	7
Left OMS pod	1	9
Totals	9	124

Tile and Blanket Flight Assessment

The Thermal Protection System (TPS) and blankets performed satisfactorily. The post-flight inspection of the Orbiter Atlantis (OV-104) TPS following the STS-132 Mission identified the minor damages as follows:

1. The gap filler installed between the chin panel and nose cap is showing some signs of fraying and one small breach approximately ½-in. Right Hand (RH) outboard. The gap was approximately 0.2-in. at the centerline, 0.16-in. on the Left Hand (LH) side and 0.15-in. on the RH side.
2. The LH Main Landing Gear Door (MLGD) thermal barriers had one fray at the outboard aft end; RH MLGD thermal barriers had one minor fray on outboard side.
3. Two protruding gap filler were seen. One appeared as seen on orbit photography. The second one was protruding 0.09-in. outboard of the LH MLGD and was loose.
4. Damage on tile seen on orbit was coating only damage with no visible change.
5. All Payload Bay Door (PLB) ceramic plugs installed pre-flight were present. Two locations where Felt Reusable Surface Insulation (FRSI) plugs that were installed were present but charred.
6. LH External Tank (ET) door forward outboard corner showed signs of flow with a white-color deposit on fingers, door and sidewall. Tile repairs in that location of the door perimeter showed signs of slumping. This area was in line with the protruding AMES gap filler.
7. Large damage on lower LH vertical tail tile, approximately 3.0 by 1.0 by 0.5 in.
8. LH split line thermal barrier was blown out with internal batting showing.
9. A tile was damaged with dimensions at Outer Mold Line (OML) 0.5 by 0.2 in. and Interior Mold Line (IML) was 0.2 by 0.2 in. and extended the full depth.

RCC Flight Assessment

The Reinforced Carbon-Carbon (RCC) performed nominally, and no IFAs were identified from the review and analysis of the data.

After the completion of the Flat Field Survey, the Starboard T0 Umbilical Survey, and OMS Starboard Pod Survey, the crew had issues setting up the sensor package for the Starboard RCC Survey. It was determined that a cable became pinched while the sensor package was commanded to tilt up, thus limiting the amount of travel. The DAT learned that digital imagery of the Port Chine and RCC area was obtained during the first EVA on FD 4, and began their assessment of the imagery. On FD 5, the RCC coverage was improved with the additional images, but resolution was still less than optimal in some areas. The options for obtaining additional RCC imagery were still being evaluated. Checkout of the PTU after the repair made during the second EVA confirmed that the full range of motion was now available in the pan and tilt axes. On FD 7, the MMT decided that additional docked surveys were not required.

On FD 11, the Starboard RCC survey began at 144/08:29 GMT (09/14:08 MET) and was completed at 144/09:49 GMT (09/15:28 MET). The Nose RCC was surveyed from 144/10:18 GMT (09/14:57 MET) to 144/10:51 GMT (09/16:30 MET). The Port RCC was surveyed from 144/11:20 GMT (09/16:59 MET) to 144/11:17 GMT (09/16:56 MET).

On FD 12, all of the Late Inspection data for the RCC were downlinked and analyzed. The RCC Debris Assessment Team (DAT) reported that no anomalous conditions were identified and that the vehicle was ready for entry. The Mission Management Team (MMT) accepted the report and cleared the vehicle for entry.

Windows

The post-flight inspection of the Orbiter Windows showed the following items:

1. Window no. 1 had one defect, and remains acceptable for flight.
2. Window no. 2 had no defects.
3. Window no. 3 had two defects, and remains acceptable for flight.
4. Window no. 4 had one defect and remains acceptable for flight.
5. Window no. 5 had two defects and remains acceptable for flight.
6. Window no. 6 had four defects and has been scrapped.
7. Window no. 7 had two defects and remains acceptable for flight.
8. Window no. 8 had one defect and remains acceptable for flight.
9. Window no. 11 had no new defects and remains acceptable for flight.

Waste Collection System

The Waste Collection System operated satisfactorily and no problems were reported during the crew debriefings.

EXTRAVEHICULAR ACTIVITY

The crew performed three Extravehicular Activities (EVAs) on STS-132 in a total EVA time of 21 hr, 20 min. Space Shuttle Mission Specialists Steve Bowen, Garrett Reisman, and Mike Good were the designated EVA crewmembers on this flight. The primary EVA mission objectives were to install the redundant Space to Ground Antenna (SGANT) onto the Z1 truss, install the Enhanced Orbital Replacement Unit (ORU) Temporary Platform (EOTP) onto the Special Purpose Dexterous Manipulator (SPDM), and Remove and Replace (R&R) six (6) Batteries on the P6 lower Integrated Element Assembly (IEA). The Airlock campout prebreathe protocol was utilized in preparation for all of the EVAs.

FIRST EXTRAVEHICULAR ACTIVITY

The first EVA was performed by Garrett Reisman Extravehicular 1 (EV1), and Steve Bowen EV2, on Flight Day (FD) 4. The highest priority objective on first EVA was the installation of the redundant SGANT Ku-band antenna onto the International Space Station (ISS). To complete the task, the EV1 and EV2 crewmembers first worked together to release the SGANT boom from its Flight Support Equipment (FSE) on the Integrated Cargo Carrier – Vertical Light Deployable (ICC-VLD). After removing the boom from the carrier, the EV1 crewmember maintained control of the boom while the Space Station Remote Manipulator System (SSRMS) maneuvered EV1 to the Z1 truss worksite. There EV1 and EV2 worked together to install the boom onto the truss. Next, EV1 returned to the ICC-VLD to release the SGANT dish from its FSE. While holding the dish, EV1 translated via SSRMS to the Z1 truss, where EV1 and EV2 worked together to install the SGANT dish onto the boom. The crew members removed thermal insulation from the boom and installed a protective heat shield to prepare the SGANT for operations. Due to an unanticipated configuration of the dish-to-boom interface, the crew was instructed to install EVA tethers to further secure the hardware while the engineering teams conducted additional assessments.

Following the installation of the SGANT, EV1 returned to the ICC-VLD and released the EOTP from the carrier using the SSRMS as a work platform. The SSRMS then maneuvered EV1 to the EOTP installation location where he worked with EV2 to install the EOTP onto the SPDM. EV1 remained at the SPDM worksite to complete the installation of ancillary equipment while EV2 translated to the ICC-VLD. EV2 then released the torque on all of the batteries that were launched on the carrier in preparation for Battery R&R operations on subsequent EVAs.

The first EVA was completed in a total EVA time of 7 hr and 25 min. EVA glove inspections and post-EVA photographs indicated no glove damage had been incurred during the EVA.

SECOND EXTRAVEHICULAR ACTIVITY

The EVA crew successfully completed the second EVA on FD 6 in a total EVA time of 7 hr and 9 min. This EVA was performed by Steve Bowen (EV1), and Mike Good (EV2). The crew began the EVA by translating to the P6 Integrated Equipment Assembly (IEA) to conduct the Battery R&R operations. On his way to P6, EV1 paused at an intermediate worksite to perform an unscheduled task. Using a procedure developed during the flight, EV1 reconfigured the Space Shuttle Laser Dynamic Range Imager (LDRI) cable to prevent it from jamming the sensor's pan-and-tilt mechanism. Upon successful completion of that task, EV1 joined EV2 on the P6 truss. There the two crewmembers set-up the Articulating Portable Foot Restraints (APFRs) and installed gap spanners to provide worksite stabilization for the operations. The EV2 crewmember moved into an APFR on the P6 Integrated Equipment Assembly (IEA) and released the first spent battery from the truss. This battery was then temporarily stowed on a nearby handrail using EVA tools, thereby creating an open slot in the truss for the installation of the first new battery. Operating from an APFR on the P6 long spacer, EV1 removed the first new battery from the ICC-VLD, which was grappled and presented to EV1 by the SSRMS. Using a shepherding technique, EV1 transferred the battery to EV2 for installation onto the truss. Once the new battery was secure, EV2 removed the second spent battery and shepherded it to EV1 for installation onto the ICC-VLD for return. EV1 released the second new battery from the ICC-VLD and then shepherded it to P6 for installation by EV2. This process continued until four new batteries had been installed into the P6 IEA. At the conclusion of this EVA, three spent batteries had been installed into the ICC-VLD for return and the fourth spent battery remained attached to the truss handrail in the approved temporary stowage configuration.

Prior to ingress, the EVA crew returned to the Z1 SGANT worksite and applied additional torque to the SGANT dish/boom interface bolts. The EVA tethers that had been installed during the first EVA were subsequently removed. Lastly, the crew completed the removal of the SGANT gimbal locks, thereby leaving the redundant SGANT in its nominal Stage configuration.

Glove inspections were performed per procedure and no damage was noted throughout the EVA.

THIRD EXTRAVEHICULAR ACTIVITY

On FD 8, Mike Good (EV1), and Garrett Reisman (EV2), performed the third EVA, which 6 hr and 46 min. The primary objective on EVA 3 was the completion of the remaining P6 Battery R&Rs. On their way to the P6 worksite, the crew performed a get-ahead task by installing ammonia jumpers on the port truss fluid lines. The two crewmembers then moved to the P6 IEA to continue the Battery operations which had commenced on the second EVA. The EV2 crewmember ingressed an APFR on the P6 IEA and removed the fifth spent battery from the truss. EV2 then shepherded this

battery to the ICC-VLD with assistance from EV1. EV1 installed the battery for return prior to removing the fifth new battery from the carrier. This new battery was then shepherded to EV2, who installed it onto the truss. EV2 then removed the sixth and final spent battery from P6, which was subsequently installed onto the ICC-VLD. The EV1 crewmember removed the final new battery from the ICC-VLD and transferred it to EV2 for installation onto the truss, thereby completing the replacement of all six batteries on the P6 lower IEA. The battery that had been temporarily stowed at the beginning of second EVA was installed onto the ICC-VLD for return. Before leaving the worksite, the crew members gathered tools and foot restraints and then translated inboard.

Next, the EV1 and EV2 then translated to the Orbiter Payload Bay where together, both crewmembers retrieved a Power Data Grapple Fixture (PDGF) from the Orbiter sidewall. Once released, this hardware was taken to the Airlock for stowage inside the ISS. The crew completed additional get-ahead tasks, including reconfiguration of EOTP Multi-Layer Insulation (MLI) and EVA tool relocations, prior to final ingress.

EVA glove inspections and post-EVA photographs indicated no glove damage had been incurred during the EVA.

