

STS-126 SPACE SHUTTLE MISSION REPORT

August 2009



**National Aeronautics and
Space Administration**

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

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STS-126
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STS-126 SPACE SHUTTLE MISSION REPORT

INTRODUCTION

The Space Transportation System (STS) -126 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 Solid Rocket Booster (SRB), the Reusable Solid Rocket Motor (RSRM) and the Space Shuttle Main Engine (SSME) performance during the 124th mission of the Space Shuttle Program. The purposes of this mission, designated as Utilization Logistics Flight-2 (ULF-2), were to deliver and integrate the Launch Package (LP) to the International Space Station (ISS), exchange the ISS Flight Engineer 2 crewmembers, conduct four Extravehicular Activities (EVAs) and deliver critical equipment and cargo to the ISS.

STS-126 was the 11th mission since the return to flight following the STS-107 mission, and the 27th mission to the ISS. STS-126 was also the 22nd flight of the Orbiter Endeavour vehicle.

The flight vehicle consisted of the OV-105 Orbiter; the ET, a Super Lightweight Tank (SLWT) designated ET-129; three Block II SSMEs that were designated as serial numbers (S/Ns) 2047, 2052, and 2054 in positions 1, 2 and 3, respectively; and two SRBs that were designated BI-136. The two RSRMs were designated flight set RSRM-104. The individual RSRMs were S/N 360W104A (left) and S/N 360W104B (right). Launch pad 39A and Mobile Launch Platform (MLP) -3 were used as the platform for launch of the STS-126 mission.

The primary objectives of the STS-126 mission were as follows:

1. Deliver the Multi-Purpose Logistics Module (MPLM), which carried seven Systems/Science Racks, six Resupply Stowage Platforms (RSPs), three Resupply Stowage Racks (RSRs) and three zero-g Stowage Racks (ZSRs) that were mounted onto the RSRs.
2. Exchange the ISS Flight Engineer 2 crewmembers and transfer mandatory crew rotation cargo.
3. Deliver one Flex Hose Rotary Coupler (FHRC) and return one Nitrogen Tank Assembly (NTA).
4. Deliver and install other ISS equipment, supplies, ISS Utilization middeck payloads, EVA equipment and ISS logistics from the Orbiter crew compartment.
5. Perform four EVAs.

The secondary objectives were as follows:

1. Maintenance of the Starboard and Port Solar Array Rotary Joints (SARJs)
2. Launch and deploy the Pico-Satellite Solar Cell (PSSC) mounted on the Space Shuttle Picosat Launcher (SSPL) 5510.

The STS-126 mission was planned to be a 15-day plus 1 plus 2-contingency-day flight

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, RSRM, ET, SSME, Systems Engineering and Integration (SE&I), Flight Software, Flight Operations and Integration (FO&I), and Mission Operations Directorate (MOD) 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 eight crewmembers (seven up, seven down) that were on the STS-126 flight were Christopher J. Ferguson, Captain U. S. Navy, Commander; Eric A. Boe, Colonel, U. S. Air Force, Pilot; Heidimarie Stefanyshyn-Piper, Captain, U. S. Navy, Mission Specialist 1; Stephen G. Bowen, Captain, U. S. Navy, Mission Specialist 2; Robert S. Kimbrough, Lieutenant Colonel, U. S. Army, Mission Specialist 3; Donald R. Pettit, PhD, Civilian, Mission Specialist 4; Sandra H. Magnus, PhD, Civilian, Mission Specialist 5 (up to ISS); and Gregory E. Chamitoff, PhD, Civilian, Mission Specialist 5 (down from ISS).

STS-126 was the second Shuttle flight for the Commander, Mission Specialist 1, Mission Specialist 4, Mission Specialist 5 (up to ISS) and Mission Specialist 5 (down from ISS). STS-126 was the first Shuttle flight for the Pilot, Mission Specialist 2 and Mission Specialist 3.

MISSION SUMMARY

The objectives of the STS-126 mission included rotating the Expedition 17/18 ISS Flight Engineer and NASA Science Officer Gregory Chamitoff with Expedition 18 Flight Engineer and NASA Science Officer Sandra Magnus, installing the Multi-Purpose Logistics Module (MPLM), transferring and installing to the International Space Station (ISS) from the MPLM the racks and equipment to increase the ISS capability to allow six crewmembers, transferring critical items and mandatory quantities of water, and performing four Extravehicular Activities (EVAs).

The STS-126 crewmembers and the ISS crewmembers collaborated on the delivery of key life support and habitability systems that will enable long-term self-sustaining ISS operations after the Shuttle fleet is retired.

Pre-launch

During the Global Positioning System (GPS) activation, all three GPS receivers did not transition to precision-code tracking within the allowable time of 1 hr. A set of Military-key-codes is required for the receivers to transition to the precision code. The Communications Navigation System Engineer (CNSC) determined that the problem was that the receivers had been powered off for more than 7 days and were not able to recognize the military-daily-key codes during this power up. The three-string GPS does not have to be in the precision-mode to launch, since this system was certified for landing in the standard mode. The anomaly cleared with the Miniature Airborne GPS Receiver (MAGR) power up on all three MAGR receivers, which was expected.

