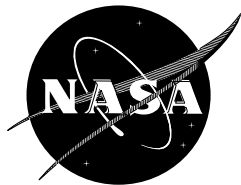


STS-131 SPACE SHUTTLE MISSION REPORT

October 2010



**National Aeronautics and
Space Administration**

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

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STS-131

SPACE SHUTTLE MISSION REPORT

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STS-131 SPACE SHUTTLE MISSION REPORT

INTRODUCTION

The Space Transportation System (STS) -131 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 STS-131 mission of the Space Shuttle Program.

The primary objectives of the STS-131 mission were as follows:

1. Perform middeck and Multi-Purpose Logistics Module (MPLM) cargo transfers.
2. Remove current Ammonia Tank Assembly (ATA) on S1 and install a new ATA.
3. Transfer and install six racks that were:
 - a. Muscle Atrophy Research and Exercise System (MARES).
 - b. Window Observational Research Facility (WORF).
 - c. Minus 80-Degree Laboratory Freezer for ISS (MELFI-3).
 - d. Expedite the Processing of Experiments to Space Station (EXPRESS) Rack no. 7.
 - e. Crew Quarters No. 2
 - f. Two Zero-g Stowage Racks (ZSR).
4. Retrieve Light Weight Adapter Place Assembly payload.
5. Retrieve Japanese Experiment Module Space Environment Exposure Device (SEED) payload.
6. Return three Integrated Stowage Platforms.
7. Perform three Extravehicular Activities (EVAs).

STS-131 was the 18th mission since the return to flight following the STS-107 mission, and the 33rd mission to the International Space Station (ISS). STS-131 was also the 38th flight of the Orbiter 103 vehicle.

The flight vehicle consisted of the OV-103 Orbiter; the ET, a Super Lightweight Tank (SLWT) designated ET-135; three Block II SSMEs that were designated as serial numbers (S/Ns) 2045, 2060, and 2054 in positions 1, 2 and 3, respectively; and two RSRBs that were designated BI-142. The two RSRMs were designated flight set RSRM-110. The individual RSRMs were S/N 360W110A (left) and S/N 360W110B (right). Launch pad 39A and Mobile Launch Platform (MLP) -3 were used as the platform for launch of the STS-131 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-131 flight were Alan G. Poindexter, Captain, U. S. Navy, Commander; James P. Dutton, Jr. Colonel, U.S. Air Force, Pilot, Richard Mastracchio, Civilian, NASA, Mission Specialist 1; Dorothy Metcalf-Lindenburger, Civilian, NASA, Mission Specialist 2 ; Stephanie Wilson, Civilian, NASA, Mission Specialist 3; Naoki Yamazaki, Civilian, Japanese Aerospace Exploration Agency (JAXA) Mission Specialist 4, and Clayton Anderson, Civilian, NASA, Mission Specialist 5.

STS-131 was the third flight for the Mission Specialist 1 and Mission Specialist 3, the second flight for the Commander, and Mission Specialist 5, and the first flight for Pilot, Mission Specialist 2, and Mission Specialist 4.

MISSION SUMMARY

The objectives of the STS-131 mission included docking with the International Space Station (ISS), performing middeck and Multi-Purpose Logistics Module (MPLM) cargo transfers, replacing the Ammonia Tank Assembly (ATA) on Starboard Zero (S0), transferring experiment equipment and performing three Extravehicular Activities (EVAs).

Pre-Launch

During prelaunch operations at 094/22:30:44 Greenwich Mean Time (GMT), the fuel cell 2 pump-motor-condition measurement spiked upward to 0.74 Volts (V) over a 5-min period. At 094/22:38:07 GMT, the pump-motor-condition measurement returned abruptly to the nominal reading of 0.62 V. The reading remained stable for the remainder of the prelaunch period and ascent.

Just prior to Space Shuttle Main Engine (SSME) 3 start, the Main Propulsion System (MPS) Liquid Hydrogen (LH₂) inlet pressure measurement began behaving erratically at 095/10:21:15 GMT and eventually went to Off-Scale Low (OSL) (STS-131-V-01). The loss of these data did not affect the ascent and was no concern for the remainder of the flight.

Ascent and Flight Day 1

The STS-131 mission was launched at 095/10:21:24.992 GMT on April 5, 2010, on the thirty-third Space Shuttle Program (SSP) mission to the ISS, and the 38th flight of the OV-103 (Discovery) vehicle.

The Reusable Solid Rocket Booster (RSRB) separation was visible. A nominal Orbital Maneuvering System (OMS) assist maneuver was performed following RSRB separation. Ignition occurred at 095/10:23:41.0 GMT [00/00:02:16.0 Mission Elapsed Time (MET)], and cutoff for the maneuver was 095/10:25:25.6 GMT (00/00:04:00.6 MET). The maneuver was 104.6 sec in duration.

Main Engine Cutoff (MECO) occurred at 095/10:29:49 GMT (00/00:08:24 MET). The External Tank (ET) separated from the Orbiter at 095/10:30:10 GMT (00/00:08:45 MET).

A nominal OMS-2 maneuver was performed at 095/10:58:39.4 GMT (00/00:37:15.4 MET). The maneuver was a straight-feed dual engine firing that was 128.6 sec in duration with a Differential velocity (ΔV) of 196.9 ft/sec. The achieved orbit was 140.1 by 123.6 nmi.

At 095/10:42:55 GMT (00/00:21:30 MET), the fuel cell 2 Hydrogen (H₂) flow-meter output became erratic, but returned to the nominal reading at 095/10:48:30 GMT (00/00:27:05 MET). The fuel cell 2 flow-meter did continue to show periods of intermittent erratic output.

The Payload Bay Doors (PLBDs) were opened at 095/11:52:01 GMT (00/01:30:36 MET). The Ku-Band antenna was deployed and the self-test was performed.

The Ku-Band Antenna was deployed at 095/12:02:00 GMT (00/01:40:35 MET). The system was powered ON at 095/12:06:05 GMT (00/01:44:40 MET), and the RADAR self-test was started at 095/12:11:33 GMT (00/01:50:08 MET). The Ku-Band system failed the self-test (IFA STS-131-V-02). Signal-strength telemetry was low (0.56 Volt (V) versus typical 0.9V) and the range remained at 0 ft, when it should have been 10,240+/- 500 ft. In addition, the Detect-and-Track indications were missing. During the second self-test, indications looked good, except the signal strength was still low. Both self-tests indicated that the failure was due to Electronics Assembly-2 (EA-2). After selecting the Communication (COMM) mode, in both General Purpose Computer (GPC) Acquisition and GPC Designate, the antenna tracked the Tracking and Data Relay Satellite (TDRS) as expected, but never achieved a forward link. The return link was unusable on all three channels. A power cycle was commanded from the ground with no change in Ku-Band response. The crew cycled the Main B bus Ku-Band circuit breaker with no change in Ku-band response. Various system modes were configured with no change in Ku-Band response. The Ku-Band was not available for COMM operations (video/file downlinks and file uplinks) and did not work during RADAR operations; however RADAR operations were attempted during the rendezvous on FD 3.

The OMS-3 Nominal Correction (NC) 1 maneuver was an OMS two-engine, straight-feed firing performed at 095/13:07:28 GMT (00/02:46:03 MET). The firing was 63.2 sec in duration with a ΔV of 97.6 ft/sec. The resulting orbit was 138.7 by 180.9 nmi. OMS performance was nominal.

The Shuttle Remote Manipulator System (SRMS) On-Orbit Initialization was completed without issue at 095/14:49 GMT (00/04:27 MET).

Flight Day 2 (96/00:21 – 97/00:21)

The main activities for Flight Day (FD) 2 were the SRMS checkout, the exterior-surface surveys with the Orbiter Boom Sensor System (OBSS), the NC2 and NC3 maneuvers, the Extravehicular Mobility Unit (EMU) checkout, rendezvous tools checkout, and Orbiter Docking System (ODS) ring extension.

The OMS-4 NC2 maneuver was a dual-engine straight-feed OMS firing that occurred at 096/01:56:28.4 GMT (00/15:35:03.4 MET). The firing time was 39.4 sec with a ΔV of 61.6 ft/sec. The resulting orbit was 171.2 by 181.1 nmi. Engine performance was nominal.

The SRMS power-up began at 096/02:12 GMT (00/15:50 MET). The checkout was initiated at 096/02:26 GMT (00/16:04 MET) and was nominal. The maneuver for OBSS grapple was started at 096/03:31 GMT (00/17:09 MET), with unberthing of the OBSS completed at 096/04:01 GMT (00/17:39 MET). The Starboard Survey began with the Flat-Field Survey at 096/05:03 GMT (00/18:41 MET), and was completed at 096/07:09 GMT (00/20:47 MET). The Nose Survey began at 096/07:30 GMT (00/21:08 MET) and was completed at 096/08:17 GMT (00/21:55 MET). The Port Survey began at 096/08:34 GMT (00/22:12 MET) and was completed at 096/10:35 GMT (00/14:15 MET). The OBSS was berthed and latched at 096/11:04 GMT (01/43:04 MET).

As a result of the loss of Ku-Band, the FD 2 Reinforced Carbon-Carbon (RCC) survey imagery was not downlinked until after the Shuttle docked to the ISS on FD 3 so that ISS assets could be used. The Damage Assessment Team (DAT) analyses of the FD 2 imagery could not commence until after receipt on FD 3. Completion of the Thermal Protection System (TPS) DAT analysis of the FD 3 R-Bar Pitch Maneuver (RPM) was not expected to be affected. In addition, the onboard ascent imagery and Wing Leading Edge (WLE) sensor data were not downlinked until after docking.

The rendezvous-tools checkout was performed and all systems were nominal. The Trajectory Control Sensor (TCS) was powered on at 096/12:05 GMT (01/01:43 MET) and was powered off at 096/12:24 GMT (01/02:03 MET).

The first on-orbit fuel cell purge (manual) was initiated at 096/12:36 GMT (01/02:14 MET). The purge was nominal.

The NC3 maneuver was a multi-axis firing using the Primary Reaction Control System (PRCS). Ignition occurred at 096/13:32:22 GMT (01/03:10:57 MET), and the maneuver was 19 sec in duration. The ΔV was 4.4 ft/sec and the resulting orbit was 172.7 by 181.8 nmi.

The ODS ring extension was completed at 096/13:52:40 GMT (01/03:31:16 MET). No anomalies were noted during the ring extension. The ring extension was performed with nominal dual-motor drive to the initial position of 76.4% ring extension.

Flight Day 3 (97/00:21 – 98/00:21)

The main activities on FD 3 were rendezvous and docking with the ISS, and unberthing and hand-off of the OBSS.

The Ku-Band antenna was taken to the RADAR mode at 097/01:54:02 GMT (01/15:32:37 MET), but failed the self-test. This was expected given the previous issues with the Ku-Band system. A subsequent attempt to utilize RADAR data was unsuccessful. As a result, RADAR data was not available during rendezvous. With the rendezvous radar failure, the crew used the Radar-Fail procedure. The Star Tracker and Crew Optical Alignment Sight (COAS) were used in place of the radar. The crew was extensively trained in the use of the Radar-Fail procedure.

The first maneuver of the day was the OMS-5 NC4, which was a straight-feed dual-engine firing. Ignition was at 097/03:35:14.9 GMT (01/17:13:50 MET) with the cutoff 13.7 sec later. The maneuver had a ΔV of 21.2 ft/sec, and the resulting orbit was 181.9 by 184.8 nmi. Engine performance was nominal.

The Nominal Corrective Combination (NCC) maneuver was a multi-axis Reaction Control System (RCS) firing using four primary thrusters. The time of ignition was 097/04:09:03 GMT (01/17:47:38 MET). The ΔV delivered was 0.76 ft/sec and the resulting orbit was 181.6 by 184.8 nmi.

The OMS-6 Terminal Initiation (TI) maneuver was a straight-feed, left-OMS engine firing. Ignition was at 097/05:06:44.2 GMT (01/18:45:19 MET) with the cutoff 10.4 sec later. The ΔV delivered was 7.7 ft/sec, and the resulting orbit was 181.8 by 184.8 nmi. Engine performance was nominal.

The Midcourse Correction (MC) 1 maneuver was initiated at 097/05:26:44 GMT (01/19:05:19 MET) and was completed nominally. The ΔV delivered was 0.52 ft/sec. The MC2 maneuver was initiated at 097/06:00:29 GMT (01/19:39:04 MET) and was completed nominally. The ΔV delivered was 0.57 ft/sec. The Out-of-Plane Null maneuver was initiated at 097/06:12:12 GMT (01/19:50:47 MET) and was completed nominally. The ΔV delivered was approximately 0.1 ft/sec. The MC3 maneuver was performed at 097/06:17:51 GMT (01/19:56:26 MET) and was completed nominally. The ΔV delivered was 1.51 ft/sec. The MC4 maneuver was not required.

The RPM started at 097/06:48:09 GMT (01/20:26:44 MET) and ended at 097/06:56:24 GMT (01/20:34:59 MET). The peak pitch-rate during the maneuver was 0.69 deg/sec. The maximum attitude excursion was in roll and reached approximately 13.6 deg. Performance was nominal.

The Triangulation Light Intensification Detection and Ranging (TriDAR) Development Test Objective (DTO) was activated for the rendezvous with the ISS. There were initially some issues during the power-up that were associated with circuit breaker labeling and communication between the TriDAR unit and the flight deck Payload and General Support Computer (PGSC), but these were resolved. TriDAR was restarted and ran nominally for 2 hr. Following the RPM, telemetry showed that communication stopped. The TriDAR team reviewed log data, which indicated that the unit successfully ran from 125,000 ft to 612 ft, but was not operational thereafter. Subsequent testing by the contractor reproduced the failure signature by quickly connecting and disconnecting the Ethernet cable. The cause was that the RJ45 cable was not properly seated.

The TCS began tracking the ISS at a distance of approximately 9600 ft at 097/08:27:41 GMT (01/20:47:16 MET) and worked nominally throughout the rendezvous activities.

The ODS was activated at 097/07:26:25 GMT (01/21:05:00 MET). The Shuttle captured the ISS at 097/07:44:09 GMT (01/21:22:44 MET), and the Post-Contact Thrust (PCT) firing sequence was performed nominally. Ring retraction using dual motors was

started at 097/07:58:21 GMT (01/21:36:56 MET). The hooks were driven closed nominally and final ring extension was performed, releasing the capture latches and the ring final-position was acquired at approximately 097/08:10 GMT (01/21:48 MET). The ODS X4 connector-mated indication was not acquired after docking. The Orbiter Interface Unit (OIU) connectivity through that connector was successfully obtained.

Hatch opening took place around 097/09:10:57 GMT (01/22:49:32 MET).

Attitude control was released by the Shuttle at 097/09:16:17 GMT (01/22:54:52 MET). Attitude control was resumed by the ISS at 097/09:16:40 GMT (01/22:55:15 MET).

At 097/10:14:00 GMT (01/23:52:35 MET), the SRMS maneuvered to the OBSS Pre-Grapple Handoff Position. The Space Station RMS (SSRMS) unberthed the OBSS at 097/11:06:49 GMT (02/00:45:45 MET) and maneuvered it to the Handoff Position. At 097/11:33:50 GMT (02/01:12:50 MET), the SRMS grappled the OBSS and maneuvered it to the MPLM Viewing Position.

The Station-to-Shuttle Power Transfer System (SSPTS) activation was completed at 097/10:38 GMT (02/00:17 MET). All four Orbital Power Converter Units (OPCUs) and Assembly Power Converter Unit-2 (APCU-2) were on-line.

All Wing Leading Edge (WLE) Impact Detection System (IDS) ascent summary data was successfully downlinked using ISS assets on FD 3 at approximately 097/14:43:16 GMT (02/04:21:52 MET). Four indications exceeded the 1 Grms reporting criteria; however, none of these indicated a need for a Focused Inspection (FI). Three magnitudes observed on the port wing were 1.51 Grms on panel 6, 1.03 Grms on panel 7, and 1.46 Grms on panel 16, all of which have a low-damage category. One indication on the starboard chine had a magnitude of 2.56 Grms, but nothing exceeding the on-orbit inspection in this area was observed by the DAT during their review of RPM imagery. WLE IDS on-orbit monitoring with Port and Starboard Group 1 began at approximately 097/15:15 GMT (02/04:54 MET) and continued for 24 hr.

The ground received the first of six Laser Dynamic Range Imager (LDRI) video files at approximately 097/15:18:32 GMT (02/04:57:07 MET). This imagery, along with the Integrated Sensor Inspection System (ISIS) Digital Camera (IDC) imagery for the starboard wing, was also downlinked using ISS assets. The LDRI video files were very large files (6 to 7 GB each) and the downlink rates from ISS were highly variable (6 to 60 MB/sec), thus making the process very slow. Also the downlink occurring. To ease this situation it was decided to break up the last file into smaller segments of the files had to be restarted several times due to data dropouts.

Three Contingency Water Container-Iodine (CWC-I) were filled and transferred to the ISS for a total of 122 lbm of water.

Flight Day 4 (98/00:21 – 99/00:51)

The main activities on FD 4 were the installation of the MPLM, the preparations for the first EVA, and the downlink of remaining inspection imagery from the FD 2 inspection.

The DAT reviewed the LDRI data, the IDC imagery, and the RPM imagery for the starboard wing and determined by FD 4 crew wakeup that there was no requirement for a focused inspection of the starboard wing. Therefore, the recommendation was to proceed with the FD 4 installation of the MPLM as planned. The DAT continued to assess the remainder of the vehicle.

The SSRMS unberthed the MPLM at 098/03:28:53 GMT (02/17:07:28 MET) and installed it on the Node 2 Nadir port at 098/04:41:46 GMT (02/18:20:21 MET) without issue. The Videospection Keel Camera operated nominally during the FD 4 MPLM unberthing; alleviating the concern with the camera heater not being activated until FD 3.

The fourth CWC-I was filled at 098/03:46 GMT (02/17:25 MET) with 38.1 lbm. The fifth CWC-I was filled at 098/03:56 GMT (02/17:35 MET) with 34.7 lbm. The sixth CWC-I was filled at 098/04:07 GMT (01/17:46 MET).

The remaining LDRI video file, which was broken up into 26 parts for downlink; to speed up the process, was received on the ground by 098/13:01:46 GMT (03/02:40:21 MET).

During the planned WLE IDS Micrometeoroid/Orbital Debris (MM/OD) monitoring at 098/16:37:34 GMT (03/06:16:09 MET), starboard wing sensor unit S/N 1041 acquired a trigger, but failed to force-trigger the other 10 sensor units in its group as it was programmed (IFA STS-131-V-05). The ground verified that sensor unit S/N 1041 and the other sensors in its group were properly programmed. This was the first time a WLE IDS sensor unit has been triggered and all of the sensors in its group fail to force-trigger.

The crew reported both work-lights had sustained battery-tab damage and could no longer hold batteries in place. Battery tabs nominally hold the battery adapter and Lithium-ion battery in place. These units will be returned. Because of the Ku-Band failure and loss of downlink capability and therefore no video of Public Affairs Office (PAO) events, the work-lights are no longer needed for this mission for event-supplemental-lighting.

Flight Day 5 (99/00:51 – 100/01:21)

The main activity on FD 5 was the first EVA.

The seventh CWC-I was filled at 099/01:32 GMT (03/15:11 MET) with 39.5 lbm. The eighth CWC-I was filled at 099/01:43 GMT (03/15:22 MET) with 38.3 lbm.

At approximately 099/02:20 GMT (03/15:58 MET), the Ku-Band gimbals were locked since the system was not functional. The antenna was not stowed until after the completion of the late inspection and the OBSS was berthed.

The first EVA started at 099/12:31 GMT (03/19:09 MET) and was completed at 099/18:58 GMT (04/01:36 MET) for an EVA duration of 6 hr and 27 min. Tasks accomplished during the EVA included removing the ATA from the PLB and stowing the ATA on the Payload Orbital Replacement Unit (ORU) Accommodation (POA), retrieving the Japanese Experiment Module (JEM) Space Environment Exposure Device (SEED), and removing and replacing the S0 Rate Gyro Assembly (RGA).

The EV1 crewmember reported at 099/18:10 GMT (04/00:48 MET) that the Communication Carrier Assembly (CCA) had an intermittent loss of communication in the left ear.

During the EVA, the EV1 crewmember contacted the port-forward Payload Retention Latch Assembly (PRLA) and noted movement. This was confirmed as nominal, as the forward PRLAs have designed movement with a spring to bring them back into the centered position.

The Leading Edge Subsystem (LESS) DAT reviewed all the LDRI data, Integrated ISIS Digital Camera (IDC) imagery, and RPM imagery for the entire vehicle, and determined there was no requirement for a FI on FD 6. The DAT continued to assess a protrusion on the Forward Reaction Control System (FRCS) and a missing tile on the Rudder Speed Brake (RSB).

The Thermal Protection System (TPS) was cleared for entry at the FD 5 Mission Management Team (MMT) meeting.

The MMT, at the request of the Mission Operations Directorate (MOD), made the decision to approve the addition of a docked day to accommodate a Docked Late Inspection (DLI) and to undock the next flight day even if the DAT assessment has not been completed. The key to the decision was the repair team's statement that the Intensified (Black and White) Television Camera (ITVC) picture through the Still Sequential Video (SSV) is adequate for post-repair verification, but also that ultimately the crew training and procedures are satisfactory to assess the repair. A DLI is required in order to have ISS assets available to downlink the imagery associated with the inspections. ISS assets were required because of the previous failure of the Ku-band communications system.

Flight Day 6 (100/01:21 – 101/01:21)

The main activities on FD 6 were transferring critical items, maneuvering of the OBSS to the EVA 2 Viewing Position, and preparations for the second EVA.

The first Contingency Water Container (CWC) was filled at 100/03:55 GMT (04/17:33 MET) with 94.4 lbm of water.

The SRMS maneuver of the OBSS to the EVA 2 Viewing Position was started at 100/04:52 GMT (04/18:30 MET). At 100/04:58 GMT (04/18:36 MET), the EVA 2 Viewing Position was reached.

The Gaseous Nitrogen (GN₂) System 2 200-psi regulator experienced a small in-specification leakage of 0.03 psi/min after GN₂ repressurization concluded at 100/06:17:48 GMT (04/19:56:23 MET). The specification is 0.21 psi/min limit. This leakage has been observed on previous missions.

The second on-orbit fuel cell purge was performed, beginning at 100/12:26 GMT (05/02:04 MET). During the 96-hour purge interval, the approximate performance decay was 0.17 Vdc for fuel cell 1, 0.11 Vdc for fuel cell 2, and 0.12 Vdc for fuel cell 3. All three fuel cells continue to perform nominally.

The WLE IDS Group 2 Port and Starboard sensors began monitoring at approximately 100/17:30 GMT (05/07:08 MET). Group 2 Port sensors monitored for 5 hr, while Group 2 Starboard sensors monitored for only 4 hr due to battery-life thermal constraints.

At the FD6 MMT, the Real Time Flight Rule for the Docked Late Inspection Clearance was approved. This new annex rule was required for an exception to the Shuttle Remote Manipulator System (SRMS) 5-ft clearance requirement to meet the required damage detection criteria. The minimum clearance will be 41 in. and violations are 10 min or less in duration. The ability to detect, correct and safe SRMS unexpected motion has been enhanced since the original 5 ft clearance requirement was specified. Position-Orientation Hold Select (POSH) will be in auto mode. A trajectory tracking error of more than 8 in. for translation and 3 deg rotation will be detected and auto brakes will be applied. The stuck encoder malfunction threshold was reduced, which improves encoder detection at low rates. The joint runaway analysis was performed and shows the worst case Point of Reference (POR) off-track motion before auto-brakes are applied is 18 in. Adequate views of the clearance are available to the crew. The SRMS side view camera provides a viewing of the Orbiter Boom Sensor System (OBSS), and ISS views are also available. A similar rationale was accepted for SSRMS inspections required on STS-133 and will be the baseline plan for STS-134.