REMOTE MANIPULATOR SYSTEM AND ORBITER BOOM SENSOR SYSTEM

The Shuttle Remote Manipulator System (SRMS) performed nominally during the mission. No IFAs were identified during the review and analysis of the flight data.

The SRMS on-orbit Initialization began at 134/21:13 GMT [00/02:53 Mission Elapsed Time (MET)] on Flight Day (FD) 1. The port and starboard Manipulator Positioning Mechanisms (MPMs) were deployed and the SRMS shoulder brace was released. The SRMS power-up began at 134/21:38 GMT (00/03:18 MET) and was completed 4 min later. The SRMS checkout began immediately after power-up and was completed at 134/22:48 GMT (00/04:28 MET). After the completion of the SRMS checkout, the crew performed a Payload Bay (PLB) survey before maneuvering to the pre-cradle-position.

On FD 2, the SRMS grappled the Orbiter Boom Sensor System (OBSS) at 135/11:52 GMT (00/17:32 MET) and maneuvered it to the OBSS hover-position 12 min later. An abbreviated inspection was performed due to a snagged cable on the Laser Dynamic Range Imager (LDRI) pan-tilt unit which prevented proper pointing of the LDRI. The crew was able to obtain complete coverage of the nose cap and almost complete coverage of the starboard Reinforced Carbon-Carbon (RCC). The Port scans provided very limited coverage and scans were completed at 135/19:25 GMT (01/01:05 MET). Six minutes later, the SRMS maneuvered to the OBSS Hover position and the OBSS was berthed at 135/20:06 GMT (01/01:46 MET).

On FD 3, the Orbiter Discovery docked with the International Space Station (ISS) with the SRMS in the pre-cradle-position. The SRMS maneuvered to the Integrated Cargo Carrier-Vertical Light Deployable (ICC-VLD) unberthing-viewing-position at 136/17:24 GMT (01/23:04 MET).

On FD 4, the SRMS maneuvered to the Space-to-Ground Antenna (SGANT) and Enhanced ORU Temporary Platform (EOTP) viewing position at 137/08:47 GMT (02/14:27 MET). The SRMS then maneuvered to the Mini Research Module (MRM) -1 pre-grapple-position at 137/18:10 GMT (02/23:50 MET) and grappled the MRM-1 12 minutes later

On FD 5, the SRMS maneuvered the MRM-1 to the low-hover-position at 138/09:56 GMT (03/15:36 MET) and then to the MRM-1 Handoff Position at 138/10:02 GMT (03/15:42 MET). The SRMS released the MRM-1 at 138/10:36 GMT (03/16:16 MET), and maneuvered to the MRM-1 dock-viewing-position at 138/11:26 GMT (03/17:06 MET). After MRM-1 docking, the Space Station Remote Manipulator System (SSRMS) grappled the OBSS and the SRMS maneuvered to the OBSS pre-grapple-position at 138/13:26 GMT (03/19:06 MET). The SRMS grappled the OBSS at 138/15:08 GMT (03/20:48 MET) and maneuvered to the Battery R&R Position at 138/18:06 GMT (03/23:46 MET).

On FD 6, the SRMS began its maneuver to the Pan & Tilt Unit (PTU) cable-repair-position. After the EVA crew released the snagged cable, the SRMS maneuvered back to the battery-R&R position at 138/18:06 GMT (03/23:46 MET).

There were no SRMS operations on FDs 7 and 8.

On FD 9, the SRMS maneuvered the OBSS to the Undock Position at 142/11:25 GMT (07/17:05 MET).

There were no SRMS operations on FD 10.

On FD 11, the Docked Late Inspection of the Shuttle Starboard Wing RCC began at 144/08:23 GMT (09/14:03 MET) and the survey was completed at 144/09:29 GMT (09/15:09 MET). The Late Inspection of the Nose Cap began at 144/10:18 GMT (09/15:58 MET) and was completed 33 minutes later. The Port Wing RCC survey began at 144/11:20 GMT (09/17:00 MET) was completed 52 minutes later. The OBSS was berthed at 144/12:51 GMT (09/18:31 MET) and the SRMS was cradled 22 min later, thus completing the SRMS activities for the STS-132 mission.

WING LEADING EDGE IMPACT DETECTION SYSTEM

ASCENT MONITORING

The Wing Leading Edge (WLE) Engineering completed ascent analysis and issued its findings by Launch (L) plus 12 hrs reporting 1 possible impact indications over 1.0 Grms to the starboard RCC and 1 questionable indication to the port chine. The damage likelihood for the Reinforced Carbon-Carbon (RCC) indication was less than 1/1000 (Risk Category I). The ascent A1 case was presented to the Orbiter Project Office (OPO) to aid in determining the risk of waiting until the late inspection to obtain complete imagery coverage of the WLE RCC. The delay in obtaining the imagery for the remainder of the WLE RCC was caused by a cable that was preventing the LIDAR pan and tilt unit from obtaining the necessary imagery from the port RCC. This problem is discussed in more detail in the Government Furnished Equipment section of this report.

All units triggered and began recording data on Main Engine Ignition within 0.13 sec of each other with the exception of unit 1078, which was approximately 0.5 sec out of synchronization. Mission Elapsed Time (MET) was set to 9.19 sec behind Data Elapsed Time (MET = DET – 9.19 sec) for both port and starboard wing units.

Only one possible impact indication over 1.0 Grms was identified on the starboard RCC and one questionable indication on the port chine. The following table provides the data on these two possible impacts.

SUSPECTED ASCENT DEBRIS IMPACTS ABOVE 1.0 GRMS

Times		Location			Magnitude		Criteria						Impact ^{ab}		Damage Likelihood Category ^b
MET, Hr	DET, hr	Wing	RCC	Unit-Channel	Max. Grms	Max. G	Transient	Non-Mission	Spectral	Shock	Damping	Multi-Sensor	In-Flight	Post-Flight	
115.3	124.5	Stbd	6	1076-J3	1.65	8.47	+	+	+	+	+	+	P	P	I
106.6	115.8	Port	Chine	1086-J3	2.24	9.21	+	+	+	+	+	O	Q	Q	n/a

^aP = Probable Q = Questionable

^b Assessed from ascent data (I:<1/1000, II:1/1000~1/500, III:1/500~1/200, IV:1/200~1/100, V:>1/100)

ORBIT MONITORING

On-Orbit Micrometeoroid/Orbital Debris (MM/OD) monitoring began at approximately L+16 hr. Due to sensor unit battery-life limitations, continuous on-orbit monitoring of each RCC panel was not possible. The WLE IDS monitored each wing with two groups

of sensors consisting of 10 and 11 units. On-orbit monitoring was performed when the risk of critical damage to the RCC from MM/OD was expected to be highest. The periods of increased risk to the RCC for STS-132 were during the early and late imagery inspections of the RCC as well as during docking and undocking operations with the International Space Station. The total MM/OD monitoring time for the port and starboard wings was 46.5 hours per wing.

The WLE IDS recorded 9 triggers related to 7 events, none of which satisfied all impact criteria. Analysis of these triggers resulted in no possible or questionable MM/OD impact indications. Review of post-flight data revealed no additional on-orbit indications.

CONCLUSIONS

The WLE IDS system performed well for ascent impact monitoring. During the mission, one ascent impact indication above the 1.0 Grms threshold was reported with a damage likelihood of Category I (<1/1000). One questionable impact indication to the Port chine was also reported. Post-flight review of the data found no additional ascent impact indications over 1.0 Grms.

No possible or questionable MM/OD indications were detected and reported during flight.

Based on the ascent and on-orbit findings from all systems, including WLE IDS, the Orbiter Project Office (OPO) recommended not performing a focused WLE RCC inspection. The late mission OBSS survey visually inspected the WLE after Orbiter undocking and prior to entry. No critical damage was found.

GOVERNMENT FURNISHED EQUIPMENT/FLIGHT CREW EQUIPMENT

The overall performance of the Government Furnished Equipment (GFE) and Flight Crew Equipment (FCE) was acceptable.

Following the Orbital Maneuvering System (OMS) Starboard Pod Survey, the crew had issues setting up the sensor package for the Starboard Reinforced Carbon-Carbon (RCC) Survey. It was determined that a cable became pinched while the sensor package was commanded to tilt up, thus limiting the amount of travel (IFA STS-132-V-01). As a result, only the Integrated Sensor Inspection System (ISIS) Digital Camera (IDC) was used during the remaining surveys. The IDC, however, only provided limited coverage of the RCC and tile that is normally imaged during the FD 2 surveys.

During the second EVA, The first task was to tie the cable on the Pan-Tilt Unit (PTU) to allow the proper tilting of the Orbiter Boom Sensor System (OBSS) Laser Dynamic Range Imager (LDRI). Subsequent checkout of the PTU after the repair confirmed that the full range of motion was now available in the pan and tilt axes. The OBSS LDRI PTU was fully functional and supported the Late Inspection surveys.

POST-LAUNCH PAD INSPECTION

The post-launch inspection of the Main Launch Platform (MLP) -2, Pad A Fixed Service Structure (FSS), and Pad A apron/infield/flame trench was conducted on May 14, 2010. The inspection proceeded relatively quickly while Safing Teams secured the Pad. The entire Pad, FSS and MLP were inspected. The only flight hardware found was Reusable Solid Rocket Booster (RSRB) throat plug material.

Orbiter lift-off lateral acceleration data indicated a maximum of 0.10g. Hold-down stud hang-ups are typically noted with lateral accelerations above 0.19g.

Reusable Solid Rocket Booster Hold-down Posts (HDP) Inspection

HDP No. 1 – The EA934 poured sidewalls were nominal with moderate acceptable pitting. The Phenolic shim had evidence of heavy blistering and erosion. Both firing lines were missing. No galling or chatter marks were noted in the chamfer of the through-hole and the stud was set down.

HDP No. 2 – The EA934 poured sidewalls were nominal with minor acceptable pitting. The Phenolic shim was nominal. Eighteen inches of one firing line was intact. Approximately 2.5-ft of Range Safety System (RSS) cable remained past the tie-off point. No galling or chatter marks were noted in the chamfer of the through-hole and the stud was set down.

HDP No. 3 – Nominal indications of erosion on the Room Temperature Vulcanizing (RTV) -coated blast shield were noted and the HDP showed proper closure.

HDP No. 4 – Nominal indications of erosion on the RTV- coated blast shield were noted and the HDP showed proper closure.

HDP No. 5 – The EA934 poured sidewalls were nominal with minor acceptable pitting. The Phenolic shim was nominal. Both firing lines were missing. No galling or chatter marks were noted in the chamfer of the through-hole and the stud was set down.