During the External Tank (ET) Inter-tank arm retraction, a bolt (approximately 1/2" long, 1/4" diameter) was discovered on the right side of the ET on top of the box beam approximately where the Liquid Oxygen (LOX) feed-line passes over the box beam. The bolt was retrieved during the ET feed-line inspection and appeared to be the one missing from a platform handrail in the Forward Reaction Control System (FRCS) room on the 207-ft level. The ET mechanical group inspected the resting location as well as the path of travel. No damage was observed on the components or acreage. The Orbiter Thermal Protection System (TPS) personnel observed no tile or Reinforced Carbon-Carbon (RCC) panel damage. It was noted that some of the handrail bolts have 1/4" split lock washers weighing 1 gram under the bolt heads, but no washer was found.

No Solid Rocket Booster (SRB) or Reusable Solid Rocket Motor (RSRM) Launch Commit Criteria (LCC) or Operations and Maintenance Requirements and Specifications Document (OMRSD) violations occurred during the pre-launch period. Also, no SRB- or RSRM- related Interim Problem Reports (IPRs) were written during propellant loading and launch.

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

No ET LCC or OMRSD violations occurred, and no ET related IPRs occurred during propellant loading and launch.

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

All ET objectives and requirements associated with propellant loading were met. No significant oxygen or hydrogen concentrations were detected in the Intertank. All electrical equipment and instrumentation operated satisfactorily. Purge and heater operations were monitored and performed properly.

There were no Space Shuttle Main Engine (SSME) LCC or OMRSD violations. No SSME related IPRs or Failure Identifiers (FIDs) occurred during propellant loading. Changes to the SSME controller software included several safety enhancements that were identified by the post-Columbia review team. The new software operated as expected.

All SSME systems performed as expected during launch countdown and performance was typical of previous pre-launch operations. The SSME pre-launch countdown was nominal and no potential SSME IFAs were identified.

Light-to-moderate condensation was noted on the Liquid Hydrogen (LH₂) tank of the ET with condensate increasing toward the end of the inspection. The Liquid Oxygen (LO₂) tank and Intertank were observed to be dry. Surface temperatures ranged from 70 to 85 °F. Less than typical ice/frost formations were observed on the umbilicals. Observation of the LO₂ feed-line brackets indicated good performance with minimal ice/frost noted on the bracket base-to-tank fitting interface at all locations, and no ice frost was noted on metal/Super Lightweight Ablator (SLA) area of brackets. Some TPS defects were noted by the Flight Inspection Team (FIT) and all were typical and acceptable per NSTS 08303 documentation. All ice/frost formations were within NSTS 08303.

There were no exceedences of the November 90th percentile database limits for both the in-plane and out-of-plane components based on the Launch (L) -2:20 Day of Launch I-Loads Update (DOLILU) assessment. There were no wind-shear exceedences. The maximum measured wind velocity was 110.5 ft/sec at 41,100 ft and 257 deg. 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 High Resolution (HR) balloon and the 0030 Universal Time Code (UTC) 50-MHz Doppler Radar Wind Profiler (DRWP). The L-1:25 HR data was validated for the roll maneuver assessment with the 2331 UTC Mosquito Lagoon 915-

MHz profiler. The maximum measured wind velocity in the roll maneuver region was 31.9 ft/sec at 2300 ft and 174 deg.

The Mission Support Computers at the Cape Weather Station had to be rebooted which resulted in the loss of the L-2:20 Jimsphere data. Therefore, the L-2:20 HR was used for the DOLILU assessment. The L-1:08 Jimsphere data was delayed, so the roll maneuver assessment was completed with the L-1:25 HR.

During pre-launch, beginning at 320/00:50:54 GMT(L-04:45), the Auxiliary Power Unit (APU) 3 Z-axis accelerometer exhibited a slow start-response and brief periods of an intermittent dropout to zero-g peak-to-peak during ascent (IFA STS-126-V-02). This had no effect on APU performance.

Just prior to Orbiter Access Arm (OAA) retract, it was noticed that the OAA-to-Orbiter interface door was not properly pinned in its stowed position. It was determined that door was unlikely to swing back through its full range of motion while the OAA was being retracted, but there was a handrail that would stop it from hitting the orbiter if it did. It was also determined that the door would not interfere with crew escape. The OAA was retracted as planned and the door did move initially, but returned to a position very close to its stowed configuration once retraction was complete.

Ascent and Flight Day 1

The STS-126 mission was launched at 320/00:55:38.996 Greenwich Mean Time (GMT) on November 14, 2008, on the twenty-seventh Space Shuttle Program (SSP) mission to the ISS.

Engine "Ready" was achieved at the proper time, all LCCs were met, and thrust build-up was nominal. Flight data indicated nominal SSME performance during startup, mainstage, throttling, and shutdown.

High Pressure Oxidizer Turbo Pump (HPOTP) and High Pressure Oxidizer Fuel Turbo Pump (HPFTP) temperatures appeared to be well within specifications throughout engine operation.

Commanded Max Q throttle-down was a one-step throttle to 72% indicating Adaptive Guidance Throttling (AGT) was not initiated.

The SRB separation was visible. Both SRBs successfully separated from the ET and reports from the recovery area indicated that the deceleration subsystem performed as designed.

A nominal Orbital Maneuvering System (OMS) assist maneuver was performed following SRB separation. Ignition occurred at 320/00:57:55.5 GMT [00/00:02:16.5 Mission Elapsed Time (MET)], and the maneuver was 103.5 sec in duration.

Main Engine Cutoff (MECO) occurred at 320/01:04:02 GMT (00/00:08:23 MET). The ET separated from the Orbiter at 320/01:04:24 GMT (00/00:08:46 MET). ET separation was nominal.

Propellant dump operations data appeared normal and MECO time was Engine Start plus 510 sec.