Flight Day 7 (101/01:21 – 102/01:51)

The main activity on FD 7 was the second EVA.

Solid State Recorder 2 (SSR 2) unexpectedly switched to standby (STBY) (IFA STS-131-V-06) mode at 101/05:43:10 GMT (05/19:21:46 MET) and reported a corresponding 2-sec Critical Built-in Test Equipment Failure (CBF). A Comprehensive Self Test (CST) was initiated and completed nominally; however, another 2 sec CBF occurred 17 sec after the completion of the CST. SSR2 has been operating nominally since the second CBF.

The second CWC was filled at 101/09:02 GMT (05/22:40 MET) with 98.7 lbm of water.

The second EVA started at 101/12:30 GMT (06/02:08 MET) and was completed at 101/19:56 GMT (6/09:34 MET) for an EVA duration of 7 hr and 26 min. Tasks accomplished during the EVA included removing the old Ammonia Tank Assembly (ATA) from the Starboard (S) 1 truss and installing the new ATA. Due to difficulties with some ATA bolts, the ammonia connections were not mated to the new ATA. In addition, the Airlock MM/OD shielding stored on External Stowage Platform (ESP) -2 was not retrieved. These tasks were deferred to the third EVA.

During an ISS survey using the Orbiter's Closed Circuit Television (CCTV) cameras during crew sleep, the zoom on CCTV Camera C began to act sluggishly in its response to commands from the ground. The ground performed some troubleshooting, but the zoom eventually stopped responding to commands completely and remained zoomed out (IFA STS-131-V-07).

Flight Day 8 (102/01:51 – 103/02:21)

The main activities for FD 8 were crew off-duty time, maneuvering of the OBSS to the MPLM Viewing Position, and preparations for the third EVA.

The third CWC was filled at 102/10:44 GMT (07/00:22 MET) with 88 lbm of water.

The SRMS maneuver of the OBSS to the MPLM Viewing Position was started at 102/03:49 GMT (06/17:27 MET). At 102/04:03 GMT (06/17:41 MET), the MPLM Viewing Position was reached.

SSPTS channel 2B was powered down at 102/08:30:04 GMT (06/22:08:40 MET) in preparation for a water dump. Following the completion of the water dump, the ISS resumed attitude control of the stack and channel B was powered back up at 102/13:40:19 GMT (07/03:18:55 MET).

In preparation for a water dump, attitude control was handed over to the Orbiter at 102/10:22:24 GMT (07/00:01:00 MET). The 9.1-deg RCS maneuver to the water dump attitude was initiated at 102/10:23:39 GMT (07/00:02:15 MET). The water dump was initiated at 102/10:41:51 GMT (07/00:20:27 MET) and completed at 102/12:34:58 GMT (07/02:13:34 MET). Two CWCs and two CWC-Is were dumped during the dump operations. The 4.3-deg Reaction Control System (RCS) maneuver back to the Torque Equilibrium Attitude (TEA) was initiated at 102/12:44:54 GMT (07/02:23:30 MET). The

Orbiter moded to Free Drift at 102/13:19:17 GMT (07/02:57:53 MET). The ISS resumed attitude control at 102/13:19:40 GMT (07/02:58:16 MET). The Orbiter was in attitude control for 2 hr 57 min.

Flight Day 9 (103/02:21 – 104/03:21)

The main activities on FD 9 were the third EVA and MPLM transfer.

A request was made by the ISS Russian International Partner (IP) to vent Progress fueling lines in preparation for the Progress undocking after the departure of the Shuttle. The venting was expected to occur on successive orbits over Russian ground sites starting approximately 8 hr after Shuttle undocking. The Orbiter team evaluated the possible interaction with one or more particles originating from this plume and determined it was acceptable.

The third EVA started at 103/06:14 GMT (07/19:12 MET) and was completed at 103/12:38 GMT (08/02:17 MET) for an EVA duration of 6 hr and 24 min. Tasks accomplished during the EVA included hooking up the fluids lines to the ATA, installing the old ATA on the Lightweight Multi-Purpose Equipment Support Structure Carrier (LMC) in the PLB, retrieving the Airlock MM/OD shield and preparing the Z1 Space-to-Ground antenna. The activities that were not completed during the EVA were the installation of the Lightweight Adapter Plate Assembly (LWAPA) on the LMC, the troubleshooting of the P1 Radiator Grapple Fixture Beam and one get-ahead task.

At 103/08:00 GMT (07/21:39 MET) during the third EVA while activating the newly installed ATA, a Gas Pressure Regulator Valve (GPRV) set-point command was sent to pressurize the Nitrogen Tank Assembly (NTA) as part of the ATA activation. When the command was sent, the NTA outlet pressure did not change. Troubleshooting was unable to resolve the issue. As a result, planning began to perform an EVA to replace the NTA.

At 103/09:35:58 GMT (07/23:14:33 MET), a bright object was observed on video departing from the aft PLB (IFA STS-131-V-03). The object appeared to be moving quickly with a departure direction of radial up and out-of-plane with possibly a small posi-grade component. Identification of the object was not possible. The crew verified that all EVA tools were accounted for and the United States Strategic Command was notified in an attempt to track the object.

The fourth CWC was filled at 103/09:44 GMT (07/23:22 MET) with 89.6 lbm of water.

At an approximately 103/13:54 GMT (08/03:33 MET), the crew reported that a MM/OD impact site was found on Window 1. The crew estimated that the impact is less than 1 mm in diameter. Due to the window location and size of this impact, there were no concerns for entry.

Flight Day 10 (104/03:21 – 105/04:21)

The main activities on FD 10 were off-duty time and transfers from the middeck and MPLM.

The first Payload Water Reservoir (PWR) was filled at 104/10:01 GMT (08/23:39 MET) with 20.3 lbm of water.

The fifth CWC was filled at 104/10:54 GMT (09/00:32 MET) with 87.6 lbm of water.

The ISS Program initially requested an extra docked day to conduct a fourth EVA on FD 13. The fourth EVA was requested in response to an anomaly with an ISS NTA. The ISS Program assessed whether the NTA condition needed to be immediately addressed, or if it can be deferred until a later date, and determined that the current configuration was acceptable. As a result, the decision was made not to add an additional EVA. ISS continued to troubleshoot the NTA anomaly.

Flight Day 11 (105/04:21 – 106/04:21)

The main activities on FD 11 were middeck transfer, and MPLM un-install from the ISS and berthing in the Orbiter Payload Bay.

The sixth CWC was filled at 105/07:55 GMT (09/21:33 MET) with 96.0 lbm of water.

The third on-orbit fuel cell purge was performed, beginning at 105/10:59 GMT (10/00:37 MET). During the preceding 118.5-hr purge interval, the approximate performance decay was 0.07 Vdc for fuel cell 1, 0.05 Vdc for fuel cell 2, and 0.07 Vdc for fuel cell 3.

The un-install of the MPLM was significantly delayed due to communications issues with the Common Berthing Mechanism (CBM). Anomalous responses were seen on the Control Panel Assemblies (CPAs) during efforts to reactivate the CBM. Troubleshooting resulted in communication with all CPAs. The ground evaluated the data from the troubleshooting and the decision was made to proceed with the MPLM demate operations. The MPLM un-install was delayed approximately 6 hr.

The SSRMS uninstalled the MPLM from the ISS at 105/20:24 GMT (10/10:02 MET). The MPLM was maneuvered to the Low Hover position at 105/20:42 GMT (10/10:20 MET) where it was parked above the payload bay on the SSRMS overnight.

Flight Day 12 (106/04:21 – 107/04:21)

The main activity on FD 12 was berthing of the MPLM in the Payload Bay (PLB) and the Docked Late Inspection (DLI) survey of the RCC leading edge surfaces.

The MPLM was successfully berthed in the Orbiter PLB at 106/07:14 GMT (10/20:53 MET). The MPLM was configured for entry operations.

The DLI began with the SRMS maneuver of the OBSS to the Docked Flat Field Survey position at 106/08:09 GMT (10/21:47 MET). The Docked Starboard RCC Survey began at 106/08:28 GMT (10/22:06 MET). The Docked Nose Cap RCC Survey started at 106/10:55 GMT (11/00:33 MET). The Docked Port RCC Survey began at 106/11:46 GMT (11/01:24 MET). At the conclusion of the surveys, the OBSS was maneuvered to the Undock Position at 106/12:39 GMT (11/02:17 MET).

The seventh CWC was filled at 106/08:51 GMT (10/22:29 MET) with 84.9 lbm of water.

All imagery from the DLI survey of the Starboard Wing, Nose Cap, and Port Wing leading edge surfaces was transferred to the ISS and downlinked by 106/19:22 GMT (11/09:00 MET).

Flight Day 13 (107/04:21 – 108/04:21)

The main activities on FD 13 were hatch closure, Undocking, Flyaround, separation maneuvers from the ISS, water dumps, and stowing of the OBSS, Shuttle Remote Manipulator System (SRMS), and Ku-Band antenna.

The SSPTS was deactivated at 107/09:48 GMT (11/23:26 MET), resulting in the fuel cells assuming the entire Orbiter load. The approximate total fuel cell power level increased from 7 kW to 14 kW. The SSPTS transferred a total of 1547 kW of electricity to the Orbiter.

The Rendezvous Tools checkout was successfully completed. The TCS was powered up at 107/10:41 GMT (12/00:29 MET) and passed all self-tests.

The hatch between the ISS and the Orbiter was closed at 107/10:30 GMT (12/00:01 MET), and the vestibule was leak-checked successfully.

During the docked timeframe, by the time of hatch closure, a total of 94.5 lb of oxygen had been supplied to ISS through repressurizations and transfers.

The Orbiter resumed attitude control with Digital Autopilot (DAP) in the automatic-mode at 107/11:33:23 GMT (12/01:11:58 MET) and the maneuver to the undocking attitude was initiated at 107/11:35:11 GMT (12/01:13:45 MET). The maneuver took approximately 32 min and was complete satisfactorily. The DAP was commanded to Free Drift at 107/12:49:26 GMT (12/02:28:21 MET) for the undocking.

The command to undock from the ISS was initiated 107/12:50:07 GMT (12/02:28:43 MET) and undocking was completed at 107/12:52:10 (12/02:30:46 MET). The total hook-drive time was approximately 2 min and 3 sec and Hook Groups 1 and 2 operated satisfactorily. The ODS performed nominally for undocking.

After undocking, the fly-around maneuver was initiated with RCS +X pulses of the L1A and R1A thrusters at 107/13:12:41 GMT (12/02:51:16 MET).

The RCC was cleared for entry at the FD 13 MMT meeting.

After undocking and the flyaround on FD 13, the Separation 1 maneuver was initiated with RCS +X pulses for 6.00-sec using thrusters L1A and R1A at 107/14:01:25 GMT (12/03:40:00 MET). The Separation 2 maneuver, a 13.16-sec RCS +X maneuver using thrusters L1A and R1A, was performed at 107/14:29:25 GMT (12/04:08:00 MET).

The operation of the TCS for undocking and fly-around activities was nominal.

A supply water dump was initiated at 107/14:58 GMT (12/04:36 MET) and completed at 107/15:26 GMT (12/05:04 MET) with approximately 38 lbm dumped. A waste water dump was initiated at 107/15:07 GMT (12/04:45 MET) and completed at 107/16:07 GMT (12/05:45 MET) with approximately 126 lbm dumped.

The SRMS maneuvered the OBSS to the hover position at 107/16:30 GMT (12/06:08 MET) and berthed the OBSS at 107/16:54 GMT (12/06:32 MET). The SRMS ungrappled the OBSS, maneuvered to the pre-cradle position, and was cradled and powered down at 107/17:35 GMT (12/07:13 MET).

The Ku-Band antenna was stowed at 107/17:56:20 GMT (12/07:34:56 MET).

The LESS DAT analysis of the imagery from the DLI was completed, and the vehicle was cleared for entry.

Flight Day 14 (108/04:21 – 109/04:21)

The main activities on FD 14 were the Flight Control System (FCS) checkout, the RCS hot-fire, and the Orbit-Adjust (OA) maneuver.

A supply water dump through the Flash Evaporator System (FES) was initiated at 108/07:05 GMT (12/20:44 MET) and completed at 108/09:03 GMT (12/22:42 MET). Approximately 27 lbm of water was dumped.

The FCS checkout began at 108/07:20 GMT (12/20:59 MET) and was completed at 108/08:02 GMT (12/21:40 MET). Auxiliary Power Unit (APU) 1 ran for 4 min 2 sec, and no FCS anomalies were identified.

The procedures for the RCS hot-fire were initiated at 108/08:06 GMT (12/21:44 MET) and terminated at 108/08:16 GMT (12/21:54 MET). All 38 RCS thrusters were fired at least once for at least 0.24 sec per pulse, although the F1U thruster was initially skipped; however F1U thruster was fired during the hot-fire. All thrusters were fired. No anomalies occurred.

The crew performed a Group C power down to conserve cryogenic consumables in an attempt to gain another day of margin. An additional day will allow more flexibility for landing opportunities.

Hydrogen tank 5 was depleted to the residual quantity at 108/10:08 GMT (12/23:46 MET), and Oxygen tank 4 was depleted to the residual quantity at 108/12:32 GMT (13/02:10 MET).

A waste water dump was initiated at 108/12:17 GMT (13/01:56 MET) and completed at 108/12:25 GMT (13/02:04 MET). Approximately 26 lb_m was dumped.

A condensate dump was initiated at 108/12:37 GMT (13/02:16 MET) and completed at 108/12:49 GMT (13/02:28 MET).

Another supply water dump through the FES was initiated at 108/14:06 GMT (13/03:44 MET) and completed at 108/19:17 GMT (13/08:55 MET). Approximately 524 lb_m of water was dumped.

The Orbit Adjust maneuver was performed at 108/17:31:18.6 GMT (13/07:09:53 MET). The maneuver was a two-engine straight-feed maneuver and the duration was 11.1 sec. The ΔV was 17.7 ft/sec. The final orbit after the maneuver was 171.8 by 188.2 nmi. The orbit adjust was required to move the KSC End-of-Mission (EOM) opportunity out of the crossrange cutout for the Boundary Layer Transition DTO. The crossrange cutout reduces the likelihood of a roll reversal occurring during the boundary layer transition.

Flight Day 15 – Entry and Landing (109/04:21 – NEOM)

The main activity for FD 15 was entry and landing.

The first and second landing opportunities at Kennedy Space Center (KSC) on FD 15 were waved off because of unacceptable weather (low ceiling) at KSC.

Both Payload Bay Doors (PLBDs) were closed nominally by 109/09:02:03 GMT (13/22:40:39 MET) in preparation for landing. However, as a result of the wave-off, the PLBDs were reopened at 109/13:20:59 GMT (14/02:59:34 MET).

Following the wave-off for the second opportunity, the Left RCS Helium Isolation Fuel Valve (B-Leg) was slow to close (IFA STS-131-V-08). The valve indicated open for 45 sec after the switch command and then indicated close. Both the fuel and oxidizer valve are operated by the same switch and the oxidizer valve closed nominally within 1 sec.

Flight Day 16 – Entry and Landing

The STS-131 mission was successfully completed with a landing at KSC on the second landing opportunity on the second landing day.

Both Payload Bay Doors (PLBDs) were closed nominally by 110/07:50:14 GMT (14/21:28:49 MET) in preparation for landing.

The first landing opportunity at KSC was waved off due to low clouds and precipitation. The deorbit maneuver for the second landing opportunity at KSC, a dual-engine straight-feed firing, was performed on orbit 238 at 110/12:02:59.1 GMT (15/01:41:34 MET). The maneuver was 177.8 sec in duration with a ΔV of 302.6 ft/sec. The orbit after the deorbit maneuver was 14.5 by 190.8 nmi.

Entry interface occurred at 110/12:36:44 GMT (15/02:15:19 MET).

The main landing gear touchdown occurred on KSC runway 33 at 110/13:08:34 GMT (15/02:47:08 MET) on April 20, 2010. The drag chute was deployed at 110/13:08:36 GMT. The nose gear touchdown occurred at 110/13:08:43 GMT. Drag chute jettison occurred at 110/13:09:10 GMT. Wheels stop occurred at 110/13:09:32 GMT. The rollout was normal in all respects.

The flight duration was 15 days 02 hr 47 min 09 sec. The shutdown of the last APU occurred 16 min 34 sec after landing.

During the post flight valve test performed on the runway, the forward RCS Fuel Helium A-Leg isolation valve was sluggish (IFA STS-131-V-09). When cycled CLOSED, subject valve remained OPEN. The valve eventually indicated CLOSED approximately 82 sec after its expected closure time.

Post-Flight Activities

During the Flight Crew Equipment (FCE) Debriefing, the crew reported that the Closed Circuit Television (CCTV) monitor 2 had a red tint and was not as sharp as monitor 1 (IFA STS-131-V-12). The monitor will be replaced during the post-flight turnaround activities.

The crew also reported at the FCE Debriefing that the Multi-Purpose Logistics Module (MPLM) Keel Camera was flickering during the berthing operations, but the camera was usable (IFA STS-131-V-13). The camera was nominal during the unberth operations.

PAYLOADS AND EXPERIMENTS

LAUNCH PACKAGE OVERVIEW

The primary components carried on this mission were the Multi-Purpose Logistics Module (MPLM) named Leonardo and the Lightweight Multipurpose Experiment Support Structures Carrier (LMC), a cross-bay stowage platform located behind the MPLM in the Discovery's payload bay. The MPLM carried approximately 8 tons of science equipment and cargo to be transferred to the International Space Station (ISS) and returned, packed with a large load of cargo removed from the ISS. The LMC carried a new Ammonia Tank Assembly (ATA) for installation on the ISS and a spent ATA from the ISS S1 location was returned mounted in the same location on the LMC. The Materials on ISS Experiment (MISSE)-6 Light Weight Adapter Plate Assembly (LWAPA) was to have been returned from the ISS mounted to the underside of the LMC, but events during the mission precluded removing the LWAPA and returning it to Earth on this mission.

In addition to the hardware elements in Discovery's payload bay, the ISS 19A launch package consisted of 5 powered payloads carried in the Orbiter middeck, the General Laboratory Active Cryogenic on ISS Experiment Refrigeration (GLACIER), Microgravity Experiment Research Locker Incubator II (MERLIN), Space Tissue Loss (STL) and two Animal Enclosure Modules (AEMs).

Three Extravehicular Activities (EVAs) were successfully performed resulting in a total of 20 hrs, 17 min of EVA time on this mission. Completed EVA tasks included the removal of a depleted ATA and installation of a new serviced ATA, removal and replacement of the S0 Rate Gyro Assembly (RGA), Installation of the P1 Radiator Grapple Fixture Stowage Beams, relocation of an Articulating Portable Foot Restraint (APFR) to CETA Cart Worksite Interfaces (WIF) 2 for Utilization and Logistics Flight (ULF) 4 and preparation of the Z1 Space-to-Ground Antenna (SGANT) use during the ULF 4 flight.

CREW ACTIVITY SUMMARY

Following the successful launch and insertion to orbit, the Ku-band system on Discovery was not successfully transmitting or receiving on orbit. With both the forward and return links experiencing problems, the Ku-Band radar was inoperable for the Shuttle's approach and docking to the ISS. The Ku-Band on Discovery was not recovered during the mission, which changed the protocol for completing late inspection of the Thermal Protection System (TPS) on the Orbiter. Late inspection was performed prior to undocking the Orbiter from the ISS and ISS Ku-band resources were used for uplink

and downlink. An additional docked day was added to the mission due to the requirement to do late inspection while docked, thus making this a 14-day mission.

On Flight Day (FD) 2, the Orbiter Boom Sensor System (OBSS) inspection of Discovery Port and Starboard Wing Leading Edge (WLE) panels and Nose Cap Reinforced Carbon-Carbon (RCC) were completed. With the loss of the Ku-band system, the Laser Dynamic Range Imager (LDRI) video was recorded utilizing 40-min tapes. The recorded images were downlinked after docking with the ISS for analysis by ground-based teams.

On FD 3, prior to docking with the ISS, Discovery completed the Radius Vector (Rbar) Pitch Maneuver (RPM) while the ISS crew obtained imagery of the Orbiter's TPS during rendezvous and the photographs were downlinked for ground analysis. The Orbiter successfully docked to Pressurized Mating Adapter (PMA)-2 at 2:44 am CDT on April 7, 2010. The Space Station Remote Manipulator System (SSRMS) grappled the Orbiter Boom Sensor System (OBSS) and unberthed it from the Orbiter sill. The OBSS was then handed off to the SRMS and SSRMS was then maneuvered to a park position.

On FD 4, The Space SSRMS grappled the MPLM, unberthed it from the Orbiter and installed it on the Node 2 Nadir port of the ISS. The SSRMS was subsequently maneuvered to the first EVA start-position in preparation for the first EVA.

The vestibule pressurization and leak checks were completed, the Multi-Layered Insulation (MLI) thermal cover was removed and power and data jumpers were installed in preparation for MPLM ingress. After the MPLM was activated, the Inter-module Ventilation (IMV) ducts were installed and pressure was equalized between the MPLM and the rest of ISS. During the MPLM ingress procedure, the crew had difficulty opening the MPLM hatch. The hatch was eventually opened and ingress activities were initiated, including taking an air sample with a Grab Sample Container (GSC) for return.

On FD 5 in support of first EVA, the SSRMS grappled the full Ammonia Tank Assembly (ATA), maneuvered it away from the Shuttle's LMC and temporarily stowed it on the Mobile Base System (MBS) Payload ORU Accommodation (POA). The SSRMS was maneuvered to a park position after ungrappling the ATA.

The first EVA for this mission was successfully performed with all scheduled tasks completed, and a discussion of the EVA tasks is contained in the Extravehicular Activities section of the report. The duration of the EVA was 6 hr 28 min. The MPLM and rack transfers continued.

The Mission Management Team (MMT) concurred with recommendations to extend the mission duration to 14+0+2 days, to incorporate the late inspection prior to undocking. Analysis of the FD 2 inspection data concluded that no focused inspection was required.

On FD 6, Several Multi-Purpose Logistics Module (MPLM) Rack Transfers were completed. Racks transferred included the Window Observational Research Facility

(WORF) Rack from the MPLM to the ISS Laboratory, the Expedite Processing of Experiments to Space Station (EXPRESS) -7 Rack from the MPLM to the US Laboratory and three Integrated Stowage Platforms (ISP) were moved from Node 3 to the MPLM for return. In addition, a Public Affairs Office (PAO) event was conducted and the EVA tools and equipment were configured for the second EVA.

On FD 7, the second EVA for this mission was successfully performed with most of the scheduled tasks completed during the 7 hr 26 min EVA. The Extravehicular Activities section of this report contains the EVA discussion in more detail. The crew continued transfer of MPLM and Middeck logistics items.

On FD 8, The Shuttle crew had a half day off following the completion of two Extravehicular Activities (EVAs). In preparation for the third and last EVA of the mission, the EVA crew configured the required tools and equipment for the final EVA.

The third EVA was replanned to include the Starboard (S) 1 Ammonia Tank Assembly (ATA) fluid connectors not completed during the second EVA. Additionally the P1 radiator stowage beam that was installed on FD7 showed some unexpected motion after installation. Troubleshooting steps were to be performed during the third EVA to determine if this beam could remain installed. The EVA crew also collected the Micrometeoroid/Orbital Debris (MM/OD) shields that were not brought inside during the second EVA, which were to return in the Multi-Purpose Logistics Module (MPLM).