HDP No. 6 – The EA934 poured sidewalls were nominal with minor acceptable pitting. The Phenolic shim was nominal. Six inches of one firing line was intact. A cosmetic scratch was noted on the east side of the inner surface of the bearing through-hole at the top with no galling or chatter marks noted in the chamfer of the through-hole. The stud was set down.

HDP No. 7 – Nominal indications of erosion on the RTV- coated blast shield were noted and the HDP showed proper closure.

HDP No. 8 – Nominal indications of erosion on the RTV- coated blast shield were noted and the HDP showed proper closure.

Gaseous Nitrogen (GN₂) Purge Line Inspection

Left-Hand Probe -The Left-Hand (LH) probe was erect and slightly bent Southwest. Protective tape was present with no exposed braiding. No O-ring was present.

Right-Hand Probe –The Right-Hand (RH) probe was erect and slightly bent Southwest. Protective tape was present with no exposed braiding. No O-ring was present.

RSRB T-0 Ground Carrier Assemblies (GCAs) Inspection

The LH RSRB T-0 GCA appeared to be in nominal condition with proper demate. The following additional items were noted:

1. Several connector housings had broken sidewalls.
2. The 1J1, 2J1, 3J1, and 4J1 pins and sockets were raised higher than nominal.
3. All 4 frangible bolt halves were present.

The RH RSRB T-0 GCAs appeared to be in nominal condition with proper demate.

1. Several connector housings had broken sidewalls.
2. The 2J1 pin and socket was raised higher than nominal.
3. All 4 frangible bolt halves were present.

Liquid Oxygen (LO₂) and Liquid Hydrogen (LH₂) Tail Service Masts (TSM) Inspection

Both TSMs appeared to be undamaged and both bonnets appeared to have closed properly. The LH₂ TSM had a missing stud on the south most vertical riser pipe.

MLP Deck Inspection

The following items were noted during the MLP Deck inspection.

1. The main deck was in nominal condition.
2. Typical blast erosion was observed in and around the RSRB flame holes.
3. A 5-in. stud and nut were found near the LH₂ TSM ladder.
4. A 2-in. bolt was found on the Southwest corner of the MLP deck.

Orbiter Access Arm

The Orbiter Access Arm L (OAA) was retracted and secured with no apparent damage. Also, all slide wire baskets remained secured at 195-ft level with no apparent damage.

GH₂ Vent Line Ground Umbilical Carrier Plate (215-ft Level) Inspection

The following items were noted at the 215-ft level:

1. The GH₂ vent line latched on the eighth tooth (of eight) on the latching mechanism.
2. The vent line was latched biased south and the latching pawl made contact with the LH gimbal strut. The GH₂ vent line had a nominal arresting cycle. The inspection of the Ground Umbilical Carrier Plate (GUCP) LH and RH pivot assemblies indicate a nominal separation.
3. The External Tank (ET) GUCP 7-in. Quick Disconnect (QD) probe was accessible for inspection and appeared to be undamaged.
4. Both the QD poppet probe sealing surface and the poppet valve assembly were in good condition.

5. The ET GUCP exhibited less than typical blast damage and the pyrotechnic bolt fired nominally.
6. No damage was seen on the 24-ft flexible line.

Gaseous Oxygen Vent Arm (255-ft Level) Inspection

The following items were noted at the 255-ft level:

1. The Gaseous Oxygen (GOX) vent arm and hood appeared undamaged.
2. Hood windows and purge ducts appeared to be in nominal condition and the latch mechanism locked properly.

PAD Facility Inspection

PAD A appeared to be in very good condition and exceptionally clean.

North RSRB Flame Trench Inspection

The following items were noted during the inspection of the North RSRB flame trench.

1. Minor Fondue Fyre damage was noted on the RSRB main flame trench.
2. A man-hole cover was found that had been liberated and was 1000-ft from the RSRB flame trench. The NASA Test Director and the site safety organizations were notified to secure the area.
3. Minor concrete buckling was noted on the Northwest pad apron.

Debris Items Found

The following items of debris were found during the post-launch inspection.

1. Minor pieces of RSRB throat plug material were found on the PAD surface.
2. Small pieces of Fondue Fyre were found on both the East and West Pad surface area.
3. On the 275-ft level, a piece of angle iron (2-in. by 2-in.) that was 12-in. long and ¼-in. thick on the west side.
4. On the 255-ft. level, a firex line was unsecured.
5. On the 235-ft. level, punctured insulation and an unspecified line were found.
6. On the 195-ft level, an electrical connector was found in the Northeast corner, an Orange tie-wrap was found on the Southwest side and a small nut was found in the South west corner. Also, a rescue locker was found not properly secured – bottom lock was not engaged.
7. On the 175-ft level, a loose cable was hanging from the ceiling on the East side.
8. On the 155-ft level, a 3/8-in. nut was found on the North side.
9. On the 135-ft level, a locker box handle was broken but not liberated on the East side, a broken facility ground strap was found on the North side, a bracket was found in the Southwest corner, and a handrail chain was loose.

10. On the East pad surface, a 4-in. long pin was found, and a CT track inboard guide on the outboard side was loose approximately 40-ft from the Space Shuttle Main Engine (SSME) flame hole.
11. On the West pad surface, a small strap of metal ($\frac{1}{4}$ -in by $2\frac{1}{2}$ -in.), a metal seal was found on the North elevator, a rubber cap seal, a small welding piece 3-in. in length, a washer and two pieces of fondue fyre were found.

LAUNCH PHOTOGRAPHY AND TELEVISION ANALYSIS

The launch photography provided data for the evaluation by the Debris Assessment Team to determine the condition of the Thermal Protection System (TPS).

VEHICLE OBSERVATIONS

Between 23.0 and 53.9 sec MET, numerous flares, which were more than typically observed, were noted in the Space Shuttle Main Engine (SSME) exhaust plume.

At 60.124 sec Mission Elapsed Time (MET), an unidentified piece of debris was observed falling aft of the Orbiter port Orbital Maneuvering System (OMS) pod.

At approximately 103 sec MET, one or two pieces of debris that was first seen forward of the IFR at Xt 1593. This event was seen on two video frames.

At approximately 126 sec MET, a single piece of dark-colored debris appeared to travel toward the Orbiter aft fuselage belly and contact the vehicle forward of the starboard side body flap. The debris then changed direction and fell aft. No damage to the vehicle was noted.

At approximately 127 sec MET, two instances of debris were first seen aft of the -Y vertical strut travelling toward the Orbiter aft fuselage. The debris apparently impacted the Orbiter just forward of the Orbiter body flap. No damage to the vehicle was noted.

At 129.2 sec MET, a single piece of debris appeared to originate forward of the bipod area. The debris travelled outboard and aft of the -Y bipod and out of the view of the camera. The debris was noted to not contact the vehicle.

At 143.6 sec MET, debris was observed aft of bipod near the Liquid Hydrogen (LH₂) barrel area at the ET centerline.

At 151 sec MET, debris was observed forward of the port (-Y) bipod.

At 158.1 sec MET, a single piece of debris was first observed inboard of the Liquid Oxygen (LO₂) feedline, and aft of the bipod. The debris changed aft direction and fell outboard and aft under the starboard side of the Orbiter. No contact with the vehicle was noted.

At 159.7 sec MET, a single piece of debris was seen to liberate near Ice/Frost Ramp (IFR) 1205, outboard of the External Tank (ET) Feedline. The debris appeared to fall aft and to pass under the starboard wing. Contact with the vehicle could not be confirmed because of the over-exposed view of the underside of the wing.

At 322.8 sec MET, multiple pieces of debris appeared to liberate well aft and possibly just forward of the +Y thrust strut that is outboard of the LO₂ feedline. No contact with the vehicle was noted.

At approximately 373 sec MET, two pieces of debris were first seen under the starboard wing. The debris travelled outboard and aft of the vehicle, and no contact with the vehicle was noted.

A rectangular piece of missing ET Thermal Protection System (TPS) was noted on an intertank stringer outboard of the port bipod strut.

A missing piece of ET TPS was noted on the IFR extension outboard of the cable tray at Xt 1399.

A missing piece of ET TPS was observed between Intertank stringers S-3-2 and S-4-2 on the forward side of the LH₂ flange closeout and outboard of the port bipod.

A missing piece of ET TPS foam was noted outboard of the cable tray on Intertank stringer S-13-3 in the LH₂ flange closeout.

A small foam loss was noted on the port bipod fitting closeout aft of Intertank stringer S-2-1.

A small divot was noted on IFR Xt 1593 on the outboard side near the forward edge. The partially delaminated foam is visible aft of the divot.

A missing piece of ET TPS was observed on the inboard foot of the LO₂ feedline bracket at Xt 1974.

Missing ET TPS on the LO₂ IFR 553 at Xt 546. The loss could possibly be cumulative erosion/ablation. The loss pattern appears to be different from the other LO₂ IFRs.

Missing ET TPS was noted on the LO₂ feedline bracket base closeout at Xt 1129.

Missing ET TPS was noted on the LO₂ feedline bracket base closeout at Xt 1377.

LAUNCH PAD OBSERVATIONS

At 0.4 second after Space Shuttle Main Engine (SSME) start, a light-colored patch was noted at the steer-horn and nozzle manifold of SSME no.1. The area appeared to expand in size during the SSME start-up.

Between -1.6 and + 8.2 sec MET, debris was observed exiting the flame trenches during the Shuttle lift-off.

At 0.787 sec MET, Ice was visible on two locations on the Orbiter umbilical plate after the LH₂ retraction.