All ET systems performed as expected during the ascent. All ET objectives and requirements associated with flight operations were met. No significant oxygen or hydrogen concentrations were detected in the Intertank. All electrical equipment and instrumentation operated satisfactorily. Purge and heater operations were monitored and performed properly. The liquid-level and Engine Cut-off (ECO) sensors performed as designed.

All SSME systems performed as expected during ascent and performance was typical of previous flights.

The initial review of Advanced Health Monitoring System (AHMS) vibration measurements indicated nominal performance. No FIDs were reported to the Vehicle Data Table (VDT) from start of preparation through propellant dump on all engines. All accelerometer measurements appeared healthy.

During ascent and after the thrust bucket at 320/00:57:05 GMT (00/00:01:26 MET), the Engine 2 Gaseous Hydrogen (H₂) outlet pressure had a 200-psi step down without a corresponding ullage pressure signal conditioner command change (IFA STS-126-V-08). The change in outlet pressure for this flow control valve (FCV) position was 260 psi during previous command changes before the thrust bucket. The data indicated uncommanded motion of the FCV. This condition did not impact ascent or the overall mission.

The Main Propulsion System (MPS) engine 1 LH₂ prevalve close-indication data initially showed closed after which the measurement was lost. The other two prevalues closed nominally without command. This condition did not impact ascent or the mission.

The MPS pneumatic Helium pressure decay was greater than expected during ascent (IFA STS-126-V-09). Based on previous flight data, the bottle/tank pressure normally drops about 20 to 50 psi during ascent. On this flight, the drop was approximately 140 psi. The Helium tanks are all connected on one manifold, so the leak could not be detected. The Helium is used for the aft compartment purge during entry. The pressure became constant in the tanks, consequently no impact to the mission occurred.

A nominal OMS-2 maneuver was performed at 320/01:33:58.3 GMT (00/00:38:19.3 MET). The maneuver was 63.2 sec in duration with a Differential Velocity (ΔV) of 96.2 ft/sec. The achieved orbit was 85.1 by 125.6 nmi.

The payload bay doors were opened at 320/02:26:07 GMT (00/01:30:28 MET).

The Ku-Band antenna was deployed at 320/02:34 GMT (00/01:39 MET). Power was applied to the system at 320/02:37:55 GMT (00/01:42:16 MET), and the RADAR self-test was started at 320/02:42:39 GMT (00/01:47:00 MET). The Ku-Band system passed the self-test, and the crew placed the system in the Communications (COMM) mode approximately 4 min later.

From the initial lock-on to the Tracking and Data Relay Satellite (TDRS) after configuring to the COMM mode, the Ku-Band antenna was not remaining locked in the General Purpose Computer (GPC) Acquisition (ACQ) mode (IFA STS-126-V-03). Angles appeared to drift off until the forward-link lock was lost, after which the Ku-Band antenna repointed to the designated angles and reacquired the forward link. This condition repeated each time that the GPC ACQ mode was selected and on both TDRS W171 and TDRS Spare 046. When the GPC Designate (DESIG) mode was selected by the controllers, the Ku-Band antenna forward link stayed locked.

At 320/02:25:00 GMT (00/01:29:21 MET), the OMS right-crossfeed oxidizer drain temperature dropped below the expected temperature while on the A-string heater (IFA STS-126-V-05). The Systems Management (SM) Alert was lowered with a Table Maintenance Block Update (TMBU) from 50 to 45 °F. The sensor subsequently reached 45.7 °F prior to changing from the OMS Cross-feed A to OMS Cross-feed B heater string at 320/02:44:05 GMT (00/01:48:26 MET). Once on the B-string, the heater was observed to cycle nominally.

During the post-insertion operations, fuel cell tank B was selected to provide the water to the Flash Evaporator System (FES) while tank A was being filled with fuel-cell water. The objective was to drain tank B of the water loaded pre-launch as much as possible before refilling with the water from the fuel cells. However, it appeared that the water from the fuel cells was filling tank B earlier than expected as tank A was not quite full when the tank B quantity began increasing. Based on the historical data of this valve, this behavior was not unexpected.

An OMS-3 Nominal Correction (NC) 1 maneuver was performed nominally at 320/04:36:57.4 GMT (00/03:41:18.4 MET) with the cutoff at 320/04:37:36.8 GMT (00/03:41:57.8 MET) and both OMS engines operated nominally. The maneuver was 39 sec in duration with a ΔV of 60.0 ft/sec. The resulting orbit was 111.8 by 130.9 nmi.

The Imagery Integration Team noted a single-debris release prior to the 135 sec Aerodynamic Sensor Transport Time (ASTT) aft of the vehicle at 33 sec based on available ascent imagery from ground cameras and the ET feedline camera. One

additional debris release was noted after ASTT. No potential vehicle impacts from any of the observed events were identified.

The Shuttle Remote Manipulator System (SRMS) checkout was completed without any problems noted.

The fuel cell 1 hydrogen flowmeter measurement began drifting high and erratic at 320/12:36 GMT (0/11:41 MET) (IFA STS-126-V-07). Ground controllers inhibited the on-board class 3 alarm for this measurement. This condition has been noted in the past and did not impact to the mission.

After processing the downlinked Wing Leading Edge (WLE) ascent data, it was discovered at 320/15:15:00 GMT (00/14:19:21 MET) that all three channels of WLE Sensor Unit 1163 (on the Starboard wing) were scaled higher (approximately 7 times) than all other sensors (IFA STS-126-V-04). The data collected was still analyzed, but the unit was not used for on-orbit sensor Group 2 operations. As a result, the Reinforced Carbon-Carbon (RCC) panel 4 was monitored with two horizontal sensors rather than the nominal diagonal sensor.