Following the FD 7 successful change out of the Water Process Assembly (WPA) Catalytic Reactor, ground specialists checked out the newly installed On-orbit Replacement Unit (ORU) by successfully flushing the Catalytic Reactor and initiating a WPA processing cycle after the Waste Tank acquired the required quantity. The system is now delivering potable water into the stowage tank and the crew was given a 'go' to use the Potable Water Dispenser (PWD). The Water Delivery System (WDS) was deactivated.

On FD 9, the third and final EVA for this mission, which had a duration of 6 hr 24 min, was successfully completed but ran behind schedule due to difficulty with engaging one of the four ATA bolts for the returning ATA. All four bolts were eventually seated and torqued to the proper levels for entry, but the EVA crew was unable to retrieve the Light Weight Adapter Plate Assembly (LWAPA) for installation on the LMC for return and was unable to perform the troubleshooting on the P1 Radiator Grapple Fixture Beam.

On FD 10, the MPLM closeout activities included the installation of the four Node 2 Nadir Common Berthing Mechanism (CBM) Control Panel Assemblies (CPAs) on to the active CBM Hatch Beam in preparation for MPLM uninstal on FD11. The last four MPLM Lamp-Housing-Assemblies (LHA) were scavenged and transferred for use as spares on ISS, and the crew verified all the MPLM racks were rotated and secured for MPLM uninstal and return to Earth.

On FD 11, the Shuttle crew continued with middeck cargo transfers and the MPLM deactivation and egress were successfully completed.

On FD 12, The SSRMS was used to successfully move the MPLM from the overnight low-hover position to its final stow position in Discovery's Payload Bay (PLB). Four good Payload Retention Latch Assemblies (PRLAs) were mated and the Remotely Operated Electrical Umbilical (ROEU) was connected. After ungrappling the MPLM, the SSRMS was maneuvered to the Docked Late Inspection (DLI) clearance position.

The Shuttle crew members performed inspections of the Starboard and Port Wings, Nose-cap TPS and RCC. The files were downlinked for analysis. The Shuttle crew continued with middeck cargo transfers in preparation for undocking from ISS.

On FD 13, all middeck transfers were completed prior to the Shuttle and ISS crewmembers participating in the farewell ceremony and closing of the hatches between the two vehicles. Checkout of rendezvous tools was successfully completed and Space Shuttle Discovery successfully undocked from the ISS at 7:52 am Central Daylight Time (CDT) and the Orbiter completed a flyaround and photography of the ISS.

On FD 14, the Flight Control System (FCS) checkout and Reaction Control System (RCS) hotfire were performed successfully. Cabin stow operations were completed in preparation for the anticipated deorbit and landing.

On FD 15, cabin-stow operations were completed in preparation for the anticipated deorbit and landing. Discovery was unable to land at the Kennedy Space Center (KSC) on FD15 due to weather conditions. The crew backed out of the deorbit configuration and opened the payload bay doors to stay in orbit for another day. The MPLM pressure checks were completed.

On FD 16, cabin stowage, stowing the radiators and payload bay door closure were completed in preparation for the anticipated deorbit and landing. The first opportunity on FD 16 was waived and Discovery used the second End of Mission (EOM) +1 day landing opportunity on FD 16 to Kennedy Space Center (KSC) with the landing on Tuesday, April 20, 2010 at 8:08:35 am CDT.

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	13,762	5,404
Middeck	1,460	1,235
Totals	15,222	6,639

1. **Water** – A total of 974.6 lb_m was transferred.
2. **Oxygen** – No tank to tank oxygen was transferred, but 94.5 lb_m was used to repressurize the ISS-stack.
3. **Nitrogen** – No tank to tank nitrogen was transferred but 66 lbm was used to repressurize the ISS stack.
4. **Lithium Hydroxide** – A total of 46 canisters were launched and 46 were returned with 8 of those LiOH canisters used that had previously been on ISS.
5. **Food** – No food was transferred.

SIGNIFICANT FIRSTS

The significant firsts for the STS-131 mission were as follows:

1. Four female astronauts were in space at the same time on the Orbiter and ISS.
2. Two Japanese Aerospace Agency (JAXA) astronauts were in space at the same Time.

SIGNIFICANT ISS ANOMALIES

On FD 7, the crew reported an anomalous sound emanating from Treadmill with Vibration Isolation System (TVIS). Ground specialists declared a “no-go” for exercise on TVIS and asked the crew members to use the Treadmill 2 (T2) until the TVIS was recovered. Still photographs were taken showing Foreign Object Debris (FOD) at one end of the tread belt. The crew was asked to retrieve a sample after they cleaned up the FOD. There were no spare tread belts on ISS.

On FD 11, increased temperatures were observed in the Treadmill with Vibration Isolation System (TVIS) 2 (T2) Power Avionics Unit (PAU) as well as a voltage drop in the output of the PAU. A procedure was performed by ground specialists to load Solid State Power Control Module (SSPCM) software onto an on-orbit laptop, connect that laptop to the T2 rack and configure the PAU settings to bypass the circuit that is causing the over-current. This configuration will limit the maximum T2 speed to 7 to 9 mph until a new PAU can be flown and installed.

Numerous automated shutdowns of the Elektron micro-pumps had been noted over previous days. The Elektron was deactivated and troubleshooting was suspended until the designers could analyze all of the data and make a recommendation for further

action. The loss of Elektron was not an immediate concern for ISS. On FD 12, following several days of unsuccessful Elektron start/shutdown cycles, specialists determined Elektron does not function properly when the Onboard Measurement Telemetry Subsystem [БИТС] uses the Synchronization Unit [БС]2. Mission Control Center-Moscow (MCC-M) switched from [БС]2 to [БС]1 and successfully reactivated Elektron. As of FD 12, the Elektron had operated nominally for more than 24 hours.

Ground teams were not able to open the S1 Nitrogen Tank Assembly (NTA) Gas Pressure Regulating Valve (GPRV), which has been integrated with the new ATA. The NTA supplies pressure to the ATA, which in turn feeds the External Thermal Control System (ETCS) Loop A. Loop A was operating nominally and was isolated from the ATA. Ammonia (NH₃) is supplied to the ETCS via the ATA when there are volume changes in the system due to varying thermal conditions. Assessments were in work to determine whether the ATA will need additional NH₃ and to evaluate work-rounds such as adjusting the Thermal Radiator Rotary Joint (TRRJ) angle and/or increasing the heat load on Loop A.

Ground teams determined that a Removal and Replacement (R&R) of the S1 Nitrogen Tank Assembly (NTA) was not required during this mission because the External Thermal Control System (ETCS) can be operated well within operational margins for the over-pressure and under-pressure cases, given the accumulator capability in the ETCS Loop A. No new operational constraints or special operations are required for the anticipated high-beta cases in the next few months. Existing leak rates in the system, which would gradually decrease performance margins, are well below specifications and are nearly indistinguishable.

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

No.	Task	Flight Day Task Completed
Category 1 Tasks		
1	Dock Shuttle Flight 19A to Pressurized Mating Adapter (PMA) -2 and perform mandatory safety briefing for all crewmembers	FD3
2	Move MPLM to ISS Node 2 Nadir port using SSRMS, activate and checkout the MPLM	FD4
3	R&R depleted S1 ATA with new ATA using SSRMS	FD 5,7 & 9 EVA 1,2,3
4	Transfer mandatory quantities of water from Orbiter to ISS per flight 19A Transfer Priority List (TPL) – None identified	Deleted
5	Transfer and stow critical items per flight 19A TPL	FD 3-4
6	Return MPLM to the Orbiter Payload Bay using SSRMS	FD 11-12

ISS MISSION PRIORITIES COMPLETION STATUS (Continued)

No,	Task	Flight Day Task Completed
Category 2 Tasks		
7	Transfer and install racks from MPLM to the ISS	FD 5-6
	a. Muscle Atrophy Research and Exercise (MARES)	FD 5
	b. Window Observational Research Facility (WORF)	FD 6
	c. Minus Eighty Degree Laboratory Freezer for ISS (MELFI) -3	FD 5
	d. Express Rack no. 7	FD 6
	e. Crew Quarters no. 2	FD 5
	f. Zero-G Stowage Racks (ZSRs)	FD 5
8	R& R the S0 Rate Gyro Assembly (RGA)	FD 5/EVA 1
9	Retrieve Japanese Experiment Module (JEM) Micro-Particles Capture (MPAC) and Space Environment Exposure Device (SEED) from Space Environment Data Acquisition-Attached Payload (SEDA-AP)	FD 5/EVA 1
10	Stow Adjustable Grapple Bar (AGB) on Flex Hose Rotary Coupler (FHRC) and Fixed Grapple Bar (FGB) on P1 or S1 ATA	FD 9/EVA 3
11	Retrieve Airlock MM/OD Shields from ESP-2 for return	FD9/EVA 3
12	Retrieve Lightweight Adapter Plate Assembly (LWAPA) from Columbus and secure to the LMC for return	FD 9/EVA 3 Deferred
13	Perform ISSs Daily Payload Status checks as required	FD 3-13
14	Perform critical non-recoverable utilization activities	FD 3-13
15	Transfer 3 Integrated Stowage Platforms (ISPs) from ISS and install in the MPLM for return	FD 6
16	Install Sensor Test for Orion RELNAV Risk Mitigation (STORRM) DTO-703 target-reflector kit on the PMA-2 docking target	FD 3
17	Perform high priority ISS maintenance activities	
	a. Catalytic reactor R& R	FD 7
	b. Water Recovery System (WRS) Recycle Filter Tank Assembly (RFTA) R&R	FD 10
	c. Waste & Hygiene Compartment (WHC) urine hose R& R	FD 7
	d. ARED upper stop cable procedure and installation	FD 3
18	Transfer remaining cargo items per flight 19A TPL	FD 3-13
18.5	Perform SGANT preparation tasks	FD 9/EVA 3
18.6	Open Node 2 zenith Centerline Berthing Camera System (CBCS) flap	FD 5/EVA 1
19	Install Cupola debris shields inside Cupola	FD 12
20	Perform ISS Russian segment preventative maintenance	ISS Crew ISS Crew
	a. 25 of 27 Russian tasks completed	
21	Perform Russian Satellite navigation equipment test	GMT 108 - 110

ISS MISSION PRIORITIES COMPLETION STATUS (Concluded)

No,	Task	Flight Day Task Completed
22	Perform EVA tasks deemed to fit within the existing EVA timelines <ul style="list-style-type: none"> a. Perform P6 battery preparation tasks for ULF 4 b. Relocate Worksite Interface Fixture (WIF) extender c. Move two Articulating Portable Foot Restraint (APFR) to support ULF4 d. Remove Special Purpose Dextrous Manipulator (SPDM) EP1 thermal cover e. Install SPDM Camera/Lamp/Pan-Tilt Unit Assembly (CLPA) f. Install P1 Radiator Grapple Fixture stowage beam g. Install S1 Radiator Grapple Fixture stowage beam 	Deferred FD 5/EVA 1 FD 7 & 9/EVA 2 & EVA 3 Deferred Deferred FD 7/EVA 2 Deferred
23	Perform EVA Get-Ahead Tasks if time permits <ul style="list-style-type: none"> a. Close P1 RBVM Thermal Bootie b. Install P4-P5 Ammonia jumper c. Open and release P1 FHRC P clamps d. Open and release S1 FHRC P clamps e. Perform pre-approved tool relocations f. Camera Port (CP) 13 Luminaire R&R 	Deferred Deferred FD 5/EVA 1 Deferred FD 9/Partial Deferred
24	Perform daily middeck activities to support payloads	Daily
25.	Perform ISS payload research operations tasks	Daily
26	Perform remaining water transfer to ISS as needed	FD 3 –FD12
27	Unpack and install Kid/Kubric into European drawer rack	FD 9
28	Install MARES rack and prepare packing material for return	FD 8/FD 9
29	Perform TRIDAR DTO 701A activities	FD 3/FD 13
30	Perform ISS IVA Get-Ahead tasks as time permits 13 of 25 tasks completed	FD9/FD 13
31	Shuttle Reboost of ISS if mission resources allow and are consistent with ISS trajectory analysis and planning	N/A
32	Perform imagery survey of the ISS exterior during Orbiter flyaround after undocking	FD 13
33	Perform STTO 13005-U, ISS Structural Life Validation and Extension during Shuttle-mated ISS Reboost	N/A
34	Perform STTO 13005-U, ISS Structural Life Validation and Extension during 19A Orbiter docking (IWIS Required)	FD 3
35	Perform STTO 13005-U, ISS Structural Life Validation and Extension during 19A undocking (IWIS highly desired but not required)	FD 13
36	Perform STTO 13005-U, ISS Structural Life Validation and Extension during MPLM berthing and unberthing (IWIS required)	FD 4/FD 11
37	Perform Payloads of Opportunity <ul style="list-style-type: none"> a. Perform Maui Analysis of Upper Atmospheric Injections (MAUI) b. Perform Shuttle Exhaust Ion Turbulence Experiments (SEITE) c. Perform Shuttle Ionospheric Modification with Pulsed Local Exhaust (SIMPLEX) d. Perform Ram Burn Observation 2 (RAMBO-2) 	No opportunity No opportunity No opportunity No opportunity

DEVELOPMENT TEST OBJECTIVES

DEVELOPMENT TEST OBJECTIVE 701A TriDAR AUTONOMOUS RENDEZVOUS AND DOCKING SENSOR

The TriDAR Autonomous Rendezvous and Docking Sensor Development Test Objective (DTO) was flown for the second time. The TriDAR is a rendezvous and docking 3-Dimension (3D) vision system. The sensor optimally combines active laser triangulation and LIDAR 3D imaging in a single optical package.

The TriDAR was to be operated during the undocking and fly-around phase of the mission. Successful TriDAR operation during these portions of the flight will collect data required to achieve all remaining mission objectives. To maximize the chances of obtaining valid data for post-flight assessment, modifications to activities and procedures have been submitted.

TriDAR operations on STS-131 were successful. The sensor was operated for all required ranges and the data collected met or exceeded all requirements. Data analysis and comparison to Shuttle tools was proceeding as this report was written. Because of the Ku-Band failure, receipt of data was delayed during the flight.

TriDAR communications issues observed during FD 3 rendezvous operations were caused by a faulty connection between the Payload and General Support Computer (PGSC) and the TriDAR hardware. The cable was replaced with a spare prior to undocking operations and the unit operated nominally for the remainder of the flight.

DEVELOPMENT TEST OBJECTIVE 854 BOUNDARY LAYER TRANSITION FLIGHT EXPERIMENT

The Boundary Layer Transition (BLT) experiment gathered data on the effect of the high Mach number BLT caused by a protuberance on the Space Shuttle during the entry trajectory. This was the 3rd flight of the BLT DTO, 2nd flight of 0.35" protuberance (same configuration as STS-128) and the 2nd flight of the catalytic coating. Post flight tile scans revealed no shape change. The earliest BLT onset occurred at Mach 17.4 (based on the STS-131 BET) which was consistent with STS-128. The observed BLT onset is within BLT Prediction Tool 1- σ uncertainty. The STS-131 BLT DTO thermocouples experienced the anomaly observed on previous missions. The initiation of the anomaly correlated with a roll reversal. The peak protuberance temperature was $\approx 2200^{\circ}\text{F}$, this was $\approx 400^{\circ}\text{F}$ lower than the STS-128 peak protuberance temperature. This was as a result of upstream early BLT on STS-128. The STS-131 vehicle transition (upstream of the BLT protuberance) occurred at \sim Mach 6.8 and was symmetric.

DEVELOPMENT TEST OBJECTIVE 805 CROSSWIND LANDING PERFORMANCE

Observations at the Shuttle Landing Facility indicated a 4-knot crosswind component. This DTO of opportunity was not performed during landing because of the minimum DTO requirement of a 10-knot crosswind at landing.

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

This DTO collected high-fidelity data to contribute additional knowledge of Reusable Solid Rocket Motor (RSRM) flight characteristics for RSRB analysts. It is assumed that data collection was acquired during ascent. No subsequent assessment of the data was available when this report was written.

DEPARTMENT OF DEFENSE PAYLOADS OF OPPORTUNITY

MAUI ANALYSIS OF UPPER-ATMOSPHERIC INJECTIONS

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

SHUTTLE EXHAUST ON TURBULENCE EXPERIMENT

The Shuttle Exhaust on Turbulence Experiment (SEITE) utilizes 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 utilized 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.

SHUTTLE IONOSPHERIC MODIFICATION WITH PULSED LOCAL EXHAUST

The objective of the Shuttle Ionospheric Modification with Pulsed Local Exhaust (SIMPLEX) activity is to determine the source of Very High Frequency (VHF) radar echoes caused by the Orbiter and its OMS engine firings when in the Field-Of-View (FOV) of a SIMPLEX radar or radio telescope ground-site. The collected data is used to examine the effects of orbital kinetic energy on ionospheric irregularities and to understand the processes that take place with the venting of exhaust materials. No SIMPLEX observation opportunities occurred during this mission.

RAM BURN OBSERVATION 2

The objective of the Ram Burn Observation-2 (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) uses two Space Tracking Surveillance System (STSS) satellites to make observations of Space Shuttle 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 6) were as follows; wind speed was 4 knots, wind direction was 137 deg, temperature was 67 °F, humidity was 86% and ambient pressure was 30.19 in. Hg (pressure measured at Camera Site 3).

The I-loads were designed with the L-4:50 Jimsphere. Based on the L-2:20 Day of Launch I-Load Update (DOLILU) assessment profile, no exceedances of the April 90th percentile database limits for the in-plane or out-of-plane components were identified. The maximum measured wind velocity was 87.8 ft/sec at 44.200-ft and 321 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 1000 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 0901 UTC False Cape 915 MHz profiler. The maximum measured wind velocity in the roll maneuver region was 32.9 ft/sec at 4400 ft and 33 deg.

FINAL INSPECTION

The External Tank (ET) Final Inspection Team (FIT) observed moderate-to-heavy condensate over the entire tank. Small pockets of frost were noted on the -Z/-Y Liquid Oxygen (LO₂) tank Thermal Protection System (TPS) at approximately Xt 550, but dissipated once the FIT returned from the pad. Surface temperatures ranged from 48 °F to 64 °F. No intertank stringer valley cracks were noted. The LO₂ feedline brackets exhibited typical ice/frost formations at the bracket base-to-tank fitting interface. The Ice Frost Ramps (IFRs) looked clean with no observations recorded. Typical ice/frost was noted on the LO₂ and Liquid Hydrogen (LH₂) umbilicals, with moderate-to-heavy ice/frost formations on the aft EB fittings. Two typical cracks were observed on the vertical strut cable tray -Y side with no offset (3-in. by 0.25 in. and 7-in. by 0.25-in.). All observations were acceptable per NSTS documentation.

REUSABLE SOLID ROCKET BOOSTERS

All Reusable Solid Rocket Booster (RSRB) systems performed as expected during the launch- countdown and ascent of the STS-131 mission. No In-Flight Anomalies (IFAs) were identified.

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 (beginning with the commencement of tanking) and launch.

All RSRB systems performed as expected during launch countdown and ascent. The RSRB pre-launch countdown was nominal and no potential RSRB In-Flight Anomalies (IFAs) were identified.

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.

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

Both RSRBs were successfully separated from the ET and reports from the recovery area indicate that the deceleration subsystem performed as designed. Recovery ships returned both boosters to Kennedy Space Center (KSC) for inspection and refurbishment.

REUSABLE SOLID ROCKET MOTORS

The STS-131 Reusable Solid Rocket Motor (RSRM) set performed within established and predicted limits (nominal). No RSRM LCC or OMRSD violations occurred.

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.

Power up and operation of all igniter and field joint heaters was accomplished routinely.

No RSRM-related Interim Problem Reports (IPRs) occurred during the countdown (beginning with the commencement of tanking) and launch

EXTERNAL TANK

The External Tank (ET) pre-launch countdown was nominal and the ET performed satisfactorily throughout the ascent phase.

No ET LCC or OMRSD violations occurred, and no ET IPRs occurred during the launch countdown.

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. Since Main Engine Cut-Off (MECO) was nominal, the ET impact occurred at 37.233 deg S and 159.667 deg W, which was approximately 67 nmi up range of the predicted impact point.

SPACE SHUTTLE MAIN ENGINES

All Space Shuttle Main Engine (SSME) systems performed as expected during launch countdown and ascent performance was typical of previous flights. Engine "Ready" was achieved at the proper time, all LCCs were met, and thrust build up was nominal. Flight data indicates nominal SSME performance during startup, mainstage, throttling, and shutdown.

No SSME LCC or OMRSD violations occurred, and no SSME-related IPRs occurred during the countdown and launch. There was one Failure Identifier (FID) identified during launch.

A FID was posted on SSME2 Advanced Health Monitoring System (AHMS) High Pressure Fuel Turbopump (HPFTP) 21-deg accelerometer at approximately Engine Start plus 439 sec due to a high data spike combined with a high signal noise floor causing the sensor to be disqualified. The 2 remaining accelerometer sensors on this pump were nominal and ascent performance was not affected. The noise was not due to pump vibrations, and the AHMS system logic performed as designed in disqualifying the sensor.

Review of AHMS vibration measurements indicates nominal performance. Only the one FID, discussed in the previous paragraph, to the Vehicle Data Table (VDT) was identified from start preparation through propellant dump on all engines. All other accelerometer measurements appeared healthy.

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

Commanded Max Q throttle-down was a single-step throttle bucket to 72% Rated Power Level (RPL) (Adaptive Guidance Throttle (AGT) was not activated).

The predicted average SSME specific impulse (ISP) tag value (using the ground-based tag value method) was 451.58 seconds at 104.5% RPL. Data indicate that the delivered ISP will be within the expected range. Propellant dump operations data were normal.

SHUTTLE RANGE SAFETY SYSTEM

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 launch countdown and ascent. Data indicate that the MPS performed as planned. One IFA as well as a Failure Identifier (FID) was identified during the flight and the anomaly is discussed in a later paragraph.

No MPS LCC or OMRSD violations occurred, and no MPS-related IPRs occurred during the launch countdown.

Data from the prelaunch, MECO, post-MECO and entry/landing events revealed no anomalous valve movements. All timings were within the required specifications and within the current historical data-base.

The maximum hydrogen concentration level in the Orbiter aft compartment, with the normally elevated system backpressure used for fastfill, was 86.6 ppm (System B was used to determine the maximum concentration). This compares favorably with previous data for this vehicle.

All Liquid Hydrogen (LH₂) and Liquid Oxygen (LO₂) loading parameters were nominal. All LO₂ and LH₂ fill and drain valves performed nominally. All LO₂ and LH₂ Engine Cutoff (ECO) sensors passed all pre-flight checkouts and operated nominally through ascent.

The LH₂ pre-pressurization cycle count was 8 cycles; 14 cycles or more violates the LCC criteria. The 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.

One failure occurred during ascent when the LH₂ inlet pressure on SSME 3 failed Off-Scale-Low (OSL) approximately 2 min into ascent IFA/FID STS-131-V-01). This failure had no impact during ascent and the remainder of the mission. A more detailed discussion of the anomaly is contained in the IFA Appendix (B) of this report.

The overall GOX and GH₂ system in-flight performance was nominal. All three Flow Control Valves (FCVs) performed nominally with 2 cycles on FCV no. 1, 2 cycles on FCV no. 2 and 12 cycles on FCV no. 3.

Hazardous Gas Concentrations

The aft hazardous gas concentrations during loading were nominal. The following table summarizes the results.

HAZARDOUS GAS CONCENTRATIONS AT LAUNCH

Parameter	Peak, ppm	Steady State, ppm
Helium	8900	6200
Hydrogen	87	12
Oxygen	17	7
LD54/55	0	0

Gas Sample Analysis

The measured sample bottle pressures indicate the redesigned Orbiter aft fuselage gas sampler system performed satisfactorily. 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 15 TORR below the minimum acceptable value. The constituents of the sample appeared valid so it was included in the analysis.