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APPENDIX A

STS-132 MISSION EVENTS

EVENT	DESCRIPTION	ACTUAL GMT
APU Activation	APU-1 Gas Generator Chamber Pressure APU-2 Gas Generator Chamber Pressure APU-3 Gas Generator Chamber Pressure	134:18:15:21.041 134:18:15:22.195 134:18:15:23:318
SRB HPU Activation	LH HPU System A Start Command LH HPU System B Start Command RH HPU System A Start Command RH HPU System B Start Command	134:18:19:41.021 134:18:19:41.181 134:18:19:41.341 134:18:19:41.511
Main Engine Start	SSME-3 Start Command Accepted SSME-2 Start Command Accepted SSME-1 Start Command Accepted	134:18:20:02.437 134:18:20:02.557 134:18:20:02.678
SRB Ignition	SRB Ignition Command	134:18:20:08.991
Throttle Up 104.5 Percent	SSME-1 Command Accepted SSME-2 Command Accepted SSME-3 Command Accepted	134:18:20:13.275 134:18:20:13.293 134:18:20:13.294
Throttle Down to 74 Percent	SSME-1 Command Accepted SSME-2 Command Accepted SSME-3 Command Accepted	134:18:20:36.155 134:18:20:36.173 134:18:20:36.174
Throttle Up to 104.5 Percent	SSME-1 Command Accepted SSME-2 Command Accepted SSME-3 Command Accepted	134:18:20:58.556 134:18:20:58.574 134:18:20:58.574
Maximum Dynamic Pressure (Max Q)	Derived Ascent Dynamic Pressure	134:18:21:16
Both SRMs at 50 psi	LH SRM Chamber Pressure RH SRM Chamber Pressure	134:18:22:08.911 134:18:22:09.351
End SRM Action	LH SRM Chamber Pressure RH SRM Chamber Pressure	134:18:22:11.391 134:18:22:12.191
SRB Separation Command	SRB Separation Command Flag	134:18:22:13
SRB Physical Separation	LH APU A Turbine Loss of Signal RH APU B Turbine Loss of Signal LH APU B Turbine Loss of Signal RH APU A Turbine Loss of Signal	134:18:22:13.871 134:18:22:13.951 134:18:22:13.991 134:18:22:13.991
OMS Assist Ignition	L Engine Bipropellant Valve Position R Engine Bipropellant Valve Position	134:18:22:24.2 134:18:22:24.3
OMS Assist Cutoff	R Engine Bipropellant Valve Position L Engine Bipropellant Valve Position	134:18:23:54.8 134:18:23:54.9
Throttle Down for 3g	SSME-1 Command Accepted SSME-2 Command Accepted SSME-3 Command Accepted	134:18:27:32.964 134:18:27:32.980 134:18:27:32.981
3G Acceleration	Total Load Factor (g)	134:18:28:17.0
Throttle down to 67 percent for Cutoff	SSME-1 Command Accepted SSME-2 Command Accepted SSME-3 Command Accepted	134:18:28:27.685 134:18:28:27.701 134:18:28:27.702
SSME Shutdown	SSME-1 Command Accepted SSME-2 Command Accepted SSME-3 Command Accepted	134:18:28:34.245 134:18:28:34.262 134:18:28:34.262
Main Engine Cutoff (MECO)	MECO Command Flag MECO Confirmed Flag	134:18:28:34 134:18:28:36
ET Separation	ET Separation Command Flag	134:18:28:56

APPENDIX A

STS-132 MISSION EVENTS

EVENT	DESCRIPTION	ACTUAL GMT
APU Deactivation	APU-1 Gas Generator Chamber Pressure APU-2 Gas Generator Chamber Pressure APU-3 Gas Generator Chamber Pressure	134:18:34:33.081 134:18:34:57.285 134:18:35:18.308
OMS 1 Ignition	L Engine Bipropellant Valve Position R Engine Bipropellant Valve Position	Not Required
OMS 1 Cutoff	L Engine Bipropellant Valve Position R Engine Bipropellant Valve Position	Not Required
OMS 2 Ignition	R Engine Bipropellant Valve Position L Engine Bipropellant Valve Position	134:18:58:24.2 134:18:58:24.3
OMS 2 Cutoff	R Engine Bipropellant Valve Position L Engine Bipropellant Valve Position	134:18:59:27.6 134:18:59:27.7
Payload Bay Doors Open	Right Payload Bay Door Open 1 Left Payload Bay Door Open 1	134:19:52:53 134:19:54:11
OMS 3 Ignition	R Engine Bipropellant Valve Position L Engine Bipropellant Valve Position	134:21:54:58.7 134:21:54:58.9
OMS 3 Cutoff	R Engine Bipropellant Valve Position L Engine Bipropellant Valve Position	134:21:55:25.1 134:21:55:25.3
OMS 4 Ignition	L Engine Bipropellant Valve Position R Engine Bipropellant Valve Position	135:11:33:02.7
OMS 4 Cutoff	L Engine Bipropellant Valve Position R Engine Bipropellant Valve Position	135:11:33:13.1
OMS 5 Ignition	L Engine Bipropellant Valve Position R Engine Bipropellant Valve Position	136:09:21:56.3 136:09:21:56.3
OMS 5 Cutoff	L Engine Bipropellant Valve Position R Engine Bipropellant Valve Position	136:09:23:20.9 136:09:23:20.9
OMS 6 Ignition	L Engine Bipropellant Valve Position R Engine Bipropellant Valve Position	136:10:08:10.7 136:10:08:10.7
OMS 6 Cutoff	L Engine Bipropellant Valve Position R Engine Bipropellant Valve Position	136:10:09:13.9 136:10:09:14.1
OMS 7 Ignition	L Engine Bipropellant Valve Position R Engine Bipropellant Valve Position	136:11:40:09.3
OMS 7 Cutoff	L Engine Bipropellant Valve Position R Engine Bipropellant Valve Position	136:11:40:21.7
Docking	Capture	136:14:28:27
Undocking	Undocking Complete	143:15:22:03
Flight Control System Checkout – APU 1 Start	APU-1 Gas Generator Chamber Pressure	145:07:42:02.151
APU 1 Stop	APU-1 Gas Generator Chamber Pressure	145:07:45:19.011
OMS 8 Ignition	L Engine Bipropellant Valve Position R Engine Bipropellant Valve Position	145:15:23:20.3 145:15:23:20.3
OMS 8 Cutoff	L Engine Bipropellant Valve Position R Engine Bipropellant Valve Position	145:15:23:30.5 145:15:23:30.5
Payload Bay Door Close	Left Payload Bay Door Close Right Payload Bay Door Close	146:09:25:46 146:09:28:10
APU Activation	APU-2 Gas Generator Chamber Pressure APU-1 Gas Generator Chamber Pressure APU-3 Gas Generator Chamber Pressure	146:11:37:07.935 146:12:03:49.591 146:12:03:52.178

APPENDIX A
STS-132 MISSION EVENTS

EVENT	DESCRIPTION	ACTUAL GMT
Deorbit Maneuver Ignition	R Engine Bipropellant Valve Position L Engine Bipropellant Valve Position	146:11:41:59.2 146:11:41:59.4
Deorbit Maneuver Cutoff	L Engine Bipropellant Valve Position R Engine Bipropellant Valve Position	146:11:45:05.0 146:11:45:05.0
Entry Interface	Orbital Altitude Referenced to Ellipsoid	146:12:16:35
Blackout End	Data Locked (High Sample Rate)	NO BLACKOUT
Terminal Area Energy Management (TAEM)	Major Mode Code (305)	146:12:41:42
Main Landing Gear Contact	Main Landing Gear Left Hand Tire Pressure Main Landing Gear Right Hand Tire Pressure	146:12:48:08 146:12:48:08
Main Landing Gear Weight on Wheels	Main Landing Gear Left Hand Weight on Wheels Main Landing Gear Right-Hand Weight on Wheels	146:12:48:08 146:12:48:15
Drag Chute Deployment	Drag Chute Deploy 1 CP Volts	146:12:48:10.5
Nose Landing Gear Contact	Nose Landing Gear Left Hand Tire Pressure 1	146:12:48:19
Nose Landing Gear Weight on Wheels	Nose Landing Gear Weight on Wheels	146:12:48:20
Drag Chute Jettison	Drag Chute Jettison 2 CP Volts	146:12:48:47.1
Wheels Stop	Velocity with respect to Runway	146:12:49:28
APU Deactivation	APU-1 Gas Generator Chamber Pressure APU-2 Gas Generator Chamber Pressure APU-3 Gas Generator Chamber Pressure	146:13:06:39.801 146:13:07:10.225 146:13:07:34.258

APPENDIX B

STS-132 IN-FLIGHT ANOMALIES

INTRODUCTION

This appendix contains listings and discussions of each of the In-Flight Anomalies (IFAs) that were identified for the STS-132 mission.

1. Orbiter
2. Reusable Solid Rocket Booster (RSRB)
3. Reusable Solid Rocket Motor (RSRM)
4. External Tank (ET)
5. Space Shuttle Main Engine (SSME)
6. Systems Engineering and Integration (SE&I)
7. Flight Software
8. Flight Operations and Integration (FO&I)
9. Mission Operations Directorate

APPENDIX B STS-132 IN-FLIGHT ANOMALIES

ORBITER ANOMALIES

IFA Number	Title	Comments
STS-132-V-01	OBSS-PTU Video Cable Interference	<p>The Sensor Package 1 (SP1) was unable to position to the first pan/tilt angle to start the Flight Day (FD) 2 Reinforced Carbon-Carbon (RCC) Inspection. Subsequently, the Crew determined that a portion of the cable was snagging, preventing the PTU from being able to have full tilt-range (0° to 288°). With the PTU unable to point at the RCC, the nominal FD 2 inspection could not be completed nominally. Instead, the RCC Inspection data were obtained using the ISIS Digital Camera (IDC) during daylight to assure quality imagery. SP1 flew on STS-130, though post-flight, a PTU change-out was required. The W601 cable was demated and remated as part of that operation, and full pan and tilt range was confirmed post re-assembly. Additionally, this same cable has flown on STS-130, STS-128, STS-125, STS-123, STS-124, STS-115, and STS-114.</p> <p>During the second Extravehicular Activity (EVA), the crew successfully released the snag, repositioned the cable, and secured the cable in place via wire ties. After a PTU reset was performed, the PTU was tested to verify the full range of tilt had been recovered.</p> <p>Post-flight Plan: Destow SP1. Test with and without tie wrap that was used during the EVA. The cable snag was recreated in the laboratory. The cable was removed and replaced with a new cable and it did not snag. However a cable tie will be added for the remaining flights to guard against a snag.</p>
STS-132-V-02	RCS L3D Thruster Heater Failed OFF	<p>Both the fuel and oxidizer injector temperatures for thruster L3D reached 59 °F and 60 °F, respectively, with no sign of thruster heater activation. The adjacent thrusters, L2D and L4D, both indicated nominal thruster heater activation when their injector temperatures reached approximately 75 °F. Both of those thrusters exhibited the distinct signature of 4/5 heater cycles while the injector temperatures of L3D only declined. After discussions with Flight Controllers, the heater of L3D was declared Failed OFF.</p> <p>During the rendezvous NC-3 maneuver, the L3D thruster fired twice. The subsequent soakback resulted in the thruster temperatures climbing to 72 °F. Given the observed rate of temperature decline – approximately 1 deg/hr – the thruster temperatures should not decline low enough to Fail Leak or cause an Redundancy Management (RM) alert. Additionally, computer model predictions show the docked phase temperature to stay between 63 ° F and 71 ° F. Therefore, no vehicle attitude or procedural changes were required by the Crew.</p> <p>Post-undocking, the temperature predictions were marginal – potentially bottoming at 40 °F. The End of Mission (EOM) attitude was favorable.</p> <p>Post-flight Plan: Remove and Replace (R&R) all thrusters on the L3D manifold.</p>