Based on the processed WLE ascent data, there were three indications above the 1 Gravity root mean square (Grms) reporting threshold. All three indications were later cleared by the Orbiter Boom Sensor System (OBSS) surveys of the RCC.

The Ku-Band Antenna Auto Handover mode was enabled and the Ku-Band DATA PRESENT was high and signal strength appeared to meet the threshold; however, the handover never occurred. The ground controllers were able to command the Ku-Band by an uplink using the Stored Program Command (SPC).

During the post-insertion activities, both Payload Signal Processor (PSP) 1 and 2 System Management (SM) reject flags annunciated upon attempting commands. The PSP did not reconfigure to payload (PL) Umbilical as expected. An uplink command to configure to PL Umbilical in the PSP was successful and enabled the PSP to properly route commands to the Orbiter Interface Unit (OIU).

Upon further analysis, the Ku-band Forward Link Auto Handover and PSP Format Configuration error anomalies were determined to be caused by a single software change in OI-33 (IFA STS-126-I-001). This mission was the first flight of the OI-33 software. A data relocation impacted variables used for these functions, resulting in the inability of the SM GPC to issue Ground Command Interface Logic (GCIL) commands. An extensive audit of the OI-33 software determined that these were the only functions affected by the change.

Analysis of the ground imagery taken during ascent appeared to show that the Tyvek cover for the Reaction Control System (RCS) thruster F4D experienced a hang-up and late release at approximately 42 sec MET (IFA STS-126-I-010). The cover did not impact the Orbiter as it moved aft and was not observed exiting the vehicle plume.

Flight Day 2

The main events of Flight Day (FD) 2 were the OBSS surveys of the RCC, docking ring extension, and rendezvous tools checkout.

The OMS-4 NC2 maneuver ignition was at 320/17:54:37.8 GMT (00/16:58:58.8 MET) with the cutoff at 320/17:54:48.2 GMT (00/16:59:09.2 MET), and the maneuver was performed with the right Orbiter Maneuvering Engine (OME). Engine performance was nominal. The duration was 10.4 sec with a ΔV of 7.5 ft/sec. The resulting orbit was 132.3 by 114.1 nmi. The NC3 was cancelled as it was not required.

At 320/19:50 GMT (00/18:55 MET), the crew reported that when they selected the SRMS Elbow camera Automatic Light Control (ALC) average mode, the picture went black (IFA STS-126-V-06). A normal picture was obtained when using the manual iris control mode. The ALC command sequence required an additional command to activate the automatic iris control. Pushing the ALC button a second time activated the iris. This camera was flown on STS-117 and was removed post-flight and sent to the vendor for repair.

At 320/22:16:42 GMT (00/21:21:03 MET), the OMS cross-feed string-A heater was selected to verify the OMS oxidizer drain cross-feed heater failure (IFA STS-126-V-05). The right cross-feed oxidizer drain temperature dropped below 35 °F confirming the heater failure. The B-string heater was reselected at 320/23:19:31 GMT (00/22:24:52 MET) and the heater was observed to cycle nominally.

The OBSS surveys of the starboard RCC, nose-cap RCC and port RCC were completed and the data were downlinked for analysis. It was noticed during the surveys that the tilt angle had a greater offset than is usually seen (as much as 14 deg). This tilt offset did not adversely affect the collection of the survey data. Also, the hand-held imagery of the OMS pod and tail were downlinked successfully.

The ascent imagery of the port T-0 area showed what was initially thought to be a loss of a Flexible Reusable Surface Insulation (FRSI) blanket. As a result, the team requested additional imagery of this location. During the Port RCC Survey, the crew zoomed onto the OMS Pod/T-Zero umbilical carrier panel interface and determined that the FRSI was in place. Additional Launch Pad imagery was reviewed and the debris source was determined to be ice (STS-126-I-002).

The Docking ring extension was completed at approximately 321/03:26:11 GMT (01/02:30:32 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% ring extension.

The Rendezvous Tools checkout was performed and all systems were nominal.

Due to the inability to command via the umbilical to PSP, the MPLM environment check was moved from FD 1 to FD 2 once the workaround was implemented. The check was completed successfully.

The Wing Leading Edge (WLE) sensor system collected data for approximately 6 hr, and the completed analysis showed no new reportable indications.

Flight Day 3

The main events for FD 3 were the rendezvous and docking to the ISS, hatch opening, and the handoff of the OBSS from the Space Station Remote Manipulator System (SSRMS) to the SRMS.

The first maneuver of the day was the OMS-5 Nominal Height (NH) using both engines. The time of ignition was 321/17:04:02.6 GMT (01/16:08:23.6 MET) with the cutoff at 81.2 sec later. The maneuver had a ΔV of 125.8 ft/sec, and the resulting orbit was 126.8 by 191.7 nmi. Engine performance was nominal.

The second maneuver of the day was the OMS-6 Nominal Correction (NC) 4 and it was a dual engine firing. The time of ignition was 321/17:43:53.8 GMT (01/16:48:14.8 MET) with the cutoff at 60.4 sec later. The maneuver had a ΔV of 94.3 ft/sec, and the resulting orbit was 178.9 by 192.3 nmi. Engine performance was nominal.

The Nominal Corrective Combination (NCC) maneuver was a 1.2-sec multi-axis RCS firing using 10 primary thrusters. Ignition for the maneuver was 321/18:29:06.7 GMT (01/17:33:29 MET). The ΔV delivered was 0.3 ft/sec which placed the Orbiter in a 178.9 by 192.3 nmi orbit.