The highest oxygen concentration was 2.6% in bottle left hand no. 2. All oxygen concentrations were below the flammability limit. The presence of argon in the samples indicates air was the source of the oxygen. The highest estimated hydrogen system leak was 845 SCIM in bottle right hand no. 1. The low SCIM leak-rate was consistent with the low parts per million (ppm) in the aft during loading. All H₂ leak rates were well below the flammability limit. Helium concentrations were nominal.

SUMMARY OF BOTTLE PRESSURES AND GAS CONCENTRATION

Bottle No.	Position	Pressure, psia	Helium, %	Measured Oxygen, %	Hydrogen, %
1	RH 1	2.85	0.78	2.51	0.02
2	LH 1	1.67	0.47	1.14	0.01
3	RH 2	1.45	0.86	1.80	0.02
4	LH 2	0.89	1.01	2.66	0.04
5	LH 3	0.18	3.49	2.38	0.09
6	RH 3	0.06	5.03	1.48	0.06

The Ascent Hazard Analysis indicates the maximum hydrogen firing leak rate is shown in the following table.

HYDROGEN FIRING LEAK RATES

Bottle no.	Position	Hydrogen Firing Leak Rate, scim
1	RH 1	845
2	LH 1	275
3	RH 2	505
4	LH 2	730
5	LH 3	430
6	RH 3	103

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

AFT FUSELAGE SAMPLE BOTTLE GAS ANALYSIS

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, %
1113 FLT-1	RH1	147.1	0.10	10.81	0.78	<0.01	0.01	<0.01	2.27	2.51	0.02	0.02
1106 FLT-1	LH1	86.4	0.05	5.35	0.47	<0.01	<0.01	<0.01	1.12	1.14	0.01	0.01
1123 FLT-1	RH2	75.0	0.08	8.35	0.86	<0.01	<0.01	<0.01	1.75	1.80	0.02	0.02
1109 FLT-1	LH2	46.0	0.12	13.17	1.01	<0.01	<0.01	<0.01	2.77	2.66	0.04	0.04
1112 FLT-1	LH3	9.49	0.10	10.39	3.49	0.13	<0.01	0.01	2.18	2.38	0.16	0.09
1146 FLT-1	RH3	3.16	0.09	9.53	5.03	2.18	<0.01	0.03	2.00	1.48	1.24	0.06

Purge, Vent, and Drain System

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

The Hazardous Gas Detection System (HGDS) system B was primary. Aft Hydrogen (H₂) peaked at approximately 87 ppm during fast-fill and returned to approximately 12 ppm. The Aft Oxygen (O₂) peaked at approximately 17 ppm during loading and returned to approximately 7 ppm after loading. The Helium peaked at approximately 8,900 ppm during initial LH₂ ET loading.

The purge was initiated within 30 min (was 20 min) of the upper aft safety assessments. The after-landing purge was initiated approximately 54 min after touchdown, exceeding the 45-min limit. The internal HGDS checks were not started until 15 min after the upper-aft was cleared by Safety, thus delaying purge initiation.

Five of the six bottle pressures were nominal. The first bottle in the sequence, right hand number 1, was ~14 torr low at 147.1 (minimum is 161.81). The data appeared valid so a leak rate was calculated for this bottle

The highest oxygen concentration was 2.6% in bottle left hand no. 2. All oxygen concentrations were below the flammability limit. The presence of argon in the samples indicates air was the source of the oxygen. The highest estimated hydrogen system leak was 845 SCIM in right-hand bottle no. 1. The low leak rate is consistent with the low ppm level in the aft compartment during loading. All H₂ leak rates were well below the flammability limit. The Helium concentrations were nominal.

Reaction Control System

The Reaction Control System (RCS) performed all functions required for successful completion of the mission. Two IFAs were identified and discussed in later paragraphs. The propellant loading for the mission is shown in the following table.

RCS PROPELLANT LOADING

Parameter	Forward RCS		Left RCS		Right RCS	
	Oxidizer	Fuel	Oxidizer	Fuel	Oxidizer	Fuel
Target, %	67.70	67.41	100.48	100.76	100.48	100.76
Target, pounds	1141.0	712.0	1523.0	962.0	1523.0	962.0
Calculated, %	72.35	69.15	100.79	100.72	100.63	100.79
Advertised (a), %	1203.7	726.8	1527.1	961.6	1525.0	962.2
PASS WHI^b	4.3628	4.2627	4.3782	4.2368	4.3866	4.1840
BFS WHI ^c	4.3673	4.2658	4.3938	4.2479	4.4029	4.2224

Notes:

^a Quantities were taken from the RCS propellant-loading sheet. Advertised quantities include unusable propellants

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

^c 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 following table

TYVEK COVER RELEASE TIMES, VELOCITIES AND ALPHA/BETA ANGLES

Cover	MET (sec)	Velocity (mph)	Alpha (deg)	Beta (deg)
F1D	4.7	53	1	6
F2D	5.6	65	1	5
F3D	5.9	68	1	5
F4D	6.6	78	1	5
F2F	8.3	103	3	4
F4R	8.4	105	4	4
F2R	8.7	109	4	3

**TYVEK COVER RELEASE TIMES, VELOCITIES AND ALPHA/BETA ANGLES
(Concluded)**

Cover	MET (sec)	Velocity (mph)	Alpha (deg)	Beta (deg)
F1F	9.0	113	4	2
F3L	9.0	114	4	2
F1L	9.2	117	4	2
F3F	9.3	117	4	2
F2U	9.5	121	3	2
F1U	10.4	134	4	1
F3U	10.9	142	4	1

The RCS window-protect firing, using thrusters F1U, F2U and F3U, was initiated at 095/10:23:29 Greenwich Mean Time (GMT) [00/00:02:04 Mission Elapsed Time (MET)] for total duration of 2.08 sec. The forward RCS performance was nominal. The window-protect firing deflects Booster Separation Motor (BSM) exhaust from the RSRB separation away from windows.

The ET Separation translation maneuver was performed at 095/10:29:53 GMT and was a 7-sec, 10-thruster firing. The ET Photo +X was performed at 095/10:30:20 GMT (00/00:08:28 MET) and was a 10.6-sec, four-thruster translation. ET Photo Pitch maneuver was performed at 095/10:30:34 GMT (00/00:09:09 MET).

The left RCS helium valves were configured for orbit at 095/11:03:50 GMT (00/00:42:25 MET). The right RCS helium valves were configured for orbit at 095/11:04:13 GMT (00/00:42:48 MET). This configuration placed the system in the desired configuration for the leaking/failed open right RCS helium isolation valve as agreed to pre-flight.

The forward RCS helium valves were configured for orbit at 095/11:05:03 GMT (00/00:43:38 MET). The heaters, which included the forward RCS, left and right pods and crossfeed, were configured to the A-strings at 095/11:21:03 GMT (00/00:59:38 MET).

The following table provides the pertinent data for all RCS firings.

RCS MANEUVERS AND FIRING DATA

Maneuver/Firing	Engine/System	Time of Ignition, GMT	ΔV , ft/sec	Duration, sec
RCS Window Protect	RCS	095/10:23:29	N/A	2.08
ET Separation	RCS	095/10:29:53	N/A	7.0
ET Photo +X	RCS	095/10:30:20	N/A	10.6
ET Photo Pitch	RCS	095/10:30:34		
NC3	RCS	096/13:32:22	4.4	19.0
NCC	RCS	097/04:09:03	0.8	
MC1	RCS	097/05:26:44	0.5	

RCS MANEUVERS AND FIRING DATA (Concluded)

Maneuver/Firing	Engine/System	Time of Ignition, GMT	ΔV , ft/sec	Duration, sec
MC2	RCS	097/06:00:29	0.6	
Out of Plane Null	RCS	097/06:12:12		
MC3	RCS	097/06:17:51	1.51	
MC4	RCS	Not Required		
Separation 1	RCS	107/14:01:25		6.00
Separation 2	RCS	107/14:29:25		13.2
RCS Hotfire	RCS	108/08:04:54		
Forward Reaction Control System Dump	RCS	110/12:18:45.7		38.4

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	3.1	41.9
Forward Fuel	0.0	0.0	0.0	0.0
Left Oxidizer	46.0	621.0	45.2	610.2
Left Fuel	44.8	380.4	44.8	380.8
Right Oxidizer	37.0	499.5	36.0	486.0
Right Fuel	35.6	302.6	35.5	301.8

Note:

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

The RCS propellant consumption is shown in the following table.

RCS PROPELLANT CONSUMPTION

Parameter	Oxidizer, lb	Fuel, lb	Mixture ratio, Oxidizer/Fuel
Forward RCS ¹	934.8	587.8	1.59
Left RCS	750.4	475.3	1.58
Right RCS	872.5	554.9	1.57

¹A four-thruster, 38.4 second forward RCS propellant dump was performed.

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
	097/07:44:09	DAP FREE DRIFT	Docking / ISS Capture
Orbiter	097/08:09:14	DAP VERNIER	
Orbiter	097/08:10:17	DAP AUTO	TEA Maneuver
	097/08:15:26	DAP FREE DRIFT	Set Contraction
Orbiter	097/09:05:28	DAP B	collapse attitude deadbands
	097/09:16:17	DAP FREE DRIFT	End of TEA
Orbiter	102/10:22:20		Attitude control handover for water dump
	102/13:19:17		Post water dump Handover to ISS
Orbiter	107/11:33:23	DAP AUTO	Maneuver to Undock attitude
	107/12:19:56	DAP FREE DRIFT	Logic Configuration
Orbiter	107/12:21:18	AUTO	
	107/12:49:26	FREE	Driver configuration
Orbiter	107/12:50:17	DAP B/ALT / No Low Z	
	107/12:52:20	Undock	

The maneuver to the undock attitude was initiated at 107/11:33:23 GMT (12/01:11:58 MET). As part of the undocking preparations, the forward thrusters were reselected at 107/11:54:26 GMT (12/01:33:01 MET), except for F1F and F2F. Undocking was initiated with a +Z pulse at 107/12:52:20 GMT (12/02:30:55 MET). The undocking from the ISS was nominal. The F1F and F2F thrusters were reselected at 107/12:57:16 GMT (12/02:35:51 MET) after the undocking was completed. The fly-around (full maneuver) was initiated with a +X pulse of L1A and R1A at 107/13:12:41 GMT (12/02:51:16 MET). The separation 1 maneuver was a 6.0-sec +X firing of the L1A and R1A thrusters at 107/14:01:25 GMT (12/02:51:16 MET). The separation 2 maneuver was a 13.2-sec +X firing, using the L1A and R1A thrusters, performed at 107/14:29:25 GMT (12/04:08:00 MET)

The left RCS Fuel Helium B-Leg isolation valve was sluggish following the wave-off configuration of the pressurization and propellant isolation valves at 109/12:59:57 GMT (14/02:38:32 MET) (IFA STS-131-V-08). The left oxidizer helium B isolation valve indicated closed as expected; however, the left fuel helium B isolation valve used 47 sec to close and should have closed within less than 1 sec. No additional troubleshooting was performed prior to landing. The valve was cycled nominally for entry configuration and the post-flight valve test, and valve response signatures were nominal for all these subsequent cycles. The valve demonstrated nominal indications during all other in-flight reconfigurations. Appendix B has a more detailed discussion of this anomaly.

The Forward RCS Fuel Helium A-Leg isolation valve was sluggish during the post-flight valve test. When the switch was cycled closed, the valve remained open. The

crew reported that the talkback was showing barber-pole (IFA STS-0131-V-09). The valve eventually indicated closed approximately 82 sec after its expected closure time. At that time, the crew reported that the talkback Indicated closed. This anomaly was also observed on the STS-119 (ref. STS-119/MER-17). There were no additional cycles on the valve during the valve test to verify functionality. Prior to the valve test, the valve demonstrated nominal indications during all other reconfigurations since the STS-119 anomaly including ground processing flows and in-flight for both STS-128 and -131. Appendix B has a more detailed discussion of this anomaly.

Orbital Maneuvering System

The Orbital Maneuvering System (OMS) performed satisfactorily and not IFAs were identified during the analysis of the flight data.

The OMS configuration for STS-131 is shown in the following table.

OMS CONFIGURATION

Vehicle/ equipment	Flight	Orbital Maneuvering Engine (OME)	Ancillary data
Left Pod (LP) 01	41 st	L-OME S/N 115	8 th rebuilt flight - 23 rd flight
Right Pod (RP) 03	39 th	R-OME S/N 106	12 th rebuilt flight - 36 th flight

The OMS maneuvers are shown in the following table.

OMS MANEUVERS

Maneuver designation	Configuration	Time of ignition, GMT	Firing time, sec	ΔV, ft/sec/ interconnect usage, %
Assist	DUAL OME	095/10:23:41.0	104.3	N/A
OMS-2	DUAL OME	095/10:58:39.5	128.3	196.9
OMS-3 (NC1)	DUAL OME	095/13:07:28.1	62.8	97.6
OMS-4 (NC2)	DUAL OME	096/01:56:28.4	39.4	61.6
OMS-5 (NC4)	DUAL OME	097/03:35:14.9	13.6	21.2
OMS-6 (TI)	LEFT OME	097/05:06:44.3	10.2	7.7
OMS-7 (OA)	DUAL OME	108/17:31:17.7	10.8	17.7
(Deorbit)	DUAL OME	110/12:02:59.1	177.6	302.6

The interconnect and propellant usage from the OMS to the RCS is shown in the following tables.

INTERCONNECT USAGE, %/POUNDS

Parameter	Total, %	Total, lb
Left OMS	0.000	0.000
Right OMS	1.028	133.13

PROPELLANT USAGE DATA

Parameters	Left OMS pod		Right OMS pod	
	Oxidizer	Fuel	Oxidizer	Fuel
Loaded, lbm	7050	4254	7050	4254
Residual, lbm (aft gage)	512	276	503	282
Residual, lbm (burn time integration)	432	246	586	281
Residual, lbm (SODB flow rate)	506	270	508	313

Auxiliary Power System

The Auxiliary Power Unit (APU) system performance was nominal throughout the STS-131 mission. There were no In-flight Anomalies (IFAs) identified in the APU system.

The run times and fuel consumption for the APUs are summarized in the following tables.

APU RUN TIMES

APU (S/N)	Ascent, hr:min:sec	FCS Checkout, hr:min:sec	Entry, hr:min:sec	Total time, hr:min:sec
1 (310)	00:19:25	00:04:02	1:00:55	1:24:22
2 (403)	00:19:42	00:00:00	1:26:51	1:46:33
3 (408)	00:19:53	00:00:00	1:01:22	1:21:15

APU FUEL CONSUMPTION

APU (S/N)	Ascent, lb	FCS Checkout, lb	Entry, lb	Total, lb
1 (310)	46	14	110	170
2 (403)	49	0	154	203
3 (408)	49	0	121	170

Hydraulics/Water Spray Boiler System

The Hydraulic/Water Spray Boiler (HYD/WSB) system performance was nominal during all phases of the mission. There were no identified during the flight and analysis following the flight.

All three WSB system cores were loaded with approximately 5.0 lb of the additive mixture (53% water; 47% [Propylene Glycol Monomethyl Ether (PGME)]. The initial PGME/Water Tank loading for all WSBs was approximately 133.8 lb. Nominal WSB performance was observed on all three systems throughout the mission.

WSB data for ascent is shown in the following table.

WATER SPRAY BOILER PGME/H₂O USAGE DURING ASCENT

WSB	Spray Start Temp (°F)	Time	Steady State Temp (°F)	PGME/H₂O Usage (lbs)
System 1	251	095:10:30:52	247	3.1
System 2	259	095:10:30:51	255	2.5
System 3	257	095:10:30:54	253	3.1

There were no circulation pump runs required on-orbit for thermal conditioning or bootstrap re-pressurization. There were no WSB Water Tank/Core Heater activations on-orbit.

HYD/WSB performance was nominal during entry. Hydraulic system 3 experienced a WSB lubrication oil cooling overshoot with the APU 3 lubrication dropping to 211°F. APU 3 lubrication oil cooling recovered to steady-state within 5 min 10 sec of the on-set of the cooling overshoot. This occurrence is not indicative of anomalous performance.

WSB data during entry is shown in the following table.

WSB DATA DURING ENTRY

WSB	Spray Start Temp (°F)	Time	Steady State Temp (°F)	PGME/H₂O Usage (lbs)
System 1	241°F	110:12:30:56	247°F	23.5 lbs
System 2	259°F	110:12:05:02	253°F	36.4 lbs
System 3	261°F	110:12:32:10	253°F	22.7 lbs

Power Reactant Storage and Distribution System

The STS-131 Power Reactant Storage and Distribution (PRSD) system performance was nominal throughout the mission, and no IFAs were identified during the mission. The PRSD system supplied the fuel cells with 2239 lb_m of oxygen and 282 lb_m of hydrogen for the production of 3317kWh of electrical energy. A 46-hr mission extension was possible at the mission-extension average power level of 13.09 kW with the reactants remaining at touchdown.

Hydrogen Tank 5 and Oxygen Tank 4 and 5 were depleted to residual quantities. The total oxygen supplied to the Shuttle/ISS Environmental Control and Life Support System (ECLSS) was 302 lb_m from the PRSD. No oxygen tank-to-tank transfer was made; however, 94.5 lbm of oxygen was used for ISS/Shuttle repressurization during the flight.

The following tables show the PRSD 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	100.5	100.9	101.8	3958
Remaining after off- Loading	84.3	83.9	83.9	84.3	83.9	3283
Launch	83.0	82.5	83.0	83.0	83.0	3237
Landing	27.8	21.7	27.8	5.5	6.3	696

Hydrogen

Hydrogen	Tank 1, %	Tank 2, %	Tank 3, %	Tank 4, %	Tank 5, %	Total Mass, lb _m
Loaded	102.3	101.9	102.3	101.9	103.2	470.7
Launch	98.8	98.4	98.8	98.8	99.7	454.9
Landing	59.0	55.0	57.7	13.9	2.4	173.0

Fuel Cell System

Fuel Cells

The overall performance of the OV-103 Fuel cell subsystem was nominal for STS-131. No IFAs were identified during the analysis and review of the data.

The average electrical power level and load was 9.1 kW and 293 Amperes (A). The fuel cells produced 2521 lb_m of potable water and 3317 kWh of electrical energy from 2239 lb_m of oxygen and 282 lb_m of hydrogen. Five fuel cell purges were performed, occurring at approximately 26, 122, 241, 332, and 356 hours MET.

The actual fuel cell voltages (200 A load) at the end of the mission were 0.12 Volts (V) above predicted for fuel cell 1, 0.16 V above predicted for fuel cell 2, and as predicted for fuel cell 3. The voltage margins above the minimum performance curves at 200 amps at the end of the mission were 1.06 V above minimum for fuel cell 1, 1.06 V above minimum for fuel cell 2, and 1.06 V above minimum for fuel cell 3.

During prelaunch cockpit lighting adjustment, the fuel cell 2 H₂ Pump Motor Controller (PMC) voltage measurement ramped up to 0.98 Vdc in approximately 5 min, out-of-family high (LCC redline limit is 1.0 Vdc). The measurement then abruptly returned to a nominal reading in a 1 data bit sample. Repeated manipulation of several switches did

not cause the problem to recur. Similar voltage increases have occurred during STS-42 countdown and STS-63 descent. Evaluation of this condition will be performed during turnaround activities.

The prelaunch baseline Cell Performance Monitor (CPM) values for fuel cell 1 were 4, 2, and 8 mV, for fuel cell 2 were 2, 8, and 12 mV, and for fuel cell 3 were 6, 16, and 20 mV. They were established during prelaunch operations, approximately 2 hr after the completion of the Fuel Cell Calibration requirement.

The Fuel Cells Monitoring System (FCMS) was used to monitor individual cell voltages prelaunch, on-orbit, and postlanding. Full-rate on-orbit data was recorded for 12 min beginning at 096:02:33:07 GMT (00/16:11:42 MET); there were no outliers. Due to the Ku-Band Antenna failure, the data was not down-linked until after ISS docking.

Station-to-Shuttle Power Transfer System Operation

This was the fifth flight of SSPTS on OV-103. The SSPTS transfers and converts power from the 120 Vdc ISS electrical system to supplement fuel-cell power to the Orbiter's 28 Vdc buses. The system is activated after the Orbiter is docked to ISS and has the capability to transfer up to about 8 kW of power from ISS to the Orbiter. The SSPTS supplied 1547 kWh of power to the Orbiter over a 239.8-hr period while docked to the ISS. The average power supplied to OV-103 was 6.45 kWh.

Electrical Power Distribution and Control System

The Electrical Power Distribution and Control (EPDC) system performed nominally during all mission phases. No IFAs were identified during the review and analysis of the flight data. The SSPTS PTU performance for the mission was flawless.

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 FD 2 and the ODS was activated for 7 min 42 sec, and the avionics hardware was powered for 5 min 9 sec. The system was ready for rendezvous and docking with the ISS.

The ODS was activated at 097/07:26:25 GMT (01/21:05:00 MET). The Shuttle captured the ISS at 097/07:44:09 GMT (01/21:22:45 MET), and the Post-Contact Thrust (PCT) firing sequence was performed nominally. Ring retraction using dual motors was started at 097/07:53:26 GMT (01/21:32:02 MET). The hooks were driven closed nominally and final ring extension was performed, releasing the capture latches and the ring final-position was acquired at approximately 097/08:00:24 GMT (01/21:39:00 MET).

The ODS system was powered for 44 min 52 min for the ISS docking operations.

In preparation for undocking, the ODS was activated at 107/12:05: GMT (012/01:44:18 MET). The undocking and separation from the ISS was completed satisfactorily at 107/13:08 GMT (012/02:47: MET). The ODS was operational for 63 min 03 sec for the undocking of the Orbiter.

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 analysis and review of the data. After the ascent was completed, the Pressure Control System (PCS) was configured to system 1. Although system 1 performed nominally, a complete checkout was not observed prior to 14.7-psia regulator configuration for docking. Prior to undocking, PCS system 2 was configured and used for the remainder of the mission. A good checkout was observed on PCS system 2 in the post-undocking time period. The PCS system 1 checkout was confirmed during the previous flight of OV-103 (STS-128).

There were no Orbiter-to-ISS tank-to-tank N₂, or O₂ transfers performed during this mission. There were three Orbiter/ISS stack N₂ repressurizations performed using the Orbiter PCS. A total of four O₂ repressurizations were performed of the ISS using Orbiter O₂ during docked operations.

Airlock System

The Airlock Systems performed nominally throughout the mission and no IFAs were identified during the review and analysis of the data. Also, no Orbiter-based Extravehicular Activities (EVAs) were performed during this mission. All water line and vestibule heaters cycled on all systems. During the majority of STS-131, both the heater A and heater B structure heaters were activated. All but one of the airlock structural heater measurements cycled during the mission.

Supply and Waste Water System

The Supply Water and Waste Management Systems performed nominally throughout the mission, and no IFAs were identified during the review and analysis of the data.

The Supply water was managed through the use of the Flash Evaporator System (FES), a water dump through the nozzle and water transfer to the ISS. The supply water dump line temperature was maintained between 66 °F and 94 °F throughout the mission.

The Waste Management system performed three successful dumps at a nominal average dump rate of 1.9 %/min (3.1 lb/min); one dump was performed in the pre-docking period and two after undocking. The waste water dump line temperature was maintained between 57 °F and 92 °F throughout the mission.

Seven Contingency Water Containers (CWC) and eight Contingency Water Containers-CWC-Iodine (CWC-I) were filled with supply water and transferred to the ISS, for a total of 644.4 lbm and 309.9 lbm, respectively. One Portable Water Reservoir (PWR) of iodinated water for a total 20.3 lbm was filled and transferred to ISS.

One Orbiter condensate CWC was used to collect approximately 77 lbm of condensate. One ISS condensate CWC was used on the Orbiter to collect approximately 73 lbm of condensate. Both CWCs were transferred to the ISS for processing in the Russian segment.