APPENDIX B STS-132 IN-FLIGHT ANOMALIES

ORBITER ANOMALIES

IFA Number	Title	Comments
STS-132-V-03	TPS Anomalies	<p>Due to the FD 2 OBSS Pan/Tilt Unit (PTU) failure, the nominal Laser Dynamic Range Imager (LDRI) inspection was not obtained. The ISIS Digital Camera (IDC) data were obtained and reviewed, clearing both wings and the nose cap. The missed imagery included:</p> <ol style="list-style-type: none"> 1. Starboard RCC Panels 1-8, Curry Zones 5-7 2. Port the upper LESS Carrier Panels 7-9 3. Port chine, ~150 upper surface tiles. <p>Station assets and EVA pictures of opportunity were used to complete coverage of the Port chine and improve the quality of the Port Carrier Panel imagery. A chit was considered to perform a docked inspection of the remaining areas. However, the remaining available data suggested that it was highly unlikely that ascent damage requiring repair had occurred. The imagery review indicated no anomalies, the WLEIDS had no significant indications, and the analysis of known debris releases indicated that critical damage was highly unlikely. And since the missed areas were to be imaged as part of the FD 11 Late Inspection, the MMT decided that additional docked surveys were not required.</p> <p>Four items were identified in-flight that exceeded pre-defined screening criteria and all of the times were cleared using standard procedures and tools.</p> <p>Post-flight Plan: Standard post-flight inspection and repair.</p>

APPENDIX B STS-132 IN-FLIGHT ANOMALIES

ORBITER ANOMALIES

IFA Number	Title	Comments
STS-132-V-04	FES Shutdown on Primary B Controller	<p>The FES in topping mode primary B controller shut down near the end of the radiator cold-soak in preparation for deorbit preparations. The shutdown occurred about 46 min into the radiator cold-soak. The crew then restarted the FES topper using the primary B controller. This resulted in a shutdown with the FES Freon outlet temperature failing to reach the control band. Subsequently, the crew restarted the FES using the primary A controller resulting in a successful 7-min operation. A contingency procedure using a modified radiator bypass/FES checkout with core flush (on secondary controller) followed the primary A operation. In this contingency procedure, the FES is operated in secondary high load mode, followed by a core flush, then concluded with secondary topping operation. Ice and excess carryover were observed in the FES topping ducts during the core flush. The core flush stage of the procedure was performed twice because the initial core flush produced duct temperatures that indicated ice had not been completely flushed from the core. The second core flush produced duct temperature signatures that indicated a complete flush of the core. After completion of the contingency procedure, the FES configuration was switched to primary A controller in full-mode, which prepares the orbiter for deorbit.</p> <p>Post-flight Plan: FES core borescope inspections showed no anomalies; this exonerates core corrosion/damage as possible causes. FES valve inspections with borescope showed no evidence of leakage or other anomalies. FES controller B passed full OMRSD functional; this provides confidence in the integrity of the wire harnesses. Feedline B accumulator check showed nominal accumulator travel and pressure responses. Feedline B water samples at FES valve test port showed no contamination. The Topper B Valve/Nozzle Assembly was R&R'd.</p> <p>Troubleshooting conclusions were that probable cause of ice buildup in the topping core is biased valve nozzle spray patterns due to wear and/or contamination. Long FES dumps with less-than-ideal spray patterns have an increased potential for ice formation.</p>

APPENDIX B
STS-132 IN-FLIGHT ANOMALIES
REUSABLE SOLID ROCKET BOOSTER ANOMALIES

IFA Number	Title	Comments
STS-132-B-001	Left-Hand Reusable Solid Rocket Booster (RSRB) Frustum Upper Right Booster Separation Motor (BSM) Room Temperature Vulcanizing (RTV) -133 is Missing.	LH RSRB Frustum Upper Right BSM RTV-133 is missing with darkened substrate, measuring 5 ft long. The fracture surface is heat affected. Time of occurrence has not been determined, with possibility for ascent libration. Microscopy conclusion: Heat effects and soot on Hypalon surfaces of missing RTV-133 area less than full flight exposure but greater than adjacent area with intact RTV-133. Heat effects and soot on Hypalon surfaces of missing RTV-133 on inner area next to BSM Exit Cone are the same as area of debonded RTV-133. Heat effect (depth) in cork for area missing RTV-133 and area with intact RTV-133 (full flight) is same. Microscopy analysis is inconclusive as to time of occurrence.

APPENDIX B
STS-132 IN-FLIGHT ANOMALIES
REUSABLE SOLID ROCKET MOTOR ANOMALIES

No In-flight anomalies were identified during the review and analysis of the flight data.

**APPENDIX B
STS-132 IN-FLIGHT ANOMALIES
SPACE SHUTTLE MAIN ENGINE ANOMALIES**

IFA Number	Title	Comments
STS-132-E-001	ME2051 Flow Recirculation Inhibitor (FRI) Degradation (N5007)	<p>Nozzle FRI degradation noted approximately in line with the Nozzle tubes, and this condition violates the Operations Maintenance Requirements System Document. This is the flight for this FRI. The fraying of this material into the flow path is different from other insulation.</p> <p>During the pre-launch countdown, a 3.5" by 0.062-in. crack with no off-set was observed on the outboard face of the Diagonal Strut Base Closeout in the crotch area between the Diagonal Strut and the LH₂ Aft Dome. This condition violated the Launch Commit Criteria (LCC).</p>

APPENDIX B
STS-132 IN-FLIGHT ANOMALIES
EXTERNAL TANK ANOMALIES

IFA Number	Title	Comments
STS-132-T-001	Prelaunch Diagonal Strut Base Closeout Crack Observed; LCC Violation and Waiver Resulted	<p>STS-132/ET-136 launched on May 14, 2010. During the pre-launch countdown, a 3.5-in. by 0.062-in. crack with no off-set was observed on the outboard face of the Diagonal Strut Base Closeout in the crotch area between the Diagonal Strut and the LH2 Aft Dome. This condition violated Launch Commit Criteria (LCC) No. ICE-01. Waiver No. LW-123 was generated to address this condition.</p> <p>The Diagonal Strut crack observed on STS-132 was a stress relief crack due to the relative movement of the strut with respect to the tank due to cryogen-loading. An offset is not apparent from the visual closeout inspection and photos and is not expected due to this type of relative motion. No ice/frost is observed from this area. The crack mechanism is similar to Vertical Strut cracks on previous flights and has flown with no debris observed (NSTS 08303 3.2.2.3). No TPS debris is expected for this observed condition. In addition to the crack not being exposed to the direct air-load impingement, the TPS remains rigidly attached at the substrate as evidenced by a no-offset observation. The Diagonal Strut crack observed on STS-132 was a stress relief crack due to the relative movement of the strut with respect to the tank due to cryogen-loading. An offset is not apparent from the visual closeout inspection and photos and is not expected due to this type of relative motion. No ice/frost is observed from this area. The crack mechanism is similar to Vertical Strut cracks on previous flights and has flown with no debris observed (NSTS 08303 3.2.2.3). No TPS debris is expected for this observed condition. In addition to the crack not being exposed to the direct air-load impingement, the TPS remains rigidly attached at the substrate as evidenced by a no-offset observation.</p>
STS-132-T-002	Foam Loss on the +Z Side of the Intertank	<p>Post-flight Photographic film showed one foam loss on the +Z side of the Intertank acreage. The loss is located at Station 1102, Panel 2, Stringer 18. The dimensions of this loss were approximately 9.31 in. by 2.19 in. by 0.69.8 in. and the estimated mass was 0.016 lb_m. The loss occurred at 129 sec.</p> <p>The failure mode of weak bond-adhesion was attributed to this Intertank acreage loss is not specifically covered in NSTS 60559. The most probable contributor to these Intertank acreage losses as determined by the Intertank Loss Team is potential contamination. This loss violates the NSTS 60559 Risk Assessment Masses for a Void Differential Pressure in the Intertank; 0.004 lb_m for less than or equal to 135 sec and 0.015 lb_m for greater than 135 sec.</p> <p>Reference PFAR-ET-136-002 for the EPAT Post Flight analysis of these losses.</p> <p>This loss violates the NSTS 60559 Risk Assessment Masses for a Void Delta P in the Intertank; 0.004 lbm for less than or equal to 135.sec and 0.015 lb_m for greater than 135 sec.</p>

APPENDIX B
STS-132 IN-FLIGHT ANOMALIES
SYSTEM ENGINEERING AND INTEGRATION ANOMALIES

IFA Number	Title	Comments
132-I-001	Unexpected Debris/Expected Debris Exceeding Mass Allowable Prior to Pad Earance (Liftoff Debris)	Risk Assessment indicates that given the proposed mitigations, observed debris poses no appreciable increase in risk. Lift-off debris risk is currently characterized as infrequent catastrophic due to significant limitations in controls and significant uncertainties in analysis. Expected lift-off debris risk is classified as infrequent catastrophic in IDBR-01 cause AD. Unexpected lift-off debris from KSC Facilities/GSE is transferred from IDBR-01 cause AJ to LL-0077, which is classified as infrequent catastrophic. Debris release has been mitigated for identified potential sources of critical debris by performing repairs and adding inspections for system-level components. Ongoing mitigations include Foreign Object Damage (FOD) awareness, attrition-based removal of hardware, routine inspections and monitoring for facility hardware and corrosion. No updates to NSTS 60559 were recommended as part of this IFA closure.