The OMS-7 Terminal Initiation (TI) maneuver was a 13.0-sec OMS firing using the left engine. Ignition was at 321/19:26:48.2 GMT (01/18:31:09.2 MET) with the cutoff 13.0 sec later. The ΔV delivered was 9.9 ft/sec and the Orbiter was placed in a 184.6 by 192.3 nmi orbit. Engine performance was nominal.

Midcourse Correction (MC) 1 was a 2.6-sec +X RCS firing using two primary thrusters. Ignition was at 321/19:46:50.6 GMT (01/18:51:11.6 MET). The ΔV delivered was 0.9 ft/sec and the Orbiter was placed in a 184.6 by 192.4 nmi orbit. MC2 was a 6.8-sec +X RCS firing using two primary thrusters. Ignition occurred at 321/20:23:45 GMT (01/19:28:06 MET). The ΔV delivered was 1.6 ft/sec and the Orbiter was placed in a 184.8 by 192.3 nmi orbit. MC3 was a 5.0-sec +X RCS firing using two primary thrusters. Ignition occurred at 321/20:40:46 GMT (01/19:45:06 MET). The ΔV delivered was 1.6 ft/sec and the Orbiter placed in a 185.3 by 192.3 nmi orbit. MC4 was a 1.0-sec Z-axis RCS firing using six primary thrusters. Ignition occurred at 321/20:50:45.6 GMT (01/19:55:06.6 MET). The ΔV delivered was 0.4 ft/sec and the Orbiter was placed in a 185.4 by 192.3 nmi orbit.

The R-bar Pitch Maneuver (RPM) started at 321/21:08:02 GMT (01/20:12:23 MET) and ended at 321/21:16:16 GMT (01/20:20:37 MET). The peak pitch rate was approximately 0.70 deg/sec during the maneuver. The maximum roll error reached approximately minus 0.044 deg/sec, and the maximum yaw error reached 0.063 deg/sec. Performance was nominal.

The Orbiter Docking System (ODS) was activated at 321/21:34:36 GMT (01/20:38:57 MET). The Shuttle captured the ISS at 321/22:01:17 GMT (01/21:05:38 MET). The system was allowed to dampen out for approximately 38 min. Petal 2, Ball Screw 2 indicated a stuck damper during Shuttle/ISS damping. This is a known and expected condition. During the workaround for the stuck damper, the ring was retracted for too long (14 sec versus 5 sec) which caused large oscillations. This condition had no impact on the remaining ODS activities. Ring retraction using dual motors was started at 321/22:39:25 GMT (01/21:43:46 MET), and it proceeded nominally for approximately 2 min 58 sec with good ring alignment. The hooks were driven closed nominally and final ring extension was performed, releasing the capture latches with the ring final-position being acquired at approximately 321/22:45:51 GMT (01/21:50:12 MET). At that time, docking operations were complete.

During the Trajectory Control System (TCS) deactivation while performing the post-docking activities, the TCS shutter-close indication was not received. The crew resent the close command and was successful in getting a close indication.

At 322/05:15 GMT (02/04:20 MET), the Guidance Navigation and Control (GN&C) GPC bypassed the Ku-band radar data after experiencing Input/Output (I/O) errors (IFA STS-126-V-12).

The docked hard-line audio performance was degraded, and this condition was similar to the condition that has been seen on previous flights.

All RPM imagery was downlinked and was reviewed by the Damage Assessment Team (DAT). The RCC Leading Edge Subsystem (LESS) DAT identified no Focused Inspection (FI) requirements for the starboard or port wings or the nose-cap. The Thermal Protection System (TPS) DAT had no FI candidates on the starboard side which allowed for MPLM installation on Node 2 on FD 4. There were some protruding gap fillers at various locations, tile coating damage near the Left-Hand (LH) External Tank (ET) door tile with shallow damage, and a broken Dome Mounted Heat Shield (DMHS) tile (IFA STS-126-V-01).

Flight Day 4

The main events of FD 4 were the unberthing of the MPLM and installation of the MPLM on Node 2 by the SSRMS.

The -Z Star Tracker Door was closed to prevent contamination while cleaning the starboard Solar Alpha Rotary Joint (SARJ) during the EVAs. The door was closed using a single motor per the established procedure.

The crew reported a crackling noise and some static on the middeck speaker unit. Later in the mission, the crew was able to determine that the static was likely associated with long periods of intermittent communication.

The RCC was cleared for entry at the Mission Management team (MMT) meeting.

Flight Day 5

The main event of FD 5 was the first EVA. All EVA objectives of the 6 hr 42 min EVA were met. These objectives included the removal of the Nitrogen Tank assembly (NTA), the installation of the Flexible Hose Rotary Coupler (FHRC) and the cleaning of the starboard Solar Alpha Rotary Joint (SARJ).

During the EVA, a SARJ tool bag was lost overboard. Tools in the lost bag were to be used for the SARJ maintenance activities during the first three EVAs.

The TPS was cleared for entry at the MMT meeting.

The Wing Leading Edge sensors had no new reportable triggers. The system was shutdown until the late inspection.

Flight Day 6

The activities for FD 6 were MPLM transfer operations and preparations for the second EVA.

Two additional items involving the Ku-Band were noted. An additional I/O error was logged against the Ku-Band radar, but since there was only one error this time, as opposed to on FD 3, no GNC bypass took place. The ground also noticed indications of a loss of the Ku-Band forward link frame synchronization (STS-126-V-19). This is a telemetry indication only, as no unexpected loss of uplink was confirmed via the Orbiter Communications Adapter (OCA).