Vacuum vent line temperature was maintained between 83°F and 60 °F. The thermostat control the heater range is 55 ± 5 to 75 ± 5 °F.

Smoke Detection and Fire Suppression System

The Smoke Detection and Fire Suppression (SDFS) operated nominally with no issues. The smoke detector check was accomplished. The 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 nominally throughout the mission. No problems or IFAs were identified during the review and analysis of the flight data. The radiators were not deployed during this flight.

The carbon dioxide (CO₂) level during the on-orbit mission phase was controlled below the flight-rule maximum limit of 5 mmHg except for two occasions when the PPCO₂ level exceeded the limit. The highest level recorded was 5.38 mmHg on 00\03:31:56 MET. The exceedances were brief, measured in minutes.

After undocking, the crew switched the cabin temperature controller from system 1 to system 2 around 107/14:57 GMT (12:04:36 MET). After that, the crew noticed a wider swing on the cabin temperature and that the temperature control valve was moving quicker to full Heat Exchanger (HX) position. The crew asked if they could change the controller back to system 1. Ground control concurred and the controller was switched at 108/18:56:25 GMT (013:08:35 MET). There has been no history of anomalous performance of any Orbiter cabin temperature controller. During the post-flight debriefing, the crew commented that the temperature gradient condition between the system 1 and 2 was not significant to warrant any hardware or operational procedure change for subsequent flights.

The Ammonia Boiler System (ABS) tank A and B in-flight leak rate was calculated at approximately 0.02 lb_m/day for tank A and 0.01 lb_m/day for tank B with the limit leak rate being no more than 0.05 lb_m/day.

For landing the ABS system A secondary controller was powered at 110/13:15 GMT (015\02:54 MET). Continued ABS operation on system A was for 33 min until termination at 110/13:48 GMT (015\03:27 MET) with the start of ground cooling activation. System B activation, using primary controller per scheduled rotation, 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 throughout all phases of the mission.

The PASS flight software moded successfully from Major Mode (MM) 101 through MM106, and the Backup Flight System (BFS) maintained tracking during the ascent profile. During post-insertion, the General Purpose Computers (GPCs) were successfully configured to Single G2 (GPC 1), G2FD (GPC 2 and 3), SM2 (GPC 4), and BFS in sleep mode (GPC 5) to support On-Orbit Data Processing System (DPS) operations.

The GPCs were re-configured to a Triple-G2 set to support Rendezvous and Docking operations. All operations were nominal with no unexpected errors. After docking, the GPC set was again contracted to a Single G2 configuration with GPC 1 commanding all strings.

GPC 1 was transitioned to OPS 8 to support the Flight Control System (FCS) checkout. After completion, GPC 1 was then transitioned back to OPS 2 to continue nominal on-orbit operations. All Operational Sequences 9OPS0 transitions were nominal and no unexpected errors were observed.

During deorbit preparation, the PASS GPCs were transitioned to a four G3 configuration with the BFS in OPS 3 and tracking all PASS strings to support entry operations. All OPS transitions were nominal and no unexpected errors were observed.

After wheel-stop, the PASS GPCs were transitioned to OPS 9 and the BFS was moded to OPS 0. A subsequent PASS redundant set contraction to Single G9 was performed with GPC 1 commanding all strings. All OPS transitions were nominal and no unexpected errors were observed.

Data Processing System Hardware

The data review and analysis of Data Processing System (DPS) hardware parameters indicated nominal operations throughout the mission. No IFAs were identified during the review and analysis of the flight data.

Multifunction Electronic Display System

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

Displays and Controls System

The Displays and Controls (D&C) system including Lighting performed nominally during all phases of mission. There are no IFAs/problems identified during the review and analysis of the data.

Flight Control System

The Flight Controls System (FCS) performed nominally during the preflight, countdown, ascent, orbit, FCS checkout, deorbit preparation, entry, landing and 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 there were no Spin Motor Rotation Detector (SMRD) dropouts. The outputs of the four Accelerometer Assemblies (AAs) also tracked one another normally. The Reaction Jet Driver (RJD) operation was also normal with no thruster failures or other anomalies noted. Device Driver Unit (DDU) and controller operations were nominal as well. Both the Rotational Hand Controller (RHC) and the Transitional Hand Controller (THC) were used and exhibited normal channel tracking.

Flight control actuator temperatures were also normal. The Rudder/Speed Brake Power Drive Unit (RSB PDU) motor back-drive did not occur during 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-Time of Ignition OMS gimbal profile was as expected with the OMS actuator active and standby channels reaching nominal drive rates. All AAs performed normally. Secondary differential pressures for all actuators were well within the equalization threshold, and all actuator positions closely tracked 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 throughout the mission and no IFAs were identified from the flight 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 the post-elevon-park activities.

During the 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 4.8, and deployment timing was within specification at less than 15 sec. ADTA data were incorporated into Guidance, Navigation, and Control (GN&C) at about Mach 3.2. 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 during all phases of the mission. During the flight, one adjustment of the onboard IMU accelerometer compensation values was made to all three IMUs. Also, three adjustments were made of the IMU drift compensation values.

The –Y and –Z Star Trackers (STs) performed nominally throughout the mission and no IFAs were identified from the flight data.

The –Y ST acquired a star 836 times during the mission and missed a navigation star 1836 times. Analysis showed that 1076 occurrences of missed stars was because of bright objects in the field of view, and this is considered a normal condition. The –Z ST acquired a navigation star 63 times and missed a navigation star 55 times. A total of 38 of the missed stars occurred during the docking operations and this is considered normal operation of the ST.

Global Positioning System Navigation

The Global Positioning System (GPS) performance was nominal. STS-131 was a nominal 1-String GPS Entry operational flight. Per the plan for all 1-String GPS (OV-103 and OV-104) flights, the GPS state was incorporated into both PASS and BFS in MM304 after

performance confirmation with high speed C-band tracking. A Figure of Merit (FOM) value of 1 was achieved at about 160,000 ft altitude, and prior to the GPS incorporation into the navigation. The FOM remained at 1 from then through rollout.

High-speed C-band tracking occurred at approximately 150,000 ft altitude, immediately after the call to incorporate the 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 Microwave Landing System (MLS) incorporation (approximately 16,000 ft) where the PASS automatically stops taking GPS updates per design. Likewise, the BFS navigation state-vector residuals remained consistently low from GPS incorporation through rollout.

Communications and Tracking System and Navigation Aids

The Communications and Tracking (C&T) systems performance provided the necessary communications during the mission. The Navigation Aids (NAV AIDS) performed satisfactorily. Two C&T IFAs were recorded during the mission and these are discussed in later paragraphs.

During STS-131, the Ku-Band failed from power up for both Communications (COMM) and RADAR operations (IFA STS-131-V-02). The problem occurred during the radar activation self-test. The signal strength during the self-test was low (0.56 V and normally above 0.8 V); the radar range during the test sequence remained passive at 0 ft. Some of the detect/track indications were missing, resulting in a self-test failure. When the Ku-Band system was switched to the COMM mode, both the forward and return links were failed. On-orbit troubleshooting failed to recover Ku-Band COMM operations. The Ku-Band also failed to lock on to the ISS during Rendezvous.

Starting at 109/10:30 GMT (14/00:09 MET), the Automatic Gain Control (AGC) levels on the upper-left S-Band Quad Switch-beam antenna-path became noisy causing brief drops of the uplink communications while on the upper-left path (IFA STS-131-V-11). A review of the reflected power data also showed reflected-power step-changes at random times earlier in the flight during operation (noisier AGC) in both forward and aft antenna positions.

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 from the review of the data. No anomalies or significant problems were identified during the mission or after review of the mission data. The MADS Pulse Code Modulation (PCM) ascent data was recorded on the Solid State Recorder (SSR) and dumped to the ground. The MADS PCM data from the SSR was reviewed after the flight with no problems related to the MADS PCM unit identified.

Mechanical and Hatches System

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

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. The tires were in good condition and performed nominally. It was the second flight of the nose landing gear tires. The tires had the appearance of tread-reinforcement cord materials on areas of the tire's surface, only in the area of the spin-up patch, and this is a known expected condition. The post-flight inspection of the drag-parachute hardware at the KSC parachute refurbishment facility indicated that no signs of anomalous conditions for hardware performance were identified.

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	3616.3	0.0	198.1	198.3	-1.2	
Drag Chute Deployment	4550.6	2.87	187.6	188.3		
Drag Chute Disreef	6153.4	8.20	165.8	165.8		
Nose Landing Gear Touchdown	6386.9	9.08	157.3	159.7		-3.8
Brakes On	8903.8	20.60	103.5	107.4		
Drag Chute Jettison	10923.4	35.35	N/A	57.1		
Wheels Stop	11965.1	57.92	0.0	0.0		
Parameter	From threshold, ft	Time from MLG touchdown, sec	Speed, keasa	Speed, kgs	Sink rate, ft/sec	Pitch rate, deg/sec
Parameter			Data			
Brake Initiation Speed, keas			103.5			
Brake On Time, sec			37.32			
Rollout Distance, ft			8348.7			
Rollout Time, sec			57.92			
Runway Location, Surface and Degrees			KSC 33 Concrete			
Orbiter Weight at Landing, lb			224970			

LANDING PARAMETERS (Concluded)

Parameter	Maximum Brake Pressure, psia	Total Brake Energy, Mft/lb
Left inboard	740.1	15.9
Left outboard	713.7	17.3
Right inboard	740.1	16.8
Right outboard	647.6	9.5

^aKnots equivalent air speed

Aerothermodynamics, Integrated Heating and Interfaces

The post-flight inspection indicated the Orbiter Thermal Protection System (TPS) was normal. The lower structural temperature data indicated normal entry heating. The recorded structure temperatures were within the flight experience of OV-103. From MADS surface thermocouples, boundary layer transition was symmetric and occurred at BP 1600 (X/L = 0.6) around Mach 6.1 or 1317 sec after Entry Interface (EI) based on a pre-flight End-of-Mission (EOM) trajectory.

The quick-look runway report and post-flight inspection pictures indicated that the protruding layer ceramic Ames gap filler at the port side FRCS area was still there and appeared unchanged from the on-orbit imagery. The tile damage site at the trailing edge of the SRSB showed still having some Strain Isolator Pad (SIP) and filler bar on the missing tile area with some exposed Koropon. The flight experiment/BLT protuberance and downstream tiles looked good with no appearance of slumping or glossy RCG coating. The catalytic-coating surface appeared to have some changes in its appearance, but no indications of tile slumping.

The following table shows the maximum temperatures and maximum temperature rise during entry.

ENTRY MAXIMUM TEMPERATURE AND MAXIMUM TEMPERATURE RISE DATA

Thermal Sensor Location	Maximum Temperature, °F	Maximum Temperature Rise, °F
Lower fuselage forward center (B1)	129.9	126.4
Lower fuselage forward left-hand (B2)	185.1	174
Lower fuselage forward mid left-hand (B3)	156.1	165.4
Lower fuselage mid center (B4)	145.6	159.9
Lower fuselage mid aft center (B5)	169.3	170.9
Lower fuselage aft center (B6)	171.9	148.1
Left-wing center (LW)	116.8	138.8
Right wing center (RW)	109	138.6
Port side FRCS forward (P1)	174.5	132.8
Port side fuselage forward center (P2)	122	100.8

**ENTRY MAXIMUM TEMPERATURE AND MAXIMUM TEMPERATURE RISE DATA
(Concluded)**

Thermal Sensor Location	Maximum Temperature, °F	Maximum Temperature Rise, °F
Port side fuselage forward mid center (P3)	103.8	92.7
Port side fuselage fwd-aft center (P4)	70.1	69.2
Port side fuselage aft center (P5)	88.2	61.8
Starboard side FRCS fwd (S1)	153.5	134.7
Starboard side fuselage forward center (S2)	116.8	131.2
Starboard side fuselage forward mid center (S3)	93.4	84.9
Starboard side fuselage mid-aft center (S4)	75.3*	74.4*
Starboard side fuselage aft center (S5)	80.5	61.7
Left-hand OMS pod side forward (LP)	88.2	61.8
Right-hand OMS pod side forward (RP)	67.5*	41.1*
Lower body flap center	116.8*	93.0*
Right-hand PLBD forward	67.5*	109.7*
Left-hand PLBD forward	64.9*	102.1*
Right-hand PLBD aft	75.3*	107.3*
Left-hand PLBD aft	77.9	104.9
Right wing upper center	85.6*	117.7*
Left wing upper center	85.6*	105.0*
Forward RCS center	93.4*	69.6*
Forward Fuselage upper center	70.1	92.1

Notes

^a Maximum temperature occurred 30 min after wheel stop.

Thermal Control System

All passive Thermal Control System (TCS) temperatures performed nominally and were maintained within acceptable limits.

The DAT requested the TCS group for two structure temperature predictions at Entry Interface (EI) to support the Thermal Protection System (TPS) damage assessment. The locations that were of interest for TPS assessment were the vertical stabilizer at Rudder Speed Brake (RSB) and the port OMS pod.

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	8	136
Upper Surface/Window	0	9
Right OMS pod	1	4
Left OMS pod	1	6
Totals	10	155

Tile and Blanket Flight Assessment

The overall performance of the TPS was satisfactory.

The DAT continued to assess a protrusion on the Forward Reaction Control System (FRCS) and a missing tile on the Rudder Speed Brake (RSB). A more detailed discussion of this condition is in Appendix B under IFA STS-131-V-04)

The TPS was cleared for entry at the FD 5 Mission Management Team (MMT) meeting.

The post-flight inspection indicated the Orbiter TPS was normal. The lower structural temperature data indicated normal entry heating. The recorded structure temperatures were within the flight experience of OV-103. From MADS surface thermocouples, boundary layer transition was symmetric and occurred at BP 1600 (X/L = 0.6) around Mach 6.1 or 1317 sec after EI based on a pre-flight EOM trajectory.

The runway report and post-flight inspection pictures indicated that the protruding layer ceramic Ames gap filler at the port side FRCS area was still there and appeared unchanged from the on-orbit imagery. The tile damage site at the trailing edge of the RSRB showed still having some Strain Isolator Pad (SIP) and filler bar on the missing tile area with some exposed Koropon. The flight experiment/BLT protuberance and downstream tiles looked good with no appearance of slumping or glossy RCG coating. The catalytic-coating surface appeared to have some changes in its appearance, but no indications of tile slumping.

RCC Flight Assessment

The Reinforced Carbon-Carbon (RCC) performed satisfactorily. The evaluation of the RCC identified anomalies, which are discussed in the IFA STS-131-V-04)

All Wing Leading Edge (WLE) Impact Detection System (IDS) ascent summary data was successfully downlinked using ISS assets on FD 3 at approximately 097/14:43:16 GMT (02/04:21:52 MET). Four indications exceeded the 1 Grms reporting criteria; however, none of these indicated a need for a Focused Inspection (FI). Three magnitudes observed on the port wing were 1.51 Grms on panel 6, 1.03 Grms on panel 7, and 1.46 Grms on panel 16, all of which have a low-damage category. One

indication on the starboard chine had a magnitude of 2.56 Grms, but nothing exceeding the on-orbit inspection in this area was observed by the DAT during their review of RPM imagery. WLE IDS on-orbit monitoring with Port and Starboard Group 1 began at approximately 097/15:15 GMT (02/04:54 MET) and continued for 24 hr.

The DAT reviewed the LDRI data, the IDC imagery, and the RPM imagery for the starboard wing and determined by FD 4 crew wakeup that there was no requirement for a focused inspection of the starboard wing. Therefore, the recommendation was to proceed with the FD 4 installation of the MPLM as planned.

During the planned WLE IDS Micrometeoroid/Orbital Debris (MM/OD) monitoring at 098/16:37:34 GMT (03/06:16:09 MET), starboard wing sensor unit S/N 1041 acquired a trigger, but failed to force-trigger the other 10 sensor units in its group as it was programmed (IFA STS-131-V-05). The ground verified that sensor unit S/N 1041 and the other sensors in its group were properly programmed. This was the first time a WLE IDS sensor unit has been triggered and all of the sensors in its group fail to force-trigger.

The Leading Edge Subsystem (LESS) DAT reviewed all the LDRI data, Integrated ISIS Digital Camera (IDC) imagery, and RPM imagery for the entire vehicle, and determined there was no requirement for a FI on FD 6.

The WLE IDS Group 2 Port and Starboard sensors began monitoring at approximately 100/17:30 GMT (05/07:08 MET). Group 2 Port sensors monitored for 5 hr, while Group 2 Starboard sensors monitored for 4 hr due to battery-life thermal constraints.

The Docked Late Inspection (DLI) began with the Shuttle Remote Manipulator System (SRMS) maneuver of the Orbiter Boom Sensor System (OBSS) to the docked Flat Field Survey position at 106/08:09 GMT (10/21:47 MET). The docked Starboard RCC Survey began at 106/08:28 GMT (10/22:06 MET). The docked Nose Cap RCC Survey started at 106/10:55 GMT (11/00:33 MET). The docked Port RCC Survey began at 106/11:46 GMT (11/01:24 MET). At the conclusion of the surveys, the OBSS was maneuvered to the Undock-Position at 106/12:39 GMT (11/02:17 MET).

All imagery from the DLI survey of the Starboard Wing, Nose Cap, and Port Wing leading edge surfaces was transferred to the ISS and downlinked by 106/19:22 GMT (11/09:00 MET).

The RCC was cleared for entry at the FD 13 Mission Management Team (MMT) meeting.

The LESS DAT analysis of the imagery from the DLI was completed, and the vehicle was cleared for entry

Windows

The window performed nominally. One item of interest is discussed in the following paragraph.

At an approximately 103/13:54 GMT (08/03:33 MET), the crew reported that a Micrometeoroid/Orbital Debris (MM/OD) impact site was found on Window 1. The crew estimated that the impact is less than 1 mm in diameter. Due to the window location and size of this impact, there were no concerns for entry.

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

1. W1: 4 Defects - Scrapped [High Velocity Impacts (HVIs)]
2. W2: 2 Defects - Acceptable for Flight (HVIs)
3. W3: 4 Defects - Acceptable for Flight (HVIs)
4. W4: 1 Defect - Acceptable for Flight (HVI)
5. W5: 1 Defect - Acceptable for Flight (HVI)
6. W6: 5 Defects - Scrapped (Four HVI and One Low Velocity Impact (LVI))
7. W7: 0 Defects - Stress Analysis not required
8. W8: 0 Defects - Stress Analysis not required
9. W11: 1 Defect - Acceptable for Flight (HVI)

Waste Collection System

The Waste Collection System performed satisfactorily.

EXTRAVEHICULAR ACTIVITY

The crew performed three Extravehicular Activities (EVAs) on STS-131. The EVA activities included replacing the Starboard Truss Segment 1 (S1) Ammonia Tank Assembly (ATA) along with a variety of other tasks. The total duration of the three EVAs was 20 hr 17 min.

FIRST EXTRAVEHICULAR ACTIVITY

The first EVA was performed on Flight Day (FD) 5 by Extravehicular (EV) crewmembers Richard Mastracchio (EV1) and Clay Anderson (EV2), and the total time of the first EVA was 6 hr and 27 min. The following tasks were completed:

1. Removal of the new ATA from the Lightweight Mission Peculiar Equipment Support Structure Carrier (LMC) and stowed on the Payload Orbital Replacement Unit (ORU) Accommodation (POA) using the Space Station Remote Manipulator System (SSRMS);
2. Retrieval of a Japan Aerospace Exploration Agency (JAXA) payload from the Japanese Experiment Module (JEM) external platform;
3. Replacement of S0 Rate Gyro Assembly 1;
4. Opening Node 2 Zenith Centerline Berthing Camera System (CBCS) flap,
5. Released Port Truss Segment 1 (P1) P-Clamps
6. Relocated Worksite Interface (WIF) Extender for Utilization Logistics Flight 4 (ULF4).

SECOND EXTRAVEHICULAR ACTIVITY

The second EVA was successfully completed on FD 7 by EV crewmembers Mastracchio and Anderson. The duration of the second EVA was 7 hr and 26 min. The following tasks were completed:

1. Removal of the expended ATA from S1 and stowed on the POA.
2. Installation of the P1 Radiator Grapple Bar Stowage Beams.
3. Installation of the new ATA onto S1.
4. Relocation of one Adjustable Portable Foot Restraint (APFR) for ULF4

Some motion in the grapple-bar stowage beams was observed and concerns were raised that the installation was not complete. Troubleshooting during third EVA was planned. During ATA removal from S1, a sticky spring-plunger on bolt 4 required 1.5 hr for troubleshooting.

THIRD EXTRAVEHICULAR ACTIVITY

The third EVA was performed on FD 9 (April 13, 2010) by EV crewmembers Mastracchio and Anderson. The duration of the third EVA was 6 hr and 24 min. The following tasks were completed:

1. Connected ATA fluid connectors;
2. Retrieved Airlock (A/L) Micrometeoroid/Orbital Debris (MM/OD) shields;
3. Stowed Adjustable Grapple Bar (AGB) on External Stowage Platform (ESP) 2 Flex Hose Rotary Coupler (FHRC);
4. Installed expended ATA on LMC for return;
5. Stowed Fixed Grapple Bar (FGB) on S1 ATA and
6. Performed Zenith Truss Segment 1 (Z1) Space to Ground Antenna (SGANT) preparation tasks for ULF4;

The following tasks were deferred:

1. The Light Weight Adapter Plate Assembly (LWAPA) to be retrieved from Columbus Module and installed on the LMC, and
2. P1 Radiator Grapple Fixture Beam troubleshooting.

The following get-ahead tasks were not completed: -

1. Open S1 FHRC P-clamps and
2. Additional tool relocation

The third EVA was replanned after the second EVA and the following tasks were dropped from this flight:

1. Special Purpose Dexterous Manipulator (SPDM) Electrical Power (EP)1 thermal cover removal,
2. SPDM Camera Light Pan Tilt Assembly (CLPA) installation,
3. S1 grapple fixture stowage beam installation, and
4. Camera Port 13 luminaries' were replaced.

REMOTE MANIPULATOR SYSTEM AND ORBITER BOOM SENSOR SYSTEM

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

The SRMS on-orbit Initialization began at 095/14:13 Greenwich Mean Time (GMT) [00/05:51 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. A failure of the Ku-Band Antenna self-test occurred during startup, resulting in a loss of Shuttle Ku-Band coverage for the duration of the mission. As a result, Orbiter Boom Sensor System (OBSS) late inspection had to be performed while docked to utilize ISS Ku-band assets.

On FD 2, The SRMS power-up began at 096/02:12 GMT (00/15:52 MET). After maneuvering to the pre-cradle position, SRMS checkout began at 096/02:25 GMT (00/16:03 MET) and was completed by 096/03:17 GMT (00/16:04). The SRMS grappled the OBSS at 096/03:47 GMT (00/17:26 MET) and maneuvered the OBSS to the hover-position at 096/04:01 GMT (00/17:26 MET). The Starboard survey began at 096/05:38 GMT (00/19:17 MET) and was completed at 096/07:09 GMT (00/20:48 MET). The Nose Cap Reinforced Carbon-Carbon (RCC) survey began at 096/07:40 GMT (00/21:19 MET) and was completed at 096/08:16 GMT (00/21:55 MET). The Port survey began at 096/08:42 GMT (00/22:21 MET) and was completed at 096/10:09 GMT (00/23:48 MET).

The SRMS maneuvered to the OBSS hover-position at 096/10:34 GMT (01/00:13 MET) and was berthed at 096/11:03 GMT (01/00:42 MET). The SRMS was maneuvered to the pre-cradle position 33 min later.

On FD 3, The Shuttle Discovery docked with the International Space Station (ISS) with the SRMS in the pre-cradle position. The Space Station Remote Manipulator System (SSRMS) unberthed the OBSS and handed it off to the SRMS at 097/11:33 GMT (02/01:12 MET), which then maneuvered to the Multi-Purpose Logistics Module (MPLM) viewing-position at 097/12:00 GMT (02/01:39 MET), where it remained until FD 6.