APPENDIX B STS-132 IN-FLIGHT ANOMALIES

SYSTEM ENGINEERING AND INTEGRATION ANOMALIES

IFA Number	Title	Comments
STS-132-I-002	Missing ET TPS on Intertank Stringer Outboard of Port Bipod	<p>During the ascent of STS-132 (ET-136) one piece of Thermal Protection System (TPS) was liberated from the External Tank (ET) Intertank (IT). The loss came from the top of stringer S18-2 at station Xt-1101, with a phi angle of -24 deg. It was viewed as a single piece loss in the ET feedline camera at 129 sec Mission Elapsed Time (MET). The loss extended to substrate and appeared to be consistent with the previous bond adhesion failure losses observed on ET-131 (STS-127), ET-133 (STS-129) and ET-134 (STS-130). The failure mode was most likely poor TPS bond adhesion, as indicated by the Orbiter umbilical well imagery, which showed a loss extending to the substrate. Many of the previous losses on ET-131, ET-133, and ET-134 appeared to correlate with the location of the platforms used to clean the IT in Michoud Assembly Facility (MAF) Cell G. The single loss on ET-136 (STS-132) did not correlate with any MAF platform level. This may be due to the processing location of the IT for ET-136, which was cleaned and primed in Cell Q using a scissor lift instead of the Cell G using fixed platforms. While IT losses correlating to platform levels were not expected for STS-132, the cleaning process itself was unchanged and the potential still existed for some areas to be missed, which could result in TPS adhesive failures. The performance of the IT TPS on ET-136 for STS-132 appears to be consistent with the theory that the Cell G platforms could have impeded the IT cleaning process and that the scissor lift may have provided better access to the IT for cleaning operations. The performance of the "double cleaned" ITs for ET-132 (STS-128) and ET-135 (STS-131) appears to be consistent with the proximate cause of inadequate cleaning. A total of 58 bond-adhesion tests were performed on ET-137 in preparation for STS-133. There were no adhesive test failures and only two low tensile strength cohesive failures. Re-test of the two low tensile strength test areas yielded results with high tensile strength values. Therefore, the bond adhesion tests demonstrated that there is no expectation of a gross bond adhesion problem in the areas of the IT that pose a high risk for Orbiter damage. Based on historical data from STS-127 to the present, there appears to be no trend toward an increase in the number or size of the TPS losses from the IT. The documented risk posture remains unchanged based on ET-136 performance and ET-137 processing.</p>

APPENDIX B STS-132 IN-FLIGHT ANOMALIES

SYSTEM ENGINEERING AND INTEGRATION ANOMALIES

IFA Number	Title	Comments
STS-132-I-003	Ice Observed on the T-0 Umbilical at Retraction Ice Observed on the T-0 Umbilical at Retraction	<p>NIRD 132-008 reported ice visible on the Orbiter at two locations after LH₂ T-0 umbilical retraction (Camera E022, 0.787 sec MET). The first location was external ice along the peripheral seal at the -Z perimeter of the T-0 umbilical. The second location was internal to the T-0 perimeter and was not visible to the Final Inspection Team (FIT). Ice/Frost build-up inside and outside the peripheral seal on the LH₂ T-0 umbilical has been observed on previous flights. Ice adherence to the Orbiter vehicle could lead to the release of debris that may cause Orbiter Thermal Protection System (TPS) damage during the ascent phase of the mission. Formation of interior T-0 ice is mitigated by the enhanced processes for installation and verification of the T-0 peripheral seal including inspections at the Pad. On 6-29-10, a USA team conducted an independent review and judged that the design controls and verifications to preclude ice formation and potential debris are sufficient. On STS-132, the gray-colored Room Temperature Vulcanizing (RTV) material used to seal the peripheral seal splice joints was applied per drawing in that it did not come in contact with the DAPCO 235 seal. However, this application process did leave a leak path between the DAPCO 235 and the gray RTV applied to both the left and right sides of the upper-splice joint. Boeing GSE design initiated EO G06 to drawing GW70-580517 to improve the gray RTV application process by applying the RTV along the sides of the peripheral seal upper splice plate and abutting to the DAPCO 235 seal thereby eliminating the open flow path into the seal cavity. The TSM T-0 Umbilical Carrier Plate Peripheral Seal Installation OMI's, V2094.005 for LO2 and V2093.005 for LH2, have been revised to reflect the drawing change. These OMI's will also be updated to include a LAA Engineering signature to verify proper RTV installation at these points. T-0 internal ice remains unexpected debris and no update to the Integrated Hazard Reports documents is required.</p>

APPENDIX B STS-132 IN-FLIGHT ANOMALIES

SYSTEM ENGINEERING AND INTEGRATION ANOMALIES

IFA Number	Title	Comments
STS-132-I-004	Frustum UR BSM RTV-133 Missing with Darkened Substrate	<p>During RSRB post-flight assessment, a piece of RTV-133 was discovered missing from the forward left-hand upper-right Booster Separation Motor (BSM) exit cone location. RTV is applied as an environmental seal between the BSM exit cone and the adjacent frustum closure plates. The RTV is not expected ascent debris. The missing piece of RTV was approximately ¼-in. by ¼-in. by 5-in. long with an estimated mass of 0.01 lbm. Localized regions of un-bonded and/or missing RTV were observed at other BSMs locations for this flight and on prior flights. These types of un-bonds, where there is no evidence of heat effects under the un-bonded or missing RTV are considered a nominal condition, attributed to water impact or drogue parachute suspension line entanglement. For the subject observation, the region on the closure plate exposed by the missing RTV was reported to have sooting and heating effects. This observation could indicate a potential late ascent or early decent heat/soot exposure. Liberation of RTV requires adhesive de-bonds from the BSM exit cone and the surrounding closure plates as well as two separate cohesive material failures. The liberated RTV observed during the STS-132 RSRB postflight assessment cannot be attributed to an ascent event since it was determined that there is no failure mechanism sufficient to release the RTV during the ascent timeframe, including RSRB separation plus 5 sec. RTV can be concluded to not liberate during ascent, the cause of the observed sooted substrate condition was determined to not occur earlier than 2 min past SRB separation. The discoloration on the BSM closure plates supports the possibility of late decent environments causing closure plate de-bonding. Splashdown and recovery events are also potential final contributors to the cohesive failure and ultimate release of the RTV-133. There is no expected increase in risk of debris liberation on ascent. RTV-133 remains classified as unexpected debris in NSTS 60559 and there are no impacts to IDBR-01 cause AH for: Unexpected Debris during Liftoff / Ascent Due to RSRB. This Integrated IFA STS-132-I-004 can be closed on the basis of evidence and analysis that demonstrate there is no mechanism sufficient to liberate RTV-133 on ascent.</p>

APPENDIX B STS-132 IN-FLIGHT ANOMALIES

SYSTEM ENGINEERING AND INTEGRATION ANOMALIES

IFA Number	Title	Comments
STS-132-I-005	Multiple Streaks Observed in SSME Plume	<p>STS-132 post launch imagery review of ground-based film and high definition cameras identified a greater number of streaks than usual in the Space Shuttle Main Engine (SSME) exhaust plumes at 4.6 sec MET and between 16.1 and 54.4 sec MET. Under normal circumstances, combustion of LH₂ and LO₂ yields nearly transparent plumes. Bright discernable streaks in engine plumes were observed in both test and flight and are possible indicators of abnormal events. Streaks in-flight have also been attributed to external debris sources (e.g. foam, ice, etc) falling into the plume path and are not typically indicative of abnormal events. NASA Imagery Reporting Database (NIRD) Reportable 132-017 documents the plume streak events observed for STS-132. All streaks appeared orange in color. However, the streaks ranged from small to large in size and the intensity varied from faint to very bright. Streaks were observed in each of the three SSME plumes. When reviewed individually the streaks did not appear unusual as compared to past experience. However, the quantity of streaks observed was significantly more than on prior missions. Streaks occurring after 54.4 sec MET may not have been detectable because, as the vehicle advances in flight to higher altitudes, the camera look angles of the SSME plumes and Field of View (FOV) are not ideal for detecting streaks in imagery. For STS-132, the greater number of streaks than usually observed is considered an unexplained event which could occur even with established precautions and controls in place. A single root cause has not been identified; however, the following have been considered as potential sources that could have contributed to the increased number of streaks: degraded Flexible Reusable Insulation (FRI) (SSME2), degraded Dome Mounted Heat Shield (DMHS) blanket (SSME1), Reaction Control System (RCS) thruster cover paper, base heat shield tile damages/dings, ET TPS, SRB TPS, VCN, Ice/Frost, and minor camera configuration setting changes (shutter speed). During the IIFA investigation process no indications of negative vehicle performance or out-of-family hardware degradation was revealed. No safety-of-flight concerns were identified. With all these considerations, qualitative assessments indicate the overall likelihood of experiencing catastrophic damage due to any of the aforementioned potential causes is low. Although a root cause has not been identified, the risk is considered acceptable because the potential contributors, listed above, are not a safety of flight concern. Recommend closure of this STS-132 integrated IFA as an unexplained anomaly.</p>

APPENDIX B
STS-132 IN-FLIGHT ANOMALIES
SYSTEM ENGINEERING AND INTEGRATION ANOMALIES

IFA Number	Title	Comments
STS-132-S-01	Onboard Printer Problems	<p>Flight Day 2: After the ground uplinked the Execute Package and started the print job using SpawnPrt, the crew reported that one page of the summary timeline did not print properly. Only half of the timeline printed on the page. The crew then reported cleaning the printer head after which the file printed out successfully. No printing problems were reported for the remainder of the day.</p> <p>Flight Day 3: After the ground uplinked the Execute Package and started the print job using SpawnPrt, the crew reported that the onboard printer was printing the each timeline page across two pieces of paper (it would print half of the timeline on one piece of paper, eject the paper and print the remaining half of the timeline on a second piece of paper) (MSG 132-010A). The crew reprinted the timeline pages one page at a time, using the "Current View" option in Acrobat. Photos were taken of the printouts and downlinked. These photos are on the IO website in the 132 FD 3 location. (http://io.jsc.nasa.gov/app/browse.cfm?CID=14297&&pn=2&rpp=25&ct=1) (images are s312e007217, s312e007218, s312e007219).</p> <p>Flight Day 4: The Flight Plan Revision file (MSG 132-022) was divided into separate files, each containing an individual page of the message, in an attempt to fix the problem. The ground initiated the print job using SpawnPrt. No printing problems were reported by the crew.</p> <p>Flight Day 5: The Flight Plan Revision file (MSG 132-027) was divided into separate files (since no problems were reported on FD 4). The crew reported the Flight Plan Revision message printed out nominally up to page 2-15 at which point that page and the follow pages printed out incorrectly. The crew also reported that the printing problems were occurring with other (non-timeline) messages.</p> <p>Summary. The printing problems have occurred on multiple occasions throughout this flight on different messages of varying length and content. The failures have only been reported when multiple files were printed as part of the morning Execute Package. Ground testing has been unable to recreate the problem. PGSC Engineers are continuing to work with Flight Crew Equipment personnel to try and duplicate the printing problem.</p> <p>Post-flight Plan: Standard destow and return to JSC for troubleshooting. Root cause was determined that the paper holes were larger than normal. The vendor provided paper did not meet drawing standards. The "end-of-page" sensor saw the holes and assumed it had reached the end of the page, this caused the printer to stop printing and eject paper.</p> <p>Paper hole size will be verified during pre-installation acceptance testing. Printer testing at SAIL to use paper sampling pulled from reams identified for vehicle stowage.</p>