The Orbiter assumed control of the ISS/Orbiter stack at 324/22:04:58 GMT (04/20:09:19 MET) and maneuvered the stack to the water dump attitude. Following the water dump, attitude control was returned to the ISS at 325/00:24:48 GMT (04/23:12:49 MET).

The water dump, consisting of waste water, condensate, and two Payload Water Reservoirs (PWRs) was performed beginning at 324/22:11:37 GMT (04/21:15:58 MET) and ending at 325/00:08:28 GMT (04/23:12:49 MET).

The second on-orbit fuel cell purge began at 325/03:12 GMT (05/02:17 MET). During the 102-hour purge interval, the approximate voltage decay was 0.28 Vdc for fuel cell 1, 0.21 Vdc for fuel cell 2, and 0.19 Vdc for fuel cell 3.

Flight Day 7

The primary activity for FD 7 was EVA 2, which included the relocation of Crew and Equipment Translation Assembly (CETA) carts and additional cleaning of the starboard SARJ. The Carbon Dioxide (CO₂) levels for Extravehicular crew member 3 (EV3) began to climb in the last hour of the EVA and per flight rules the EVA was terminated early with a total EVA time of 6 hr and 45 min. Due to the early termination, some EVA objectives were only partially completed and others were deferred. Replanning for the third and fourth EVAs was necessary. A Trundle Bearing Assembly (TBA) was over-torqued and had to be removed.

Video from the SRMS elbow camera had a magenta hue (IFA-STS-126-V-10). This failure mode has been seen on several previous Shuttle missions as well as on ISS cameras. The camera was turned off for a short period of time and a nominal image was restored.

Two additional Ku-Band I/O errors on multiplexer/demultiplexer Flight Forward (FF) 3 /Electronic Assembly (EA) 1 interface occurred very close to each other, at 326/09:56 GMT (06/09:01 MET). A GN&C bypass did not occur because the errors were not consecutive.

Flight Day 8

The main activities for FD 8 included an ISS reboost, equipment transfer, a crew news conference, and preparations for the third EVA.

The Orbiter assumed attitude control at 326/16:26:23 GMT (06/15:30:44 MET) and the 16-deg maneuver to the configuration 3 reboost attitude began at 326/16:28:07 GMT (06/15:32:28 MET). The reboost was initiated at 326/17:09:39 GMT (06/16:14:00 MET) and executed for a duration of 30 min. The 16-deg maneuver back to the Torque Equilibrium Attitude (TEA) began at approximately 326/17:48:00 GMT (06/16:52:21 MET). Attitude control was handed back to the ISS at 326/19:16:15 GMT (06/18:20:36 MET).

Buffer errors were seen with High Definition Television (HDTV) downlink on Digital Television (DTV) Multiplexer (MUX) Channel 2 (IFA STS-126-V-13). The DTV Multiplexer power was cycled, which temporarily cleared the errors. The errors returned during subsequent HDTV downlinks and could not be cleared. As a result, Standard Definition television format was used for all remaining video downlinks.

The water coolant loop 2 bypass valve was changed from auto to manual operation mode at 326/23:55:39 GMT (06/23:00:00 MET). The bypass valve was manually

adjusted to increase flow through the interchanger, thus raising the dew point. This was done in an attempt to raise the humidity level in the Orbiter forcing humidity removal performance to ISS in order to allow for a planned water sample collection.

The use of one of the two Orbiter Non-Oxide Adhesive Experimental (NOAX) applicators as a backup grease gun for the remaining SARJ maintenance tasks was approved by the MMT. This was in response to the loss overboard of a SARJ tool bag during EVA 1 on FD 5.

Flight Day 9

The primary activity for FD 9 was the third EVA, which lasted 6 hr and 57 min. Completed tasks included the removing and replacing the starboard SARJ TBAs, cleaning the starboard SARJ race ring, and removal and tie down of the SARJ multilayer insulation (MLI) covers.

The Main Landing Gear (MLG) Hydraulic (HYD) brake line heaters B and C were turned on at approximately 327/15:28:00 GMT (07/14:32:21 MET). These heaters were left on as a test to determine their ability to provide thermal conditioning for the MLG tires in high-beta angle docked Orbiter/ISS attitudes.

Three PWRs no. 3, 4 and 5, and Contingency Water Container (CWC) no. 8 were completed. In addition, the Nitrogen (N₂) repressurization was completed.

Power Transfer Unit (PTU)-1 of Orbiter Power Converter Unit (OPCU)-A was temporarily disconnected to avoid potential ISS power balance issues during the galley installation. The PTU was disconnected from the bus via ISS Remote Power Control Module (RPCM) at 327/20:44 GMT (07/19:49 MET) and reconnected to the bus via ISS RPCM at 327/23:44 GMT (07/22:49 MET).

A test was performed during crew sleep at approximately 328/13:24:00 GMT (08/12:28:21 MET) to assess the range of motion of the OBSS Pan-Tilt Unit. The full range of motion occurred and the tilt offset was still present.

Flight Day 10

The main activities for FD 10 were crew off-duty time, MPLM transfer, waste water dumps, and preparation for the fourth EVA.