There were no SRMS operations on FD 4 and 5.

On FD 6, the SRMS maneuvered the OBSS to the second-EVA viewing-position at 100/04:58 GMT (04/18:37 MET) where it remained until FD 8.

There were no SRMS operations on FD 7.

On FD 8, the SRMS maneuvered the OBSS back to the MPLM viewing-position at 102/04:02 GMT (06/17:41 MET).

There were no SRMS operations on FD 9 through 11.

On FD 12, the Docked Late Inspection of the Shuttle Starboard Wing RCC began at 106/08:43 GMT and was completed at 106/10:32 GMT. The Late Inspection of the Nose Cap began at 106/11:00 GMT (11/00:39 MET) and was completed at 106/11:24 GMT (11/01:03 MET). The Port-Wing RCC inspection began at 106/11:43 GMT (11/01:22 MET) and was completed at 106/12:29 GMT (11/02:08 MET).

On FD 13, the Orbiter undocked from the ISS. After undocking, the SRMS berthed the OBSS back into the Starboard MPMs at 107/16:54 GMT (12/06:33 MET) and the SRMS was cradled at 107/17:31 GMT (12/07:10 MET). The MPMs were stowed at 107/17:36 GMT (12/07:15 MET). There were no more robotics operations during the remainder of the mission.

WING LEADING EDGE IMPACT DETECTION SYSTEM

ASCENT MONITORING

The Wing Leading Edge (WLE) Impact Detection System (IDS) was configured for the ascent data download activities. All units triggered and began recording data on Main Engine Ignition within 0.12 seconds of each other. Mission Elapsed Time was set to 9.37 seconds behind Data Elapsed Time (MET = DET – 9.37 sec) for both port and starboard wing units.

Due to failure of the KU-Band on the Orbiter, no data was down-linked to the ground until rendezvous and docking with the International Space Station (ISS). Once docked with the ISS, the ISS KU-Band capability became available to the Orbiter, enabling the down-link of ascent data files to the ground for analysis. All requested ascent summary data and 17 half-second windows of raw data were received, without incident, by 62 hr Mission Elapsed Time (MET). The ascent analysis was completed and the findings were issued at L+62 hours, reporting 1 probable impact to the chine and 3 probable Reinforced Carbon-Carbon (RCC) impact indications over 1.0 Grms. The damage likelihood for these RCC indications was less than 1/1000, which is identified as Category I.

SUSPECTED ASCENT DEBRIS IMPACTS ABOVE 1.0 GRMS

Time		Location			Magnitude		Criteria						Impact ^a		Damage Likelihood Category [†]
MET, Hr	DET, hr	Wing	RCC	Unit-Channel	Max.Grms	Max.G	Transient	Non-Mission	Shock	Damping	Spectral	Multi-Sensor	In-Flt	Post-Flt	
107.6	116.9	Stbd	Chine	1037-J3	2.62	9.17	+	+	+	+	+	+	P	P	N/A
109.4	118.8	Port	6/7	1013-J3	1.03	4.29	+	+	+	+	+	+	P	P	I
117.1	126.5	Port	6/7	1023-Jj3	1.51	3.73	+	+	+	+	+	+	P	P	I
126.9	136.3	Port	16/17	1241-J2	1.46	5.18	+	+	+	+	+	+	P	P	I

^aP = Probable

[†] 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 monitoring was originally scheduled to cover the period when the risk of critical damage to the RCC from Micrometeoroid/Orbital Debris (MM/OD) was expected to be highest. However, due to the loss of Orbiter KU-Band capability, all on-orbit monitoring occurred during the docked phase of the mission, which is a period of non-elevated risk

to the RCC panels. The periods of increased risk to the RCC for STS-131 were during the early and late imagery inspections of the RCC as well as during docking and undocking operations with the ISS. The total MM/OD monitoring time was 48 hours for the Port wing and 47 hours for the Starboard wing.

For this mission, the WLE IDS recorded 3 triggers, none of which satisfied all impact criteria. Analysis of the 3 triggers resulted in 1 questionable MM/OD impact indication. Review of post-flight data did not reveal any additional on-orbit indications.

SUMMARY OF ON-ORBIT IMPACT

Time	Location			Magni- tude	Transient	Non-Mission	Criteria					Impact ^a	
	GMT	Wing	RCC				Unit-Channel	Max.G	Shock	Damping	Spectral	Multi-Sensor	Trapped Wave
098/16:37:40	Stbd	6/7	1041-J3	0.81	+	+	+	+	+	o	o	Q	Q

^a Data Analysis Findings: **Pr**=Probable; **P**=Possible; **Q**=Questionable; **N**=No Impact; **U**=Unfound

CONCLUSIONS

The WLE IDS system performed well for ascent impact monitoring. An initial ascent report was published at L+62 hr. During the mission, four ascent impact indications above the 1.0 Grms threshold were reported with damage likelihoods of Category I (less than 1/1000). Post-flight review of the data found no additional ascent indications over 1.0 Grms.

One questionable MM/OD indication was detected and reported during flight. A complication with Radio Frequency (RF) communication is believed to have caused the sensors of On-orbit Group 1 to not receive a forced data take command from Unit 1041 when it triggered. Since there were no data available from the adjacent sensors, the multi-sensor criteria could not be evaluated, and therefore the indication could not be ruled as “possible” with any level of confidence.

Based on the ascent and on-orbit findings from all systems, including WLE IDS, the Orbiter Project Office (OPO) recommended that a focused WLE RCC inspection was not required, and the Mission Management Team decided that the Late Inspection was not required. The late mission Orbiter Boom Sensor System (OBSS) survey visually inspected the WLE after the Orbiter undocked 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 satisfactory and met all planned objectives for the equipment.

During the Micrometeoroid/Orbital Debris (MM/OD) planned Group 2 Sensor monitoring from [098/16:15:00 Greenwich Mean Time (GMT) to 099/11:15:00 GMT (03/06:54 to 04/00:54 Mission Elapsed Time (MET))] with the Wing Leading Edge (WLE) Impact Detection System (IDS), the Starboard wing sensor unit Serial Number (S/N) 1041 acquired a trigger. The trigger was on WLE IDS third channel (upper 6/7 RCC panel interface location) and the trigger failed to force a trigger on the other 10 sensor units as programmed (IFA STS-131V-05).

The WIS GFE team verified that the sensor (unit 1041), as well the other sensors in its group were properly programmed by reviewing the programming commands and results files. This was the first time a unit has triggered and all of the sensors in its group have failed to force trigger.

During an ISS survey using the Orbiter's Closed Circuit Television (CCTV) cameras during crew sleep, the zoom on CCTV Camera C began to act sluggishly in its response to commands from the ground (IFA STS-131-V-07). The ground performed some troubleshooting, but the zoom eventually stopped responding to commands completely and remained zoomed out. Further attempts to operate the zoom function of the camera were not successful.

During the Flight Crew Equipment (FCE) Debriefing, the crew reported that the Closed Circuit Television (CCTV) monitor 2 had a red tint and was not as sharp as monitor 1 (IFA STS-131-V-12). The monitor will be replaced during the post-flight turnaround activities.

The crew also reported at the FCE Debriefing that the Multi-Purpose Logistics Module (MPLM) Keel Camera was Flickering during the berthing operations, but the camera was usable (IFA STS-131-V-13). The camera was nominal during the unberth operations.

POST-LAUNCH PAD INSPECTION

The post-launch inspection of the Main Launch Platform (MLP) -3, Pad A Fixed Service Structure (FSS), and Pad A apron/infield/flame trench was conducted on April 5, 2010. The inspection proceeded relatively quickly while Safing Teams secured the Pad. The entire Pad, FSS and MLP were inspected. A piece of throat plug material from the Reusable Solid Rocket Booster (RSRB) was the only flight hardware found.

The Orbiter lift-off lateral acceleration data indicated a maximum of 0.10g. The Hold-Down Post (HDP) stud hang-ups are typically noted with lateral accelerations above 0.19g.

SRB Hold-down Posts Inspection

HDP no. 1 – The EA934 poured sidewalls were nominal with acceptable moderate pitting. The North and South sidewalls had delamination. 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. 2 – The EA934 poured sidewalls were nominal with minor acceptable pitting. The East sidewall had delamination. The Phenolic shim was nominal. Both firing lines were missing. Approximately 3-ft of Range Safety System (RSS) cable remained past the door. No galling or chatter marks were noted in the chamfer of the through-hole and the stud was set down.

HDP no. 3 – This HDP showed nominal indications of erosion on the Room Temperature Vulcanizing (RTV)- coated blast shield, which had proper closure.

HDP No. 4 – This HDP showed nominal indications of erosion on the RTV-coated blast shield, which had 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 South and East sidewalls had delamination. The Phenolic shim was nominal. It was noted that ¼ in. of the West-side firing line was protruding through the post hole. No galling or chatter marks were noted in the chamfer of the through-hole and stud was set down.

HDP No. 7 – This HDP showed nominal indications of erosion on the RTV-coated blast shield, which had proper closure.

HDP No. 8 – This HDP showed nominal indications of erosion on the RTV-coated blast shield, which had proper closure. The RSS cable was missing.

GN2 Purge Lines Inspection

The Left-Hand (LH) probe was erect and slightly bent toward the Southwest. Protective tape was present with no exposed braiding. The O-ring was present but was dropped 6 in. lower on the purge line.

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

SRB T-0 Ground Carrier Assemblies Inspection

The Ground Carrier Assemblies (GCAs) inspection provided the following data:

1. The LH RSRB T-0 GCA appeared to be in nominal condition with proper demate.
 - a. Several connector housings had broken sidewalls.
 - b. The 4J1 pin and sockets were raised higher than nominal.
 - c. All four frangible bolt halves were present.
2. The RH SRB T-0 GCAs appeared to be in nominal condition with proper demate.
 - a. Several connector housings had broken sidewalls.
 - b. 3J1 and 4J1 pin and sockets were raised higher than nominal.
 - c. Heat effects were noted on the 2J1 and 1J1 connector halves.
 - d. All four frangible bolt halves were present.

Liquid Oxygen and Liquid Hydrogen Tail Service Masts Inspection

Both the Liquid Oxygen (LO₂) and Liquid Hydrogen (LH₂) Tail Service Masts (TSMs) appeared to be undamaged and both bonnets appeared to have closed properly.

Main Launch Platform Deck Inspection

The Main Launch Platform (MLP) deck was in nominal condition. Typical blast erosion was observed in and around the RSRB flame holes.

Orbiter Access Arm (195 ft level) Inspection

The Orbiter Access Arm (OAA) was retracted and secured with no apparent damage. All slide-wire baskets remained secured at 195-ft level with no evidence of damage.

As seen from the 175 ft level, the OAA lower hinge point access door was open and the pip pin was disengaged.

Gaseous Hydrogen Vent Line Ground Umbilical Carrier Plate (215-ft level) Inspection

The Gaseous Hydrogen (GH₂) vent line latched on the eighth tooth (of eight) on the latching mechanism. The vent line had no bias in positioning. The GH₂ Vent Line had a nominal arresting cycle. The inspection of the Ground Umbilical Carrier Plate (GUCP) left-hand and right hand pivot assemblies indicate a nominal separation. The ET GUCP 7-inch GH₂ Quick-Disconnect probe was accessible for inspection and appeared to be undamaged. Both the Quick Disconnect (QD) poppet probe sealing surface and the poppet valve assembly were in good condition. The ET GUCP exhibited less-than typical blast damage and the pyrotechnic-bolt fired nominally. Both the 4 ft and 24 ft vacuum-jacketed braids were damaged and torn. The shock-absorber blanket on the 24' hose was damaged and torn loose at the withdraw-weight pass-through.

Gaseous Oxygen Vent Arm (255-ft level) Inspection

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

Launch Pad Facility Inspection

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

North RSRB Flame-Trench Inspection

The North RSRB flame-trench had one large piece (2 ft by 4 ft) of fondue-fyre material liberated, which was all the way down to the substrate. Also, two other small areas of fondue-fyre liberation were found on the upper right-hand corner of the RSRB main deflector.

Debris Items Found

The following debris items were found during the inspection.

1. Minor pieces of RSRB throat plug material were found on the surface of Launch-Pad surface.
2. Small pieces of fondue fyre were found on both the East and West Launch-Pad surface area.
3. A small writing pen a black plastic disc and a piece of spring were found on the west-side of the flame trench on the pad surface.
4. Two small bolts, one stainless-steel, were found about 150-ft south of the elevators.
5. At the 275-ft level a crane access door found open. GVA top hinge cover assembly had pooled water and rust.
6. At side 4 on the 255-ft level, a rust chip was found.. A Firex clamp found was on side 2.

7. At the 215-ft level, a broken bolt that was rusted through, and 4-in. by 4 in. by ¼ in. plate found. Also, a loose-gage plate was noted on side 4.
8. At the 175-ft level, a faceplate gage was found on side 4. Also a 1½-in. by 6 in. piece of metal found.
9. At the 155-ft level, a 1 in. by 3 in. lug portion of braided metal grounding-strap was found on side 1. Small fasteners were found on side 1 of the Orbiter Work Platform (OWP) beam (not able to be retrieved).
10. At the 135 ft level, a piece of metallic tape was found.
11. At the 115 ft' level, a 1.5-in. diameter washer was found.
12. Outside pad north gate perimeter lagoon: As seen from the 255-ft level, a floating object was observed with cylindrical geometry and appeared 5 to 10-ft long. Recommend further investigation. The object was not visible from ground level.
13. On the Pad perimeter (east side tube bank), a 1 ft by 2 ft Lexan-panel was 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

The launch photography provided data for the evaluation by the Debris Assessment Team to determine the condition of the TPS.

At -3.364 sec, a small piece of debris was observed falling inboard of the starboard Orbital Maneuvering System (OMS) pod stinger. One side of the object appears darker than the other side.

At 0.791 sec MET, three small light-colored features are present on the base heat shield outboard of Space Shuttle Main Engine (SSME) no. 3 immediately after lift-off. Corroboration with on-orbit R-bar Pitch Maneuver (RPM) imagery suggests the features are most likely due to tile-coating loss. The tile coating is not observed liberating.

At 42.229 sec [Mission Elapsed Time (MET)], a single piece of debris is observed falling aft near the vertical stabilizer. A single black object is seen falling aft of the trailing edge of the port speedbrake. A residual feature is visible on the speedbrake possibly indicative of a material loss.

Between 58.7 sec and 60.8 sec MET, unidentified debris (multiple objects) were observed falling aft during ascent.

At approximately 260 sec MET, multiple pieces of External Tank (ET) TPS debris was seen liberating outboard of the Liquid Oxygen (LO₂) feedline. The release location could not be determined, but the release appears to be near or just aft of the LH₂ intertank flange (possibly just aft of the 1115 flange) between the cable tray and the feedline. The debris was liberated in several pieces with at least three large pieces. One piece of debris appears to go over the Orbiter starboard wing. One piece of debris noted changing direction, indicating possible impact with the Orbiter

At approximately 265 sec MET, a single piece of debris was first seen near the Orbiter fuselage. The piece appears to come from the acreage area aft of the bipod and inboard of LO₂ Feedline. The piece travels down and aft towards the ET, then appears to contact the ET feedline, the changes direction and falls aft. A possible impact to Orbiter fuselage prior to contact with ET feedline was under consideration. No damage to the Orbiter noted.

At approximately 270 sec MET, at least two pieces of debris first appear outboard of the LO₂ feedline and appears to travel upward toward the Orbiter fuselage. One piece

appears to change direction, indicating possible contact to the Orbiter. The debris then travels outboard and aft over the starboard wing

At approximately 317 sec MET, a single piece of debris is seen falling aft. The debris appears to come from the -Y side acreage area aft of the bipod. The piece appears to impact the Orbiter lower surface, as a directional change was noted. The debris then travels toward the ET and appears to impact the ET. No tile damage was noted.

Photography showed missing ET TPS on outboard side of LH₂ tank acreage on the outboard side of the Xt 1129 LO₂ feedline bracket foot. The color of the material is noticeably darker in the center of the feature.

Photography showed missing ET TPS on the outboard side of 1377 LO₂ feedline bracket at the base fitting closeout.

The photography showed two small pieces of missing ET TPS on Xt 1593 Ice/Frost Ramp. The features are visible on outboard of the cable tray.

LAUNCH PAD OBSERVATIONS

At -3.166 sec, Lift-off debris was observed near the triangle bracket on the LH₂ Tail Service Mast (TSM).

At 0.552 sec MET, two small pieces of debris were observed falling from the Right-Hand (RH) RSRB DCS stud hole no. 2 shortly after lift-off.

Between 0.534 and 0.969 sec MET, debris was observed falling from the Left-Hand (LH) Reusable Solid Rocket Booster (RSRB) Debris Containment System (DCS) stud hole no. 8 shortly after lift-off.

At 0.921 sec MET, debris was observed falling from LH RSRB DCS stud-hole no. 7 shortly after lift-off

At 1.704 sec MET, a circular piece of debris was observed falling inside the Liquid Hydrogen (LH₂) Tail Service Mast (TSM) after the door has closed. The debris was contained within the TSM and posed no direct threat to the vehicle.

At 2.068 sec MET, dark-colored lift-off debris was noted near the southwest corner of the LH₂ TSM.

At 2.321 sec MET, lift-off debris was noted near the northeast side of the LO₂ TSM.

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APPENDIX A

STS-131 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	095:10:16:35.624 095:10:16:38.488 095:10:16:41.151
RSRB 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	095:10:20:57.072 095:10:20:57.232 095:10:20:57.392 095:10:20:57.552
Main Engine Start	SSME-3 Start Command Accepted SSME-2 Start Command Accepted SSME-1 Start Command Accepted	095:10:21:18.442 095:10:21:18.553 095:10:21:18.685
RSRB Ignition	RSRB Ignition Command	095:10:21:24.992
Throttle Up 104.5 Percent	SSME-2 Command Accepted SSME-3 Command Accepted SSME-1 Command Accepted	095:10:21:29.469 095:10:21:29.479 095:10:21:29.502
Throttle Down to 74.2 Percent	SSME-2 Command Accepted SSME-3 Command Accepted SSME-1 Command Accepted	095:10:22:00.190 095:10:22:00.199 095:10:22:00.222
Throttle Up to 104.5 Percent	SSME-2 Command Accepted SSME-3 Command Accepted SSME-1 Command Accepted	095:10:22:13.150 095:10:22:13.160 095:10:22:13.182
Maximum Dynamic Pressure (Max Q)	Derived Ascent Dynamic Pressure	095:10:22:28
Both RSRMs at 50 psi	RH RSRM Chamber Pressure LH RSRM Chamber Pressure	095:10:23:26.192 095:10:23:26.312
End RSRM Action	RH RSRM Chamber Pressure LH RSRM Chamber Pressure	095:10:23:28.192 095:10:23:28.192
SRB Separation Command	RSRB Separation Command Flag	095:10:23:30
SRB Physical Separation	LH APU A Turbine Loss of Signal RH APU B Turbine Loss of Signal LH APU A Turbine Loss of Signal RH APU B Turbine Loss of Signal	095:10:23:30.792 095:10:23:30.792 095:10:23:30.832 095:10:23:30.832
OMS Assist Ignition	L Engine Bipropellant Valve Position R Engine Bipropellant Valve Position	095:10:23:41.0 095:10:23:41.2
OMS Assist Cutoff	R Engine Bipropellant Valve Position L Engine Bipropellant Valve Position	095:10:25:25.6 095:10:25:25.6
Throttle Down for 3g	SSME-2 Command Accepted SSME-3 Command Accepted SSME-1 Command Accepted	095:10:28:45.958 095:10:28:45.970 095:10:28:45.991
3G Acceleration	Total Load Factor (g)	095:10:28:51.6
Throttle down to 67 percent for Cutoff	SSME-2 Command Accepted SSME-3 Command Accepted SSME-1 Command Accepted	095:10:29:41.639 095:10:29:41.651 095:10:29:41.672
SSME Shutdown	SSME-2 Command Accepted SSME-3 Command Accepted SSME-1 Command Accepted	095:10:29:48.079 095:10:29:48.091 095:10:29:48.113
Main Engine Cutoff (MECO)	MECO Command Flag MECO Confirmed Flag	095:10:29:49 095:10:29:49
ET Separation	ET Separation Command Flag	095:10:30:10

APPENDIX A

STS-131 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	095:10:35:56.424 095:10:36:17.068 095:10:36:31.781
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	L Engine Bipropellant Valve Position R Engine Bipropellant Valve Position	095:10:58:39.4 095:10:58:39.6
OMS 2 Cutoff	R Engine Bipropellant Valve Position L Engine Bipropellant Valve Position	095:11:00:48.0 095:11:00:48.0
Payload Bay Doors Open	Right Payload Bay Door Open 1 Left Payload Bay Door Open 1	095:11:50:42 095:11:52:01
OMS 3 Ignition	L Engine Bipropellant Valve Position R Engine Bipropellant Valve Position	095:13:07:28.0 095:13:07:28.1
OMS 3 Cutoff	R Engine Bipropellant Valve Position L Engine Bipropellant Valve Position	095:13:08:31.1 095:13:08:31.2
OMS 4 Ignition	L Engine Bipropellant Valve Position R Engine Bipropellant Valve Position	096:01:56:28.4 096:01:56:28.5
OMS 4 Cutoff	R Engine Bipropellant Valve Position L Engine Bipropellant Valve Position	096:01:57:07.9 096:01:57:08.0
OMS 5 Ignition	L Engine Bipropellant Valve Position R Engine Bipropellant Valve Position	097:03:35:14.8 097:03:35:14.9
OMS 5 Cutoff	L Engine Bipropellant Valve Position R Engine Bipropellant Valve Position	097:03:35:28.6 097:03:35:28.7
OMS 6 Ignition	L Engine Bipropellant Valve Position R Engine Bipropellant Valve Position	097:05:06:44.2
OMS 6 Cutoff	L Engine Bipropellant Valve Position R Engine Bipropellant Valve Position	097:05:06:54.6
Docking	Capture	097:07:44:09
Undocking	Undocking Complete	107:12:52:10
Flight Control System Checkout – APU 1 Start	APU-1 Gas Generator Chamber Pressure	108:07:29:20.974
APU 1 Stop	APU-1 Gas Generator Chamber Pressure	108:07:33:20.674
OMS 7 Ignition	L Engine Bipropellant Valve Position R Engine Bipropellant Valve Position	108:17:31:18.6 108:17:31:18.7
OMS 7 Cutoff	L Engine Bipropellant Valve Position R Engine Bipropellant Valve Position	108:17:31:29.6 108:17:31:29.7
Payload Bay Door Close	Left Payload Bay Door Close Right Payload Bay door Close	110:07:47:26 110:07:49:15
APU Activation	APU-2 Gas Generator Chamber Pressure APU-1 Gas Generator Chamber Pressure APU-3 Gas Generator Chamber Pressure	110:11:57:56.958 110:12:23:37.064 110:12:23:44.631
Deorbit Maneuver Ignition	L Engine Bipropellant Valve Position R Engine Bipropellant Valve Position	110:12:02:59.1 110:12:02:59.2
Deorbit Maneuver Cutoff	R Engine Bipropellant Valve Position L Engine Bipropellant Valve Position	110:12:05:56.9 110:12:05:57.0
Entry Interface	Orbital Altitude Referenced to Ellipsoid	110:12:36:44