APPENDIX B
STS-132 IN-FLIGHT ANOMALIES
SYSTEM ENGINEERING AND INTEGRATION ANOMALIES

IFA Number	Title	Comments
STS-132-S-02	STS4 PGSC Screen Cracked	<p>On FD8 at approximately 6/13:45 MET, the crew called down to report that the screen on the Rendezvous Proximity Operations Program (RPOP) Payload and General Support Computer PGSC (STS4) was broken and that the crew considered it unusable. because the Lexan screen was cracked but remained intact. The crew took pictures of the screen that were downlinked and sent to ESC for processing.</p> <p>Per the STS-132 PGSC Backup Plan chart prepared pre-flight, the crew was informed that the new configuration was to setup RPOP2 (STS5) as prime for RPOP/TCS and DOUG while still being prime for PILOT, WVS, and backup for WLES. In the case that another PGSC were to go down, WLES (STS6) would then become prime for RPOP, DOUG, PILOT, and WVS as well as still being prime for WLES and LCC.</p> <p>The damage appears to be isolated to the screen. Pinging the PGSC worked and the images that the crew took were brought down from the RPOP machine, so all OCA functionality to the machine remains.</p> <p>The crew was informed how to setup the network with one PGSC down. RPOP2 (STS5) is prime for RPOP/TCS and DOUG while still being prime for PILOT, WVS, and backup for WLES.</p> <p>Post-flight Plan: Standard destow and return to JSC for troubleshooting.</p> <p>During the crew debriefing, the crew reported that the laptop power connector cover tethered to the power cable floated between the screen and the keyboard when the laptop was closed. The broken laptop was pulled from the flight inventory.</p> <p>Crew awareness heightened through training.</p>

APPENDIX B
STS-132 IN-FLIGHT ANOMALIES
FLIGHT SOFTWARE ANOMALIES

No Flight Software anomalies were identified during the review and analysis of the flight data.

APPENDIX B
STS-132 IN-FLIGHT ANOMALIES
FLIGHT OPERATIONS AND INTEGRATION ANOMALIES

No Flight Operations and Integration anomalies were identified during the STS-132 mission.

APPENDIX B
STS-132 IN-FLIGHT ANOMALIES
MOD ANOMALIES

No in-flight anomalies were identified during the STS-132 mission.

APPENDIX C

STS-132 DOCUMENT SOURCES

MER DAILY REPORTS

The following STS-132 MER Daily Reports by Malise M Fletcher, Lead MER Manager:

- Launch and First Daily Report, dated May 14, 2010
- Second Daily Report, dated May 15, 2010
- Third Daily Report, dated May 16, 2010
- Fourth Daily Report, dated May 17, 2010
- Fifth Daily Report, dated May 18, 2010
- Sixth Daily Report, dated May 19, 2010
- Seventh Daily Report, dated May 20, 2010
- Eighth Daily Report, dated May 21, 2010
- Ninth Daily Report, dated May 22, 2010
- Tenth Daily Report, dated May 23, 2010
- Eleventh Daily Report, dated May 24, 2010
- Twelfth Daily Report, dated May 25, 2010
- Thirteenth Daily Report, dated May 26, 2010
- Landing Plus 2 Hour Report, dated May 26, 2010
- Mission Summary Report, dated May 28, 2010

ET/SRB/RSRM/SSME REPORTS

- STS-132 In-Flight Anomalies, David W. Morr, USA-Huntsville, July 17, 2010
- STS-132 HOSC Console Flash Report, Dino Diluigi, USA-Huntsville, May 14, 2010
- STS-132 RSRM Flash Report, Robert Zahl, ATK, May 14, 2010
- STS-132 SRB Open Assessment, Thomas F. Ford, NASA-KSC, May 19, 2010

ORBITER REPORTS

- STS-132 Landing and Deceleration Mission Summary, Brian Warkentine, Boeing-Houston, June 16, 2010
- STS-132 Landing and Deceleration Quick Look Report, C. C. Heinol, Boeing-Houston, June 14, 2010
- STS-132 Communications and Tracking Report, Martha M. May, Boeing-Houston, June 8, 2010
- STS-132 Shuttle Remote Manipulator System, Stephan M. Tabladillo, MDA-Houston, June 18, 2010
- STS-132 HYD/WSB System Report, Charles A. Ritrivi, Boeing-Houston, June 17, 2010
- STS-132 Main Propulsion System Report, Trina A. Martingano, Boeing-Houston, June 17, 2010
- STS-132 Mechanical Systems Data Review, Jeff Goodmark, Boeing-Houston, June 15, 2010
- STS-132 Auxiliary Power Unit System, Christopher N. Adi, Boeing-Houston, June 18, 2010
- STS-132 OI/MADS Sensors, Signal Conditioners and Fuel Cell Monitoring System, Dwight A. Favors, Boeing-Houston, June 16, 2010
- STS-132 OI/MADS MUX and Timing Report, Bruce S. Woods, Boeing-Houston, June 18, 2010
- STS-132 Data Processing System Integrated Report, Lynna L. Wood, Boeing-Houston, June 18, 2010
- STS-132 EPDC Mission Report, William D. Peterson, Boeing-Houston, June 16, 2010
- STS-132 ATCS and ARS Post-Flight Mission Report, Carmelo S. Asuncion, Boeing-Houston, June 14, 2010
- STS-132 Wing Leading Edge Impact Detection System, Jennifer C. Hodge, Boeing-Houston, July 14,

2010

STS-132 Life Support System Report (ARPCS and Airlock Systems), Jamie M. Haynes, Boeing-Houston, June 17, 2010
STS-132 Orbiter Docking System Summary, Robert E. Davis, NASA-JSC, June 16, 2010
STS-132 OMS Report, Francesco Fusco, Boeing-Houston, June 18, 2010
STS-132 RCS Mission Report Francesco Fusco , Boeing-Houston, June 18, 2010
STS-132 Final Aeroheating Report, Roberta L. Justice, Boeing-Houston, June 28, 2010
STS-132 Fuel Cells Mission Report, Johnny D. Wong, Boeing-Houston, June 18, 2010
STS-132 Power Reactant Storage and Distribution, Johnny D. Wong, Boeing-Houston, June 18, 2010
STS-132 Global Positioning System Report, Heip M. Bui, Boeing-Houston, June 16, 2010
STS-132 Thermal Control System Summary, Kent K. Rowley, Boeing-Houston, June 18, 2010
STS-132 Flight Control System and ADTA Mission Report, Donald E. Marquith, Boeing-KSC, June 15, 2010
STS-132 Final Mission Events List, Vernon C. Hill, ESCG-Houston, May 26, 2010
STS-132 SE&I In-Flight Anomalies, R. Clayton, NASA-JSC, October 1, 2010
STS-132 Windows Report, Orlando Torres, Boeing-KSC, July 20, 2010
STS-132 Display and Controls, Quoc P. Ngo, Boeing-Houston, June 18, 2010
STS-132 Purge, Vent and Drain Report, C. C. Heinol, Boeing-Houston, June 18, 2010
STS-132 ADS – GCILC Mission Report, Arnold A. Arrington, NASA-KSC, June 18rch 12, 2010
STS-132 Mechanical Systems, Link Salvador, Boeing-Houston, June 15, 2010
STS-132 Landing and Deceleration Quick Look Report, C. C. Heinol, Boeing-Houston, June 14, 2010

OTHER REPORTS

STS-132 CSR Final Report, Phyllis F. Grounds, NASA-JSC, August 2, 2010
STS-132 Final Landing Debris Runway Report, Thomas F. Ford, NASA-KSC, May 26, 2010
STS-132 Final Debris Maps, Thomas F. Ford, NASA-KSC, May 27, 2010
STS-132 Pre-EVA No. 1 Data, Shannon Cagle-Strimple, Hamilton Sundstrand, May 17, 2010
STS-132 Post-Extravehicular Activity Report for EVA 1, Jeff Outlaw, Hamilton Sunstrand, May 17, 2010
STS-132 Pre-EVA No. 2 Data, Jonathan Kocher, Hamilton Sundstrand, May 19, 2010
STS-132 Post-Extravehicular Activity Report for EVA 2, Jeff Outlaw, Hamilton Sunstrand, May 19, 2010
STS-132 EVA no. 3 Ingress and Post-EVA Report, Shannon Cagle-Strimple, Hamilton Sunstrand, May 21, 2010
STS-132 Final Extravehicular Activity Report, Bridgette Ziegelaar, NASA-JSC, June 29, 2010
STS-132 Post-Launch Debris Report, Jeffrey S. Thon, NASA-KSC, May 14, 2010
STS-132 Descent Postflight Summary, Shawna L. Frame, USA-Houston, June 23, 2010
STS-132 prop30 Mass Properties Report, Jennifer Flynn, USA-Houston, June 1, 2010
STS-132 Imagery Reports, Imagery Integration Group, NASA-JSC, May 15 through May 20, 2010
STS-132 Ascent Hazard Analysis Final Report, C. C. Heinol, Boeing-Houston, June 28, 2010
STS-132 Flight Software Anomalies, J. A. Currie, NASA-JSC, June 28, 2010
STS-132 FO&I In-flight Anomalies, Ray Serna, NASA-JSC, June 22, 2010

APPENDIX D

STS-132 ACRONYMS, ABBREVIATIONS AND UNITS OF MEASURE

Acronym/ Abbreviation	Explanation
A	Ampere
AA	Accelerometer Assembly
ABS	Ammonia Boiler System
ADTA	Air Data Transducer Assembly
AGC	Automatic Gain Control
AHMS	Advanced Health Monitoring System
AMOS	Air Force Maui Optical Supercomputing Site
APFR	Articulating Portable Foot Restraint
APU	Auxiliary Power Unit
ARPCS	Atmospheric Revitalization Pressure Control System
ASA	Aerosurface Actuators
ATCS	Active Thermal Control System
BET	Best Estimated Trajectory
BITE	Build-In Test Equipment
BFS	Backup Flight System
BFS WHI	Backup Flight System Initial Weight of Helium Load
BLT	Boundary Layer Transition
BSM	Booster Separation Motor
C&C	Command and Control
CDR	Commander
C/O	Checkout
CO	Carbon Monoxide
COAS	Crew Optical Alignment Sight
COMM	Communications
CPM	Cell Performance Monitor
CRT	Cathode Ray Tube
CST	Central Standard Time
CW	Continuous Wave
CWC	Contingency Water Container
CWCI	Contingency Water Container Iodine
D & C	Display and Control
DAP	Digital Autopilot
DAT	Debris Assessment Team
DDU	Data Display Unit
DET	Data Elapsed Time
DOD	Department of Defense
DOLILU	Day of Launch I Load Update
DPS	Data Processing System
DRWP	Doppler Radar Wind Profile