In preparation for the waste water dumps, the Orbiter took control of the mated stack at 328/22:25:17 GMT (08/21:29:38 MET) and the maneuver to the water-dump attitude began at 328/22:25:23 GMT (08/21:29:44 MET). The Orbiter maintained attitude hold throughout the water dump procedures and began the maneuver back to TEA at 329/00:06:35 GMT (08/23:10:56 MET). The ISS assumed control of the mated

stack at 329/01:05:53 GMT (09/00:10:14 MET). The Orbiter was in attitude control for approximately 2 hr, 41 min.

While in the water-dump attitude, the waste tank, condensate, and a leaky CWC were also successfully dumped through the waste dump line. A separate CWC was filled for transfer of potable water to the ISS.

The APU 1 fuel tank outlet pressure measurement did not track the thermal pressure decay (IFA STS-126-V-17). A bias between the fuel tank internal pressure measurement and the tank outlet pressure measurement was known. The bias had remained constant, but then began to diverge.

Images of a Micro Meteoroid/Orbital Debris (MM/OD) strike on Window 6 were downlinked for ground review.

Two additional camera problems were observed. Camera B, the Intensified Television Camera (ITVC), was powering on in an incorrect state, resulting in uncommanded opening of the iris. Power to the camera was cycled and it began performing nominally. Video from camera A, a Color Television Camera (CTVC), had a yellow hue which could not be cleared (IFA-STS-126-V-11).

On FD 10, at 328/23:58 GMT (08/23:03 MET), the crew requested to downlink Shuttle high definition television. When the link came up, the DTV was in SDTV mode, Multiplexer (MUX) power was turned off, and upon turning on in HDTV mode, buffer errors again occurred (IFA STS-126-V-13). Errors continued through another MUX power cycle, as well as, after the crew switched to live-camera view. On a subsequent pass, at 329/01:31 GMT (09/00:36 MET), with a live camera view set up from the previous pass, steady video from the flight deck camera streamed with the DTV MUX buffer error occurring approximately every 30 seconds.

Flight Day 11

The primary activity for FD 11 was the fourth EVA. The primary tasks completed during the EVA included starboard SARJ cleaning and lubrication, TBA 3 installation, port SARJ lubrication, Exposed Facility Berthing Mechanism (EFBM) cover installation, EFBM latch bolt operation, External TV Camera Group (ETVCG) installation, and Japanese Experiment Module (JEM) GPS antenna A installation. The EVA was terminated early due to elevated CO₂ levels for EV 3 with a total EVA time of 6 hr, 7 min.

The ISS MMT requested and the Shuttle MMT approved the extension of the mission by one docked day to continue troubleshooting the Urine Processor Assembly (UPA).

The window 6 MM/OD impact assessment was presented and cleared for entry at the MMT meeting.

Flight Day 12

The primary activities for FD 12 were MPLM closeout activities, a waste-water dump, a Public Affairs Office (PAO) event, and EVA tool de-configuration.

The third on-orbit fuel cell purge began at 330/02:06 GMT (10/01:11 MET). During the 120-hour purge interval, the approximate voltage decay was 0.13 Vdc for fuel cell 1, 0.12 Vdc for fuel cell 2, and 0.12 Vdc for fuel cell 3.

The Orbiter took control of the mated stack at 330/16:11:02 GMT (10/15:15:23 MET) and the 17-deg maneuver to the water-dump attitude began at 330/16:11:31 GMT (10/15:15:52 MET). The 17-deg maneuver back to the TEA began at 330/17:04:30 GMT (10/16:08:51 MET) and the ISS assumed control of the mated stack at 330/18:16:00 GMT (10/17:20:21 MET). The Orbiter was in attitude control for approximately 2 hr 15 min.

Results from the MLG tire thermal conditioning test using the MLG brake line heaters B and C were presented to the Mission Management team. Based upon the data, the conclusion was that tire temperature response to the operation of the heaters was significant enough to recommend use on upcoming flights when needed.

An additional test of the OBSS Pan-Tilt Unit was performed. The test confirmed that the tilt offset was still present.

Flight Day 13

The primary activities for FD 13 were the MPLM hatch closure and berthing of the MPLM into the Orbiter payload bay.

During Remotely Operated Electrical Umbilical (ROEU) mate operations following MPLM berthing, at approximately 331/22:57:39 GMT (11/22:02:00 MET), motor 2 drove on 2 of 3 phases (IFA STS-126-N-001). This did not impact mating operations as the ROEU was successfully remated. This appeared to be similar to a signature that was observed during demate operations earlier in the flight, but was overlooked at the time.

Power Reactant Storage and Distribution (PRSD) H₂ tank 5 was depleted to residual quantity.

Approximately 20 lb of Oxygen (O₂) was transferred from the Orbiter to the ISS.

In the time interval from 332/02:24:00 GMT (12/01:28:21 MET) to 332/03:30:00 GMT (12/02:34:21 MET), the Gaseous Nitrogen (GN₂) accumulator pressure on the left OME increased by 7 psia, peaking at 334 psia. The pressure had previously been decreasing at a negligible rate. Since peaking, the pressure trended downward at a rate of 1.3 psia per hour. Similar behavior was observed in the system during STS-118. Flight rule limits were not exceeded and there were no flight issues.

Flight Day 14

The primary activity for FD 14 was hatch closure, with a half day for crew off duty.

The PSP 1 lost I/O with the SM GPC at 332/17:39:12 GMT (12/16:43:33 MET), resulting in a 'S62 BCE BYP PSP1' fault message (IFA STS-126-V-16). The PSP I/O reset command was uplinked in an attempt to reestablish I/O with the SM GPC, but was unsuccessful. PSP 1 was then power cycled from the ground, and the subsequent I/O reset successfully reestablished I/O with the SM. At 333/02:56 GMT (13/02:01 MET) the PSP 1 again lost I/O. PSP 1 was powered off from the ground at 333/03:01 GMT (13/20:06 MET).