APPENDIX A
STS-131 MISSION EVENTS

EVENT	DESCRIPTION	ACTUAL GMT
Blackout End	Data Locked (High Sample Rate)	NO BLACKOUT
Terminal Area Energy Management (TAEM)	Major Mode Code (305)	110:13:02:22
Main Landing Gear Contact	Main Landing Gear Left Hand Tire Pressure Main Landing Gear Right Hand Tire Pressure	110:13:08:34 110:13:08:34
Main Landing Gear Weight on Wheels	Main Landing Gear Left Hand Weight on Wheels Main Landing Gear Right-Hand Weight on Wheels	110:13:08:35 110:13:08:38
Drag Chute Deployment	Drag Chute Deploy 1 CP Volts	110:13:08:36.4
Nose Landing Gear Contact	Nose Landing Gear Left Hand Tire Pressure 1	110:13:08:43
Nose Landing Gear Weight on Wheels	Nose Landing Gear Weight on Wheels	110:13:08:43
Drag Chute Jettison	Drag Chute Jettison 2 CP Volts	110:13:09:08.9
Wheels Stop	Velocity with respect to Runway	110:13:09:32
APU Deactivation	APU-1 Gas Generator Chamber Pressure APU-2 Gas Generator Chamber Pressure APU-3 Gas Generator Chamber Pressure	110:13:24:29.024 110:13:24:47.188 110:13:25:03.892

APPENDIX B

STS-131 IN-FLIGHT ANOMALIES

INTRODUCTION

This appendix contains listings and discussions of each of the In-Flight Anomalies (IFAs) that were identified for the STS-131 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

APPENDIX B
STS-131 IN-FLIGHT ANOMALIES
ORBITER ANOMALIES

IFA Number	Title	Comments
STS-131-V-01	MPS Engine 3 LH ₂ Inlet Pressure 3 Off-Scale Low	<p>Just prior to Space Shuttle Main Engine (SSME) 3 start, the MPS LH₂ inlet pressure measurement began behaving erratically at 095/10:21:15 GMT and eventually went to Off-Scale Low (OSL). The loss of these data did not affect the ascent and remained no concern for the remainder of the flight.</p> <p>Postflight: Post-flight troubleshooting found an internal open circuit in the pressure transducer. The failed transducer was removed and replaced.</p>

APPENDIX B STS-131 IN-FLIGHT ANOMALIES

ORBITER ANOMALIES

IFA Number	Title	Comments
STS-131-V-02	Ku Band Forward and Return Link Failures	<p>During the Post-Insertion Ku-Band Activation, at approximately 095:/12:15 GMT [00/01:53 Mission Elapsed Time (MET)], the Ku-Band failed the self test. During the first self-test after Ku-Band activation, the signal strength telemetry was low (0.56 V; normally greater than 0.9) and the range in Radar Passive stayed at 0 ft, and should have been 10, 240 +/- 500 ft. In addition, the Detect and Track indications were missing. The self-test was repeated. During the second run, all indications looked good, except the signal strength was still low. In both cases, the self-test indicated failed due to Electronics Assembly 2 (EA-2). Ku-Band was then set up for the Communications (COMM) mode with the General Purpose Computer (GPC) Acquisition (ACQ) antenna steering mode. Forward-link signal strength was present, but low at approximately -103 dBm). Detect, track, and frame synchronization indications were never present. For the return link, the network reported receiver lock on the Ku-Band signal, but they could not acquire bit and frame synchronization. Television (TV) modulation could be seen but it was scrolling, snowy, and unusable. An attempt was also made to dump an Solid State Recorder (SSR) via Ku-Band channel 2, but it was unsuccessful.</p> <p>Several troubleshooting attempts were made, including commanding to GPC DESIG antenna steering mode, power cycling via command, power cycling via the MNB R14 KU ELEC circuit breaker, trying PM mode (48 Mbps on Ku-Band channel 3; default is FM mode with analog TV, and commanding the Ku-Band forward link from 216 Kbps mode to 72 Kbps mode. However, there was no success in recovering the Ku-Band operations. After the commanded power cycle, the signal strength was too low to be seen in the telemetry. A third self-test was attempted, but also failed. At 095/15:59 GMT (00/02:38 MET), the signal strength increased back to approximately 103 dBm, but Ku-Band forward and return links were still not functional. From this point on, sometimes signal strength was not evident in the data and sometimes it was, but it was always low.</p> <p>A fourth self-test was performed pre-Rendezvous (RNDZ) and failed again with low signal strength and an EA-2 failed indication. The attempt to use Ku-Band Radar during RNDZ was unsuccessful. Forward link lock was never achieved. Rendezvous was completed using other tools.</p> <p>Post-Flight: Troubleshooting isolated the problem to the Ku-band Deployed Assembly (DA) failed output. The DA was removed and replaced. Testing on the removed DA determined the cause of the output failure was a faulty transistor in the DA exciter circuit. Failure analysis of the transistor showed a failed attachment point of the internal bond wire to the internal emitter lead. The mechanical bond was weakened due to the presence of human contamination (possibly saliva) inadvertently introduced during the manufacturing process in 1978.</p>

APPENDIX B
STS-131 IN-FLIGHT ANOMALIES
ORBITER ANOMALIES

IFA Number	Title	Comments
STS-131-03	Rudder Speedbrake TPS Liberation	<p>A debris event occurred during ascent at 42 sec MET from port-upper Rudder Speed Brake (RSB) trailing edge. Tile has broken away, and it appeared to be liberated. Visible charring along the aft edge. Visible signs of Strain Isolation Pad (SIP) and densification layer on sidewall. Damage was located on the trailing edge of the Left Hand (LH) Upper Rudder Speed Brake Panel Assembly. The RSB Panels are aluminum-honeycomb panels attached to spars and ribs with a full-depth aluminum honeycomb trailing-edge wedge. The trailing-edge wedge is 9 in. wide and the depth is variable along the XT axes. Facesheet thickness are 0.012-in.. The tile extends approximately 1.9 in. over the trailing edge wedge. The tile covers approximately half of the full depth of honeycomb Structure..</p> <p>Post-flight: Tile condition did not differ significantly from on-orbit photos, however charring was noted on tile SIP and filler bar. No damage to the structure was noted. Removal of the adjacent gap filler identified Room Temperature Vulcanizing (RTV) contamination on the SIP and sidewall. Stress evaluation showed that the RTV contamination resulted in hard spots which produced stress concentrations and negative tile margins. A CHIT was implemented to support failure analysis by inspecting the RSB for indications of 1) evidence of tile-to-tile contact across the RSB gap, 2) tiles overhanging RSB panels, 3) configuration of new/previous through the thickness cracks/repairs, and 4) SIP contamination with RTV.</p>
STS-131-V-04	TPS Anomalies	<p>A complete listing of the Thermal Protection System (TPS) Tile, Blanket, and Reinforced Carbon-Carbon (RCC) Regions of Interest (ROI) evaluated by the Tile and RCC Damage Assessment Teams are documented in the TPS Imagery Inspection Management System (TIIMS) Database located at: http://isal-web1.jsc.nasa.gov/tiims/TIIMS.htm</p> <p>Six TPS items were identified in-flight which exceeded pre-defined screening criteria and were entered into the TIIMS Database. All 6 items were cleared using standard procedures/tools.</p> <p>No focused inspection was required based on the data available from FD3 RPM images and FD 2 inspections.</p> <p>Postflight: Standard post-flight inspection and repair</p>

**APPENDIX B
STS-131 IN-FLIGHT ANOMALIES
ORBITER ANOMALIES**

IFA Number	Title	Comments
STS-131-V-05	WLE Sensor No. 1041 Failed to Trigger 10 Sensor Units	<p>During the planned Group 2 Sensor Micrometeoroid/Orbital Debris (MM/OD) monitoring from 098/16:15:00 GMT –099/11:15:00 GMT (03/05:53:35 to 04/00:53:36 MET) with the Wing Leading Edge Impact Detection System (WLE IDS), Starboard wing sensor unit S/N 1041 acquired a trigger on its third channel (upper 6/7 RCC panel interface location) and failed to force trigger the other 10 sensor units via RF as the system is programmed. The WLE IDS team verified the sensor unit 1041 and the other sensors in its group were properly programmed by reviewing the programming commands and result files. This was the first time a unit has triggered and all of the sensors in its group have failed to force trigger.</p> <p>The probable cause is still unknown and is still under investigation. A review of the sensor unit 1041 historical database revealed no reports that may provide insight to this anomaly.</p> <p>Post-flight: The sensor unit was Removed and Replaced (R&R) post-flight at KSC and shipped back to JSC for further troubleshooting.</p>

APPENDIX B STS-131 IN-FLIGHT ANOMALIES

ORBITER ANOMALIES

IFA Number	IFA Number	Comments
STS-131-V-06	SSR2 Moded To Standby Unexpectedly	<p>At 101/05:43:10 GMT(05/19:21:45 MET), Solid State Recorder (SSR) 2 unexpectedly moded itself to standby (STBY) and reported a corresponding Critical Bite Failure (CBF) for 2 sec. SSR2 was recording Network Signal Processor (NSP) data at memory position 660 at the time. It was commanded back to record mode (RCDA) (same position, writing from the beginning of the segment) and the anomaly did not repeat. A Comprehensive Self Test (CST) was performed on the recorder and all results came back nominal. However, 17 sec after the self-test was completed, the recorder annunciated another 2-sec CBF. The recorder was already in STBY from completion of the self-test, so it is unknown if the "mode to STBY" would have repeated. SSR2 was commanded back to record mode (RCDA) and was positioned to record through position 660 again, with no recurrence of the anomaly. Two additional CBF events were found for SSR2 at 095/13:21:06 GMT (00/02:59:41 MET) and at 096/19:06:45 GMT (00/14:45:23 MET). Analysis of the archived telemetry showed no loss of data during each of the 4 CBF timeframes. SSR1 had been in record mode (RCDA) the entire time and functioned nominally. Analysis of the data from SSR1 indicated that it did not experience any CBFs during the mission. At 101/15:46:15 GMT (06/05:24:50 MET), data was successfully played back and verified from SSR2. The Solid State Mass Memory (SSMM) portion of the MMU appears to have functioned nominally.</p> <p>Post Flight: R&R SSR 2.</p>
STS-131-V-07	CCTV Camera C Zoom Not Functioning	<p>During the Flight Night (FN) 7 ISS External Survey activity, the Payload Bay Camera C (starboard aft bulkhead) zoom function stopped operating nominally. The zoom function was first noticed sluggish at 102/20:21 GMT (07/09:59 MET). The ground controller continued to command the camera for the survey activity; but at about 102/21:49 GMT (07/11:28 MET), the camera began responding to zoom commands only intermittently. To troubleshoot the zoom capability, Camera C was power cycled via ground commands, at 102/22:05 GMT (07/11:44 MET). Following this action, the camera stopped responding to zoom commands. Additionally, INCO pointed Payload Bay Camera B (port aft bulkhead) was pointed at Camera C for a visual inspection, and nothing off-nominal was observed. Camera C was left fully zoomed out, and it remained unresponsive to zoom commands for the remainder of the flight. Nominal functionality was confirmed for all other commands to the camera (e.g., pan/tilt, focus, power, etc.). On FD 13, a final attempt was made to zoom the camera, but it was unsuccessful.</p> <p>Post-flight:: The camera was returned to the vendor for failure analysis and repair.</p>

**APPENDIX B
STS-131 IN-FLIGHT ANOMALIES
ORBITER ANOMALIES**

IFA Number	IFA Number	Comments
STS-131-V-08	Left RCS Fuel Helium Isolation B Valve Slow to Close	<p>During the post-wave-off RCS helium system re-configuration, the Left RCS Fuel Helium B Isolation valve was being taken from OPEN to CLOSED at 109/12:58:57 GMT (14/02:37:32 MET. When the cockpit switch (OPEN/CLOSED as indicated by telemetry) was taken to CLOSE at 109/12:58:58 GMT (14/02:37:33 MET), the Oxidizer Helium B Isolation Valve Indicated CLOSED within the expected time (less than 1 sec); however, the Fuel Helium B Isolation Valve remained OPEN for 46 sec before finally indicating CLOSED. Since this brought the system into the desired configuration, no crew action was required. No flight impact occurred during th remainder of the mission.</p> <p>The Left RCS Helium B valves remain in the nominally closed position until system reconfiguration for deorbit/entry when the oxidizer/fuel pair were taken to the open position. If the fuel He B valve failed open following the entry reconfiguration, there is no impact unless both downstream series redundant pressure regulator stages fail open; in that instance, the burst disk/pressure relief valve would protect the propellant tanks from over-pressurization and sufficient ullage was present to support entry usage.</p> <p>There is an existing deferred PR on this valve, which documents cases where this valve (LV201) has occasionally exhibited a false Valve Position Indication (VPI) where the indication during ground processing was OPEN when it should have been CLOSED. In these few cases, the VPI anomaly occurred after Helium tank venting when the valve was confirmed closed by lack of gas flow. The PR attributes these VPI issues to the valve being exposed to low temperature Helium gas.</p> <p>Postflight: Troubleshooting tests indicated nominal valve operation. UA board approved UA with a VPI indication as the most likely cause of the flight signature.</p>

APPENDIX B STS-131 IN-FLIGHT ANOMALIES

ORBITER ANOMALIES

IFA Number	IFA Number	Comments
STS-131-V-09	FRCS Fuel Helium Isolation A Valve Slow to Close	<p>The forward RCS Fuel Helium A-leg Valve did not cycle CLOSED when commanded by the cockpit switch. The associated Oxidizer Helium valve closed nominally as indicated by its switch position telemetry 82 seconds after the switch command, the Fuel Helium valve indicated CLOSED. The valve nominally closes in less than one (1) sec. Telemetry from both Open and Closed indications showed movement at the same time, but this could be an indication problem only since both measurements are fed from a single reed switch on the valve. Since there was no pressure difference across the valve, it is indeterminate whether this is a valve or indication problem only. STS-131 flight data was reviewed, and valve performance was nominal earlier in the mission. There were no mission impacts or crew responses required. The forward RCS Fuel Helium A-leg Valve did not cycle CLOSED when commanded by the cockpit switch at 110/13:35:39 GMT (15/03:14:14 MET). The associated Oxidizer Helium valve closed nominally as indicated by its position telemetry. 82 seconds after the switch command, the Fuel Helium valve indicated CLOSED. The valve nominally closes in less than 1 sec. Both the Open and Closed measurements indicated movement at the same time, but this could be an indication problem only since both measurements are fed from a single reed switch on the valve. Since there was no pressure difference across the valve, it is indeterminate whether this is a valve or indication problem only. STS-131 flight data was reviewed, and valve performance was nominal earlier in the mission. There were no mission impacts or crew responses required.</p> <p>Troubleshooting tests indicated nominal valve operation. PRACA review found prior to the occurrence on this valve during STS-119 post-flight valve test. Problem did not repeat during ground flow or subsequent flight, STS-128. UA board approved UA with a VPI indication as the most likely cause of the flight signature.</p>
STS-131-V-10	Protruding or Missing Window Ceramic Plugs Protruding	<p>During the post-landing inspection several ceramic plugs were found to be either missing or protruding. The -186 tile near Window 6 had a plug protruding 70 millimeters, which was documented and removed. Also, near to window 6, The -184 tile had the ceramic plug missing. This plug was installed and visible during the R-Bar Pitch Maneuver (RPM) imagery, and the missing plug was documented. On window 5, the -184 tile had a plug protruding 245 millimeters. It was documented and removed.</p> <p>Post-flight: Post flight inspection indicated design/installation deficiencies. Tactile inspection of window plugs revealed several were loose or rotated in insert. Braided cord "locking feature" between the insert and the plug threads were not able to lock plug in place. The plug assembly design was improved to increase capability of braided string/cord "locking feature". All susceptible plugs were removed and replaced for STS-133.</p>

APPENDIX B STS-131 IN-FLIGHT ANOMALIES

ORBITER ANOMALIES

IFA Number	IFA Number	Comments
STS-131-V-11	The AGC Levels on the Upper Left S-Band Antenna were Noisy	Starting around 109/10:30 GMT (14/00:09 MET), the Automatic Gain Controller (AGC) levels on the Upper Left S-Band Quad Switch-Beam Antenna path became noisier causing intermittent communications in the Upper Left path. A review of the reflected-power telemetry also showed the reflected power step-changes at random times during operation in both forward and aft antenna positions prior to the noisier AGC. The reflected power step-changes were lower in String 1 than in String 2 given the better impedance match. Post-flight: Post-flight Troubleshooting did not recreate the on-orbit symptoms but did identify two suspect cable connections in the UL path. The suspect connectors were cleaned and remated. A semi-rigid cable was removed and replaced with a flexible cable. This was closed as a UA.
STS-131-V-12	CCTV Monitor 2 Had Red Tint	Crew reported at the Flight Crew Equipment (FCE) Crew Debriefing that the Closed Circuit Television (CCTV) Monitor 2 had a red tint and was not as sharp as Monitor 1. Post-Flight: The monitor was removed and replaced and was shipped to JSC for test and evaluation. The initial conditions revealed that the brightness control was set to full brightness and the contrast control was set to full low – neither were in the normal detent position. When properly adjusted, the monitor was found to be in perfect operating condition and was returned as a flight spare. .
STS-131-V-13	MPLM Keel Camera was Flickering and Usable	The crew reported during the FCE Crew Debriefing that during berthing operations the keel camera was flickering and usable. The camera was fine during the unberthing operations. Post-Flight: The camera was removed and shipped to JSC for testing and verification of the anomaly. Testing was still progress at the time of publication. No anomaly was seen when tested in ambient laboratory conditions. A thermal test is planned to try and repeat the reported problem.
STS-131-V-14	Cracked Flow Control Valve Poppet	Following post STS-131 FCV removal and inspection, CRP-1015 poppet S/N 26 was found cracked. The poppet was opened and verified to be in family with previous cracks, therefore no change to existing FCV flight rational based on the in-family crack.

**APPENDIX B
STS-131 IN-FLIGHT ANOMALIES**

REUSABLE SOLID ROCKET BOOSTER ANOMALIES

IFA Number	Title	Comments
STS-131-B-001	Uploaded Accelerometer Data from the DAS Showed 446 sec of Preflight Testing Followed by the First 94	<p>The SoMat data recorder in the BI142R DAS recorded as expected for a total of 540 seconds after its preflight initialization, but the first 446 seconds of uploaded data consisted of preflight troubleshooting activities. The last 94 seconds of the recording was the first 94 seconds of flight before the recorder came to a programmed stop. The DAS did not record a full flight-set of accelerometer data (approx. 400 seconds).</p> <p>The DAS data recorder operated correctly and recorded a full 540 seconds after preflight initialization before reaching a programmed stop 94 second after launch. The real-time clock in the data recorder documented the fact that latest 94-second record interval began on launch day starting at 0621 hours (time of launch). A review of the recorded preflight data confirmed that the DAS orientation at the time preflight accelerometer spikes occurred was consistent with the DAS sitting on the bench.</p> <p>CORRECTIVE ACTION: The Electrical Design Engineering 90PRC-0006 was updated, to record the time spent on final g-switch testing and verify it takes less than 60 sec, and to re-initialize the SoMat and repeat the final g-switch test if the DAS is powered for any reason (other than to conduct the original g-switch test) after the original initialization.</p>

APPENDIX B
STS-131 IN-FLIGHT ANOMALIES
REUSABLE SOLID ROCKET MOTOR ANOMALIES

No Reusable Solid Rocket Motor anomalies were identified during the review and analysis of the flight data.

APPENDIX B
STS-131 IN-FLIGHT ANOMALIES
EXTERNAL TANK

No External Tank anomalies were identified during the post-flight review and analysis of the flight data.

**APPENDIX B
STS-131 IN-FLIGHT ANOMALIES**

SPACE SHUTTLE MAIN ENGINE ANOMALIES

IFA Number	Title	Comments
STS-131-E-001	Main Engine 2 High Pressure Fuel Turbo Pump 21 Degree Accelerometer Disqualified at Start of Tanking plus 7 min 19 sec.	<p>During ascent, the AHMS registered a FID at 445.8 seconds that indicated disqualification of the High Pressure Fuel Turbo Pump (HPFTP) 21 accelerometer. A spike in HPFTP 21 deg accelerometer data caused the channel to be disqualified.</p> <p>A data base of all known accelerometer measurement problems was assembled, including intermittent coaxial cable continuity, improper installation torque, etc. The controller memory dump data from the flight was compared to these known measurement problems. The anomaly was determined to be caused by random spurious discharge of thermal generated charge accumulation on the accelerometer crystal surfaces, commonly known as pyroelectricity. After the postlanding Modular Auxiliary Data System (MADS) data download, the MADS data was evaluated and found to be consistent with the data from the controller memory dump.</p>

APPENDIX B STS-131 IN-FLIGHT ANOMALIES

SYSTEM ENGINEERING AND INTEGRATION ANOMALIES

IFA Number	Title	Comments
STS-131-I-001	Unexpected Debris/Debris Exceeding Mass Allowables prior to Pad Clearance (Liftoff Debris)	<p>STS-131 experienced unexpected debris and expected debris exceeding the mass allowable prior to pad clearance. 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 was 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 (e.g. grating clips; gauge face covers; conduit clamps; and mounting hardware for electrical panels). Ongoing mitigations include Foreign Object Damage (FOD) awareness, attrition-based removal of hardware, routine inspections, and monitoring facility corrosion.</p> <p>Post-flight: No updates to NSTS 60559 are recommended as part of this Integrated In-Flight Anomaly (IIFA) closure.</p>
STS-131-I-002	Rudder Speed Brake TPS Liberation	<p>During STS-131 ascent, at approximately 42.2 sec MET, a piece of a vertical tail port Rudder Speed Brake (RSB) tile was observed liberating. The RSB tile debris was seen falling aft of vehicle during ascent with no observation of any contact to the vehicle. RSB tile liberation is considered unexpected debris. Therefore, no allowable is annotated in NSTS 60559. A thermal/structural analysis was performed on the RSB components that would be affected by a RSB tile-loss to assess the risk. The analysis of the exposed internal structures for both ascent and entry showed that a partial tile loss will result in local temperature exceedances during ascent only; however the structural integrity will not be compromised. The analysis included losing one entire tile, as well as two-tile loss scenarios, with both showing similar results. Thus, a partial RSB tile-loss in itself does not represent a safety-of-flight issue from a thermal or structural concern.</p> <p>The effect of the resulting Outer Mold Line (OML) change to the RSB performance has also been assessed and does not pose a risk to controllability. A Debris Transport Assessment (DTA) was also completed to determine whether transport to other Elements was feasible. The results showed that a partial RSB tile-loss can only impact Orbiter structures, with the likelihood of such impacts is relatively low.</p> <p>Post-flight: No constraints and one-flight interim disposition for STS-132 were approved. Program documentation has been written to address all additional work to be completed by the Orbiter Project (tracked under Orbiter IFA STS-131-V-03). Documentation (Chit) has been approved to implement new inspection procedures for the RSB tiles on all Orbiter vehicles.</p>

APPENDIX B STS-131 IN-FLIGHT ANOMALIES

SYSTEM ENGINEERING AND INTEGRATION ANOMALIES

IFA Number	Title	Comments
STS-131-I-003	Windows 5, 6 Missing/Protruding Ceramic Plugs	<p>During STS-131 post flight inspection, a Ceramic plug was missing adjacent to Window 6 and several plugs located around Windows 5 and 6 were either protruding or recessed below the nominal-installed position. The Runway Inspection Team identified a protruding plug on Window 5 but due to viewing angles and difficult access, the missing Window 6 plug was not discovered until inspection in the Orbiter Processing Facility (OPF). The missing plug (Window 6) was present during STS-131 on-orbit -imaging and no protruding plugs were noted throughout the flight during the on-orbit inspections. If any of the protrusions were present on-orbit, the protrusions were below the on-orbit imagery detection threshold of 0.15-in. preventing detection during those inspections. There is no evidence of heating in the lost insert location which indicates the loss occurred following entry heating. Ceramic insert plugs for the windows, crew hatch, and Forward Reaction System (FRCS) locations were inspected for STS-132 and were determined to be acceptable or will be repaired.</p> <p>The Interim Closure of this IIFA was accepted, based on the installation of alternate cordage on the ceramic plugs in the Window, FRCS and Crew Hatch areas, which was shown to improve the running torque and decrease the likelihood of liberating the ceramic plugs. The completion of the ascent Probabilistic Risk Assessment (PRA) for the Payload Bay Door hinge locations that were not accessible for inspection to quantify any residual risk.</p> <p>While some increase in risk is expected, there is no expected increase in risk category and no changes will be required to the Integrated Hazard Report (IDBR-01, <u>Ascent Debris Impact to SSV</u>).</p>

APPENDIX B STS-131 IN-FLIGHT ANOMALIES

SYSTEM ENGINEERING AND INTEGRATION ANOMALIES

IFA Number	Title	Comments
STS-131-I-004	Tile Repair Loss on Base Heat Shield	<p>A small piece of debris was observed falling inboard of the right Orbital Maneuvering System (OMS) pod stinger after Main Engine Ignition (MEI) at -3.364 sec. Post-flight investigation revealed it was an Room Temperature Vulcanizing (RTV) material repair that liberated and likely took some additional tile material along with it. This area does not present a significant concern for ascent or entry heating. Although exposed structure was found in the cavity, the Koropon still has a nice green color, which shows that there was very little heating in the cavity. This RTV repair is typical of other locations on the base heat shield. The maximum volume that can be repaired with this method is 1 inch³. The total mass loss estimated from the final divot size was approximately 21.83 grams.</p> <p>The TPS PRT has not determined a root cause, but the leading suspect cause is MEI based on when the failure occurred. An IIFA was initiated because RTV TPS Repairs on the Base heat Shield are not considered expected debris. The TPS PRT has taken an action to review repair history to determine if there is any correlation between the maximum allowable size of the Base Heat Shield RTV repairs and the last update to the MEI environment. This lift-off debris loss was evaluated and determined to be of no concern. The impact energy from a liberated tile fragment at the time and size observed is bounded by an impact from an allowable ice loss (0.333 lb_m) from the Tail Service Mast (TSM) umbilical interface. Additionally, the coefficient of restitution for the tile material is insufficient to pose a rebounding impact risk. Since the failure took place prior to lift-off and the leading cause was MEI, no ascent DTA was performed. Interim closure of this IIFA (STS-131-I-004) was approved as an Unexplained Anomaly (UA) for STS-132 and STS-133 pending completion of TPS PRT action to review MEI environment. There is no increased risk or update required to the Integrated Hazard Report IDBR-01.</p>

**APPENDIX B
STS-131 IN-FLIGHT ANOMALIES**

FLIGHT SOFTWARE ANOMALIES

No Flight Software anomalies were identified during the STS-131 Mission.