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STS-132 ACRONYMS, ABBREVIATIONS AND UNITS OF MEASURE

Acronym/ Abbreviation	Explanation
DTO	Development Test Objective
ΔV	Differential Velocity
ECLSS	Environmental Control and Life Support System
ECO	Engine Cut-off
EDT	Eastern Daylight Time
EE	End Effector
EOTP	Enhanced Orbital Replacement Unit Temporary Platform
EPDC	Electrical Power Distribution and Control
ERA	European Robotic Arm
ET	External Tank
EV	Extravehicular (Crewmember)
EVA	Extravehicular Activity
FCE	Flight Crew Equipment
FCMS	Fuel Cell Monitoring System
FCS	Flight Control System
FCV	Flow Control Valve
FD	Flight Day
FE	Flight Engineer
FES	Flash Evaporator System
FGB	Fixed Grapple Bar
FID	Failure Identifier
FIT	Final Inspection Team
FRCS	Forward Reaction Control System
FRI	Flow Recirculation Inhibitor
FRSI	Felt Reusable Surface Insulation
FSE	Flight Support Equipment
FSS	Fixed Service Structure/Flight Support System
FSW	Flight Software
g/G	Gravity
GCA	Ground Carrier Assembly
GFE	Government Furnished Equipment
GG	Gas Generator
GH ₂	Gaseous Hydrogen
GMT	Greenwich Mean Time
GN ₂	Gaseous Nitrogen
GO ₂ /GOX	Gaseous Oxygen
GPC	General Purpose Computer
GPS	Global Positioning System
Grms	Gravity root mean square

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STS-132 ACRONYMS, ABBREVIATIONS AND UNITS OF MEASURE

Acronym/ Abbreviation	Explanation
GSE	Ground Support Equipment
GUCP	Ground Umbilical Carrier Plate
H ₂	Hydrogen
HDP	Holddown Post
Hg	Mercury
HGDS	Hazardous Gas Detection System
HPFTP	High Pressure Fuel Turbopump
HPOTP	High Pressure Oxidizer Turbopump
HYD	Hydraulic
ICC-VLD 2	Integrated Cargo Carrier-Vertical Lightweight Deployable – 2
IDC	ISIS Digital Camera
IDS	Impact Detection System
IEA	Integrated Equipment Assembly
IFA	In-Flight Anomaly
IFR	Ice/Frost Ramp
IMU	Inertial Measurement Unit
IPR	Interim Problem Report
ISIS	Integrated Sensor Inspection System
ISP	Integrated Stowage Platform
I _{SP}	Specific Impulse
ISS	International Space Station
ITVC	Intensified Television Video Camera
JAXA	Japanese Aerospace Exploration Agency
JSC	Johnson Space Center
KSC	Kennedy Space Center
L	Launch
LCC	Launch Commit Criteria
LDRI	Laser Dynamic Range Imager
LED	Light Emitting Diode
LH	Left Hand
LH ₂	Liquid Hydrogen
LiOH	Lithium Hydroxide
LO ₂	Liquid Oxygen
MADS	Modular Auxiliary Data System
MAUI	Maui Analysis of Upper Atmospheric Modification
MAX Q	Maximum Dynamic Pressure
MBS	Mobile Base System
MC	Midcourse Correction
MDM	Multiplexer Demultiplexer
MDU	Multifunction Display Unit

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STS-132 ACRONYMS, ABBREVIATIONS AND UNITS OF MEASURE

Acronym/ Abbreviation	Explanation
MECO	Main Engine Cutoff
MEDS	Multifunction Electronics Display System
MER	Mission Evaluation Room
MET	Mission Elapsed Time
MFD	Multifunction Display
MLG	Main Landing Gear
MLI	Multi-Layer Insulation
MLM	Multi-purpose Laboratory Module
MLP	Main Launch Platform
MLS	Microwave Landing System
MM	Major Mode
MM/OD	MicroMeteoroid/Orbital Debris
MMT	Mission Management Team
MPM	Manipulator Positioning Mechanism
MPS	Main Propulsion System
MRL	Manipulator Retention Latch
MRM	Mini Research Module
MT	Mobile Transporter
N ₂	Nitrogen
NASA	National Aeronautics and Space Administration
NAVAID	Navigation Aids
NC	Nominal Correction
NCC	Nominal Correction Combination
NH	Nominal Height
NH ₃	Ammonia
NSTS	National Space Transportation System
O ₂	Oxygen
OAA	Orbiter Access Arm
OBSS	Orbiter Boom Sensor System
ODS	Orbiter Docking System
OI	Operational Instrumentation/Operational Increment (Software)
OME	Orbital Maneuvering Engine
OML	Outer Mold Line
OMRSD	Operational Maintenance and Requirements Specification Document
OMS	Orbital Maneuvering System
ORGA	Orbiter Rate Gyro Assembly
ORU	Orbital Replacement Unit
OPO	Orbiter Project Office
PAO	Public Affairs Office

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STS-132 ACRONYMS, ABBREVIATIONS AND UNITS OF MEASURE

Acronym/ Abbreviation	Explanation
PASS	Primary Avionics Software System
PASS WHI	PASS With Initial Helium Load
PCM	Pulse Code Modulation
PCS	Pressure Control System
PCT	Post-Contact Thrust
PDGF	Power and Data Grapple Fixture
PDU	Power Drive Unit
PGME	Propylene Glycol Monomethyl Ether
PGSC	Payload General Support Computer
PLB	Payload Bay
PLBD	Payload Bay Door
POA	Payload and ORU Accommodation
ppm	parts per million
PRCS	Primary Reaction Control System
PRLA	Payload Retention Latch Assembly
PRSD	Power Reactant Storage and Distribution System
PTU	Power Transfer Unit/Pan-Tilt Unit
PV&D	Purge, Vent and Drain
PWP	Portable Work Platform
PWR	Payload Water Reservoir
QD	Quick Disconnect
RAMBO	Ram Burn Observations
RCC	Reinforced Carbon-Carbon
RCS	Reaction Control System
RH	Right Hand
RHC	Rotational Hand Controller
RJD	Reaction Jet Driver
RM	Redundancy Management
RPL	Rated Power Level
RPM	R-Bar Pitch Maneuver
RPOP	Rendezvous/Proximity Operations Program
R&R	Remove and Replace
RSB	Rudder Speed Brake
RSRB	Reusable Solid Rocket Booster
RSRM	Reusable Solid Rocket Motor
RSS	Range Safety System
RTV	Room Temperature Vulcanizing (material)
S	Starboard
SA	Solar Array
S&A	Safe and Arm

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STS-132 ACRONYMS, ABBREVIATIONS AND UNITS OF MEASURE

Acronym/ Abbreviation	Explanation
SDFS	Smoke Detection and Fire Suppression
SE&I	Systems Engineering and Integration
SEITE	Shuttle Engine Ion Turbulence Experiment
SGANT	Space-to-Ground Antenna
SIMPLEX	Shuttle Ionospheric Modification with Pulsed Firings
SLWT	Super Lightweight Tank
SM	System Management
SMRD	Spin Motor Rotation Detector
S/N	Serial Number
SPDM	Special Purpose Dexterous Manipulator
SRGA	SRB Rate Gyro Assembly
SRM	Solid Rocket Motor
SRMS	Shuttle Remote Manipulator System
SRSS	Shuttle Range Safety System
SSME	Space Shuttle Main Engine
SSP	Space Shuttle Program
SSPTS	Station-to-Shuttle Power Transfer System
SSR	Solid State Recorder
SSRMS	Space Station Remote Manipulator System
ST	Star Tracker
STS	Space Transportation System
STSS	Space Tracking Surveillance System
SWMMS	Supply Water and Waste Management System
TACAN	Tactical Air Navigation
TCS	Thermal Control System/Trajectory Control Sensor
THC	Translation Hand Controller
TI	Terminal Phase Initiation/Transfer Initiation
TPL	Transfer Priority List
TPS	Thermal Protection System
TSM	Tail Service Mast
TVC	Thrust Vector Controller
UF	Utilization Flight
UTC	Universal Time Code
WLE	Wing Leading Edge
WLE IDS	Wing Leading Edge Impact Detection System
WS	Worksite
WSB	Water Spray Boiler
Z	Zenith

APPENDIX D

STS-132 ACRONYMS, ABBREVIATIONS AND UNITS OF MEASURE

<u>Unit of Measure</u>	<u>Explanation</u>
°F	degree Fahrenheit
deg	degree
deg/sec	degree per second
ft	feet
ft/sec	feet per second
Grms	gravity root mean square
In. Hg	Inches of Mercury
MHz	MegaHertz
hr	hour
In.	inch
Kbps	kilobits per second
keas	knots estimated air speed
kg	kilogram
kgs	knots ground speed
kW	Kilowatt
kWh	Kilowatt hour
lb	pound
lb _m /lbm	pound mass
lb/min	pound per minute
Mbps	Megabits per second
MHZ	MegaHertz
min	minute
mmHg	Millimeters of Mercury
mph	miles per hour
mV	milliVolt
nmi	nautical mile
%	percent
%/min	percent per minute
ppCO ₂	partial pressure carbon dioxide
ppm	parts per million
psi	pound per square inch
psia	pound per square inch absolute
psid	pound per square inch differential
scim	standard cubic inch per minute
sec	second
torr	Unit of pressure (ratio of 760 to one standard atmosphere)
V	Volt
Vdc	Volt direct current

APPENDIX D

STS-132 ACRONYMS, ABBREVIATIONS AND UNITS OF MEASURE

<u>Unit of Measure</u>	<u>Explanation</u>
°F	degree Fahrenheit
deg	degree
deg/sec	degree per second
ft	feet
ft/sec	feet per second
Grms	gravity root mean square
hr	hour
In.	inch
keas	knots estimated air speed
kgs	knots ground speed
kW	Kilowatt
kWh	Kilowatt hour
lb	pound
lb _m /lbm	pound mass
lb/min	pound per minute
lbm/hr	pound per hour
Mbps	Megabits per second
min	minute
mmHg	Millimeters of Mercury
mph	miles per hour
mV	milliVolt
nmi	nautical mile
%	percent
%/min	percent per minute
ppCO ₂	partial pressure carbon dioxide
psia	pound per square inch absolute
scim	standard cubic inch per minute
sec	second
V	Volt
Vdc	Volt direct current