**APPENDIX B
STS-131 IN-FLIGHT ANOMALIES**

FLIGHT OPERATIONS AND INTEGRATION ANOMALIES

No In-flight anomalies were identified from the analysis of the data.

APPENDIX B STS-131 IN-FLIGHT ANOMALIES

MISSION OPERATIONS ANOMALIES

IFA Number	Title	Comments
STS-131-D-001	Missing Checklist Step For Keel-Camera Heater	A step was missing in the Post Insertion (PI) Checklist (C/L) that caused Standard Switch Panel (SSP) 2 Circuit Breaker (CB) 2 to be left open. This prevented power to be applied to the Multi-Purpose Logistics Module (MPLM) keel camera heaters during the PI timeframe. This situation was noticed during the TriDAR power-up at approximately 01/16:13:00 Mission Elapsed Time (MET) at which time the CB was closed and keel camera heaters activated. Subsequent investigation revealed that the step was removed by the Book Manager pre-mission as part of the Book Manager while ensuring that the procedures nomenclature was in accordance with the STS-131 Procedures Nomenclature (PNOM) book. In doing so, a logic error was made based on an error in the PNOM book. The PNOM book had an label error on SSP2 for that CB. The PNOM CR process was found to have a process escape that allowed the final version of the book to be published with the error.
STS-131-D-002	Incorrect Communications Predicts Due to PADS error	The Problem Action Data System (PADS) application AR 008079 caused the sign of the initial and all subsequent roll angles to be incorrect on a published pad for certain deorbit geometries. The workaround for this AR is described in a OPS NOTE, which requires the erroneous roll direction to be manually edited prior to publication. However, due to a different AR (058617, OPS NOTE DMON058617), each time the output is opened for editing, all of the fields revert back to the values generated by the application. In this particular case, the Trajectory Officer initially applied OPS NOTE DMON-658 correctly to all of the PADs for all of the deorbit opportunities. However, the Trajectory Officer later opened the PAD for the KSC 238 opportunity to apply a second workaround for a permanent limitation of the software, which erased the first workaround that had been applied for AR 008079. The Trajectory Officer did not notice that this had occurred and so failed to apply a third workaround required by Ops Note DMON058617, which is to reapply the first workaround for AR 008079. As a result, the PAD was published with incorrect roll directions which caused the INCO Flight Controller to make incorrect predictions for S-Band communication dropouts during the Entry.
STS-131-D-003	Flight Day 3 Water Dump Attitude Error	The planned pre-docking Shuttle waste water dump was performed in a biased posigrade attitude. It should have been performed in a retrograde attitude. The STS-131 Flight Day (FD) 3 dump situation is not explicitly addressed in the applicable Flight Rule, A2-109, due to the STS-131 Orbiter-ISS phase angle, so a pre-flight a plan was developed to delay the start of the dump until the Orbiter was in a region defined in Flight Rule A2-109. The pre-flight-coordinated plan was not communicated to all flight control shift teams and was not executed.

APPENDIX C

DOCUMENT SOURCES

MER DAILY REPORTS

The following STS-131 MER Daily Reports by Michael D. Wright, Lead MER Manager:

Launch and First Daily Report, dated April 5, 2010
Second Daily Report, dated April 6, 2010
Third Daily Report, dated April 7, 2010
Fourth Daily Report, dated April 8, 2010
Fifth Daily Report, dated April 9, 2010
Sixth Daily Report, dated April 10, 2010
Seventh Daily Report, dated April 11, 2010
Eighth Daily Report, dated April 12, 2010
Ninth Daily Report, dated April 13, 2010
Tenth Daily Report, dated April 14, 2010
Eleventh Daily Report, dated April 15, 2010
Twelfth Daily Report, dated April 16, 2010
Thirteenth Daily Report, dated April 17, 2010
Fourteenth Daily Report, dated April 18, 2010
Fifteenth Daily Report, dated April 19, 2010
Landing Plus 2 Hour Report, dated April 20, 2010
Mission Summary Report, dated April 21, 2010

ET/SRB/RSRM/SSME REPORTS

STS-131 In-Flight Anomalies, David W. Morr, USA-Huntsville, July 16, 2010
STS-131 HOSC Console Flash Report, Dino Diluigi, USA-Huntsville, April 5, 2010
STS-131 RSRM Flash Report, Daniel McGough, ATK, April 5, 2010

ORBITER REPORTS

STS-131 Communications and Tracking Report, Martha M. May, Boeing-Houston, May 5, 2010
STS-131 Shuttle Remote Manipulator System, Stephen M. Tabladillo, MDA-Houston, May 7, 2010
STS-131 HYD/WSB System Report, Charles A. Ritrivi, Boeing-Houston, May 5, 2010
STS-131 Main Propulsion System Report, Trina A. Martingano, Boeing-Houston, May 12, 2010
STS-131 Mechanical Systems Data Review, Jeff Goodmark, Boeing-Houston, April 30, 2010
STS-131 Auxiliary Power Unit System, Christopher N. Adi, Boeing-Houston, May 7, 2010
STS-131 OI/MADS Sensors, Signal Conditioners and Fuel Cell Monitoring System, Dwight A. Favors, Boeing-Houston, May 4, 2010
STS-131 OI/MADS MUX and Timing Report, Bruce S. Woods, Boeing-Houston, May 5, 2010
STS-131 Data Processing System Integrated Report, James T. Westergard, Boeing-Houston, May 7, 2010
STS-131 EPDC Mission Report, William D. Peterson, Boeing-Houston, May 4, 2010
STS-131 ATCS and ARS Post-Flight Mission Report, Carmelo S. Asuncion, Boeing-Houston, May 5, 2010
STS-131 Wing Leading Edge Impact Detection System, Jennifer C. Hodge, Boeing-Houston, May 26, 2010

ORBITER REPORTS (Concluded)

STS-131 Life Support System Report, Isaac Andu, Boeing-Houston, May 6, 2010
STS-131 Supply and Waste Water System, Salvador Castillo, Boeing-Houston, May 4, 2010
STS-131 Orbiter Docking System Summary, Robert E. Davis, NASA-JSC, May 12, 2010
STS-131 OMS Report, Eric N. Duncan, Boeing-Houston, May 7, 2010
STS-131 RCS Mission Report, Eric N. Duncan, Boeing-Houston, May 7, 2010
STS-131 Final Aeroheating Report, Dennis C. Chao, Boeing-Houston, June 9, 2010
STS-131 Fuel Cells Mission Report, Johnny D. Wong, Boeing-Houston, May 7, 2010
STS-131 Power Reactant Storage and Distribution, Johnny D. Wong, Boeing-Houston, May 7, 2010
STS-131 Global Positioning System Report, Heip M. Gui, Boeing-Houston, March 12, 2010
STS-131 Thermal Control System Summary, Than X. Nguyen, Boeing-Houston, April 30, 2010
STS-131 Flight Control System and ADTA Mission Report, Howard Damoff, Boeing-KSC, April 28, 2010
STS-131 Final Mission Events List, Vernon C. Hill, ESCG-Houston, April 26, 2010
STS-131 SE&I In-Flight Anomalies, Carla A. Santiago, NASA-JSC, June 24, 2010
STS-131 Windows Report, Orlando Torres, Boeing-KSC, June 1, 2010
STS-131 Display and Controls, Quoc P. Ngo, Boeing-Houston, May 8, 2010
STS-131 Purge, Vent and Drain Report, C. C. Heinol, Boeing-Houston, May 3, 2010
STS-131 ADS – GCILC Mission Report, Arnold A. Arrington, Boeing-KSC, May 7, 2010
STS-131 Landing and Deceleration Quick Look Report, C. C. Heinol, Boeing-Houston, May 11, 2010

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STS-131 Final Landing Debris Runway Report, Thomas F. Ford, NASA-KSC, April 20, 2010
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STS-131 Pre-EVA No. 1 Data, Shannon Cagle-Strimple, Hamilton Sunstrand, April 9, 2010
STS-131 Post-Extravehicular Activity Report for EVA 1, Angela R. Lesser, Hamilton Sunstrand, April 9, 2010
STS-131 Pre-EVA No. 2 Data, Jeff Outlaw, Hamilton Sunstrand, April 11, 2010
STS-131 Post-Extravehicular Activity Report for EVA 2, Brian Peavey, Hamilton Sunstrand, April 11, 2010
STS-131 EVA no. 3 Ingress and Post-EVA Report, Shannon Cagle-Strimple, Hamilton Sunstrand, April 13, 2010
STS-131 Post EVA 3, Sandra Peterson, Hamilton Sunstrand, April 11, 2010
STS-131 Final Extravehicular Activity Report, Linda C. Thomas, Hamilton Sunstrand, April 21, 2010
STS-131 Post-Launch Walkdown Report, Jeffrey S. Thon, NASA-KSC, April 5, 2010
STS-131 Descent Postflight Summary, Barbara C. Schill, USA-Houston, March 19, 2010
STS-131 prop30 Mass Properties Report, Barbara C. Schill, USA-Houston, April 21, 2010
STS-131 Imagery Reports, Imagery Integration Group, NASA-JSC, April 5 through April 17, 2010
STS-131 Ascent Hazard Analysis Final Report, C. C. Heinol, Boeing-Houston, March 22, 2010
STS-131 Flight Software System Anomalies, J. A. Currie, NASA-JSC, June 28, 2010
STS-131 Mission Operations Anomalies, Gregory A. Lange, NASA-JSC, June 29, 2010
STS-131 MER Tools Summary, Stephan Higgs, Oceaneering, April 15, 2010
STS-131 SRB Open Assessment, Thomas F. Ford, NASA-KSC, April 8, 2010

APPENDIX D

STS-131 ACRONYMS, ABBREVIATIONS AND UNITS OF MEASURE

Acronym/ Abbreviation	Explanation
A	Ampere
AA	Accelerometer Assembly
ABS	Ammonia Boiler System
ADTA	Air Data Transducer Assembly
AEM	Animal Enclosure Module
AGB	Adjustable Grapple Bar
AGC	Automatic Gain Control
AGT	Adaptive Guidance Throttling
AHMS	Advanced Health Monitoring System
A/L	Airlock
AMOS	Air Force Maui Optical and Supercomputing Site
APCU	Assembly Power Converter Unit
APFR	Articulating Portable Foot Restraint
APU	Auxiliary Power Unit
ARPCS	Atmospheric Revitalization Pressure Control System
ASA	Aerosurface Actuator
ATA	Ammonia Tank Assembly
ATCS	Active Thermal Control System
BFS	Backup Flight System
BFS WHI	Backup Flight System Initial Weight of Helium Load
BLT	Boundary Layer Transition
BSM	Booster Separation Motor
CBCS	Centerline Berthing Camera System
CBF	Critical BITE Failure
CBM	Common Berthing Mechanism
CCA	Communications Carrier Assembly
CCTV	Closed Circuit Television
CDT	Central Daylight Time
CLPA	Camera Light Pan Tilt Assembly
COAS	Crew Optical Alignment Sight
C/O	Checkout
CO ₂	Carbon Dioxide
COMM	Communications
CPA	Control Panel Assembly
CPM	Cell Performance Monitor
CST	Comprehensive Self Test
C&T	Communications and Tracking

APPENDIX D

STS-131 ACRONYMS, ABBREVIATIONS AND UNITS OF MEASURE

Acronym/ Abbreviation	Explanation
CWC	Contingency Water Container
CWCI	Contingency Water Container Iodine
D & C	Display and Control
DAP	Digital Autopilot
DAT	Debris Assessment Team
DCS	Debris Containment System
DDU	Data Display Unit
DET	Data Elapsed Time
DLI	Docked Late Inspection
DOD	Department of Defense
DOLILU	Day of Launch I Load Update
DPS	Data Processing System
DRWP	Doppler Radar Wind Profiler
DTO	Development Test Objective
ΔV	Differential Velocity
ECLSS	Environmental Control and Life Support System
ECO	Engine Cut-off
EDT	Eastern Daylight Time
EI	Entry Interface
EMU	Extravehicular Mobility Unit
EOM	End-of-Mission
EPDC	Electrical Power Distribution and Control
ESP	External Stowage Platform
ET	External Tank
ETCS	External Thermal Control System
EV	Extravehicular (Crewmember)
EVA	Extravehicular Activity
EXPRESS	Expedite Processing of Experiments to Space Station
FCE	Flight Crew Equipment
FCMS	Fuel Cell Monitoring System
FCS	Flight Control System
FCV	Flow Control Valve
FD	Flight Day
FES	Flash Evaporator System
FGB	Fixed Grapple Bar
FHRC	Flexible Hose Rotary Coupler
FI	Focused Inspection
FID	Failure Identifier

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STS-131 ACRONYMS, ABBREVIATIONS AND UNITS OF MEASURE

Acronym/ Abbreviation	Explanation
FIT	Final Inspection Team
FOD	Foreign Object Debris
FOM	Figure of Merit
FOV	Field of View
FRCS	Forward Reaction Control System
FSE	Flight Support Equipment
FSS	Fixed Service Structure/Flight Support System
FSW	Flight Software
g/G	Gravity
GB	Gigabites
GCA	Ground Carrier Assembly
GFE	Government Furnished Equipment
GH ₂	Gaseous Hydrogen
GLACIER	General Laboratory Active Cryogenics ISS Experiment Refrigeration
GMT	Greenwich Mean Time
GN&C	Guidance, Navigation and Control
GN ₂	Gaseous Nitrogen
GO ₂ /GOX	Gaseous Oxygen
GPC	General Purpose Computer
GPRV	Gas Pressure Regulator Valve
GPS	Global Positioning System
Grms	Gravity root mean square
GSC	Grab Sample Container
GSE	Ground Support Equipment
GUCP	Ground Umbilical Carrier Plate
H ₂	Hydrogen
HDP	Holddown Post
HGDS	Hazardous Gas Detection System
He	Helium
HPFTP	High Pressure Fuel Turbopump
HPOTP	High Pressure Oxidizer Turbopump
HVI	High Velocity Impact
HYD	Hydraulic
IBA	Inspection Boom Assembly
IDC	ISIS Digital Camera
IDS	Impact Detection System
IFA	In-Flight Anomaly

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STS-131 ACRONYMS, ABBREVIATIONS AND UNITS OF MEASURE

Acronym/ Abbreviation	Explanation
IFR	Ice Frost Ramp
IP	International Partner
IMU	Inertial Measurement Unit
IMV	Inter-Module Ventilation
IPR	Interim Problem Report
IS _p	Specific Impulse
ITVC	Intensified Television Camera
IVA	Intravehicular Activity
ISIS	Integrated Sensor Inspection System
ISS	International Space Station
ITVC	Intensified Television Video Camera
JAXA	Japanese Aerospace Exploration Agency
JEM	Japanese Experiment Module
JSC	Johnson Space Center
KSC	Kennedy Space Center
LDRI	Laser Dynamic Range Imager
LCC	Launch Commit Criteria
LESS	Leading Edge Subsystem
LH	Left Hand
LH ₂	Liquid Hydrogen
LHA	Lamp Housing Assembly
LiOH	Lithium Hydroxide
LMC	Lightweight Multi-Purpose Equipment Support Structure Carrier
LO ₂	Liquid Oxygen
LWAPA	Lightweight Adapter Plate Assembly
MARES	Muscle Atrophy Research and Exercise System
MAUI	Maui Analysis of Upper Atmospheric Modification
MADS	Modular Auxiliary Data System
MB	Megabites
MBS	Mobile Base System
MC	Midcourse Correction
MECO	Main Engine Cutoff
MEDS	Multifunction Electronics Display System
MELFI	Minus Eighty-Degree Freezer for ISS
MERLIN	Microgravity Experiment Research Locker Incubator
MET	Mission Elapsed Time
MLI	Multi-Layer Insulation

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STS-131 ACRONYMS, ABBREVIATIONS AND UNITS OF MEASURE

Acronym/ Abbreviation	Explanation
MLP	Main Launch Platform
MLS	Microwave Landing System
MM	Major Mode
MM/OD	MicroMeteoroid/Orbital Debris
MMT	Mission Management Team
MOD	Mission Operations Directorate
MPLM	Multi-Purpose Logistics Module
MPM	Manipulator Positioning Mechanism
MPS	Main Propulsion System
NASA	National Aeronautics and Space Administration
NAVAID	Navigation Aids
NC	Nominal Correction
NCC	Nominal Correction Combination
NH ₃	Ammonia
NSTS	National Space Transportation System
NTA	Nitrogen Tank Assembly
O ₂	Oxygen
OA	Orbit Adjust (Maneuver)
OAA	Orbiter Access Arm
OBSS	Orbiter Boom Sensor System
ODS	Orbiter Docking System
OI	Operational Instrumentation/Operational Increment (Software)
OIU	Orbiter Interface Unit
OME	Orbital Maneuvering Engine
OMRSD	Operational Maintenance and Requirements Specification Document
OMS	Orbital Maneuvering System
OPCU	Orbiter Power Converter Unit
ORGA	Orbiter Rate Gyro Assembly
ORU	Orbital Replacement Unit
OSL	Off-Scale Low
P	Port
PAO	Public Affairs Office
PASS	Primary Avionics Software System
PASS WHI	PASS With Initial Helium Load
PAU	Power Avionics Unit
PCM	Pulse Code Modulation

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STS-131 ACRONYMS, ABBREVIATIONS AND UNITS OF MEASURE

Acronym/ Abbreviation	Explanation
PCS	Pressurized Control System
PCT	Post-Contact Thrust
PDU	Power Drive Unit
PGME	Propylene Glycol Monomethyl Ether
PGSC	Payload General Support Computer
PLB	Payload Bay
PLBD	Payload Bay Door
PMA	Pressurized Mating Adapter
PMC	Pump Motor Controller
POA	Payload Orbital Replacement Unit Accommodation
POR	Point of Reference
POSH	Position-Orientation Hold Select
PPCO ₂	Partial Pressure Carbon Dioxide
Ppm	parts per million
PRCS	Primary Reaction Control System
PRLA	Payload Retention Latch Assembly
PRSD	Power Reactant Storage and Distribution System
PV&D	Purge, Vent and Drain
PWD	Potable Water Dispenser
PWR	Payload Water Reservoir
QD	Quick Disconnect
RAMBO	Ram Burn Observations
R&R	Removal and Replacement
RCC	Reinforced Carbon-Carbon
RCS	Reaction Control System
RF	Radio Frequency
RGA	Rate Gyro Assembly
RH	Right Hand
RHC	Rotational Hand Controller
RJD	Reaction Jet Driver
RPL	Rated Power Level
RPM	R-Bar Pitch Maneuver
RSB	Rudder Speed Brake
RSRB	Reusable Solid Rocket Booster
RSRM	Reusable Solid Rocket Motor
RSS	Range Safety System
RTV	Room Temperature Vulcanizing (material)
S	South/Starboard

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STS-131 ACRONYMS, ABBREVIATIONS AND UNITS OF MEASURE

Acronym/ Abbreviation	Explanation
S&A	Safe and Arm
SDFS	Smoke Detection and Fire Suppression
SE&I	Systems Engineering and Integration
SEED	Space Environment Exposure Device
SEITE	Shuttle Engine Ion Turbulence Experiment
SGANT	Space to Ground Antenna
SIMPLEX	Shuttle Ionospheric Modification with Pulsed Firings
SIP	Strain Isolation Pad
SLWT	Super Lightweight Tank
SMRD	Spin Motor Rotation Detector
S/N	Serial Number
SO	Starboard Zero
SPDM	Special Purpose Dexterous Manipulator
SRGA	SRB Rate Gyro Assembly
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
SSV	Still Sequential Video
ST	Star Tracker
STBY	Standby
STL	Space Tissue Loss
STS	Space Transportation System
STSS	Space Tracking Surveillance System
T2	Treadmill 2
TACAN	Tactical Air Navigation
TCS	Thermal Control System/Trajectory Control Sensor
TDRS	Tracking and Data Relay Satellite
TEA	Torque Equilibrium Maneuver
THC	Translation Hand Controller
TI	Terminal Phase Initiation/Transfer Initiation
TPS	Thermal Protection System
TriDAR	Triangulation Light Intensification Detection and Ranging
TRRJ	Thermal Radiator Rotary Joint
TSM	Tail Service Mast

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STS-131 ACRONYMS, ABBREVIATIONS AND UNITS OF MEASURE

Acronym/ Abbreviation	Explanation
TVC	Thrust Vector Controller
TVIS	Treadmill with Vibration Isolation System
ULF	Utilization and Logistics Flight
VDT	Vehicle Data Table
VHF	Very High Frequency
VRCS	Vernier Reaction Control System
W	West
WDS	Water Delivery System
WLE	Wing Leading Edge
WORF	Window Observational Research Facility
WPA	Water Processing Assembly
WSB	Water Spray Boiler
ZSR	Zero-g Stowage Rack

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STS-131 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
MHz	MegaHertz
hr	hour
In.	inch
Kbps	kilobits per second
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
Mbps	Megabits per second
min	minute
mmHg	Millimeters of Mercury
mph	miles per hour
mV	milliVolt
nmi	nautical mile
ó	sigma
%	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
V	Volt
Vdc	Volt direct current