The SRMS/OBSS was maneuvered to the undocking position at approximately 332/20:30:00 GMT (12/19:34:21 MET) in preparation for undocking operations.

The crew performed TCS activation procedures as part of the Rendezvous Tools checkout. The TCS was powered on at 332/21:21:00 GMT (12/20:25:21 MET), and passed all self tests and was operating nominally.

Flight Day 15

The primary activity for FD 15 was undocking, fly-around of the ISS, separation maneuver and late inspection. The OBSS berthing was also completed early.

The Ku-Band radar was not usable post-undocking. The range, range rate, and angle rates were highly erratic (IFA STS-126-V-20). After being switched to and operating in COMM mode for a while, the Ku-Band system was unable to provide a forward and return link in GPC DESIG. Upon configuring back to GPC ACQ, the system locked on and tracked and provided good forward and return link data. Later, the system was configured back to GPC DESIG mode and it began working again in that mode.

The ODS performed nominally for undocking. The undocking command was initiated at 333/14:45:20 GMT (13/13:49:41 MET). The Shuttle/ISS separation occurred at 333/14:47:25 GMT (13/13:51:46 MET). Total drive time for Hook Groups 1 and 2 of 2 min, 7 sec was nominal.

The fly-around of the ISS was initiated with RCS +X pulses of L3A and R1A thrusters at 333/15:08:46 GMT (13/14:13:07 MET). The separation 1 maneuver was initiated with 6.3 sec +X pulses of L3A and R1A at 333/15:55:09 GMT (13/14:59:30 MET). The separation 2 maneuver was performed at 333/16:23:09 GMT (13/15:27:30 MET). This was a 24.24 sec +X maneuver using L3A and R1A. The separation 3 maneuver was performed at 333/23:23:39 GMT (13/22:28:00 MET). This was a 21.7 sec +X maneuver using L3A and R1A resulting in a 5.36 ft/sec ΔV .

A potential conjunction with debris from a defunct Russian satellite resulted in a decision to execute the separation 3 maneuver after the Late Inspection, moving Late Inspection up by 45 min.

The operation of the TCS was nominal and was complete by 333/16:07:00 GMT (13/15:11:21 MET) for undocking and fly-around activities.

The Late Inspection started with the starboard survey at 333/18:30:00 GMT (13/17:34:21 MET) and ended with the port survey at 333/22:00:00 GMT (13/21:04:21 MET). The OBSS was berthed on the starboard Manipulator Positioning Mechanism (MPM) at 333/22:38:00 GMT (13/21:42:21 MET). During the port wing survey, the Laser Dynamic Range Imager (LDRI) video intermittently went blank and flashed (IFA STS-126-V-14). This behavior occurred at approximately 333/20:56 and 333/21:54 GMT (13/20:01 and 13/20:59 MET). Scan overlap from another sequence and data received despite the intermittent behavior were sufficient to obviate the need for additional scans.

During the Late Inspection, the OBSS Pan-Tilt Unit (PTU) offsets were in family with past missions (approximately 3-4 deg). The large tilt offset that was observed on FD 2 and during execution of the FD 10 and FD 12 tests did not appear to be present during the surveys. Both the pan and tilt errors seemed to grow over the course of the survey, but were comparable with errors observed on previous flights.

A supply water dump using the FES was started at 333/21:14 GMT (13/20:19 MET), and the scheduled 2 hr dump terminated at 333/23:30 GMT (13/22:35 MET). The FES operated nominally during the dump.

Flight Day 16

The primary activities for FD 16 were Flight Control System (FCS) checkout, RCS hot-fire, and deployment of the Pico Satellite Solar Cell (PSSC) experiment.

The Late Inspection data review was completed, and the vehicle was cleared for entry.

A waste-water dump was initiated at 334/11:27:05 GMT (14/10:31:26 MET), with a CWC dump initiated at 334/12:27:56 GMT (14/11:32:17 MET).

The FCS checkout was performed satisfactorily. APU 1 was started at 334/16:08:51.757 GMT (14/15:13:1.761 MET) and ran for 4 min and 56 sec consuming 16 lb of fuel.

During the FCS checkout, the crew took pictures of an object floating away from the Orbiter. Imagery analysis identified the object as a Tempilabel from the payload bay.

The RCS hot-fire was initiated at 334/17:08:10 GMT (14/16:12:31 MET) and completed at 334/17:18:54 GMT (14/16:23:15 MET). All 38 RCS thrusters were fired at least twice for at least 0.240 sec per pulse. No anomalies occurred.

The PSSC experiment was deployed at 334/20:31:39 GMT (14/19:36:00 MET).

The Ku-Band system operated nominally in both the GPC Acquisition and GPC Designate modes and was stowed without issue at 334/22:45:39 GMT (14/21:50:00 MET).

The SRMS was powered down and the MPMs were stowed with no issues.

Flight Day 17

During entry preparations, a double keystroke was noticed from the '3' key on the Commander's (CDR) keyboard (IFA STS-126-V-15). A review of data from earlier in the mission revealed several prior instances. This anomaly was not an impact to entry operations.

Both Payload Bay Doors (PLBDs) were closed nominally by 335/16:23.01 GMT (15/15:27:22 MET) in preparation for landing. The planned deorbit maneuvers for the first and second Kennedy Space Center (KSC) landing opportunities were waved off because of inclement weather. As a result, the decision was made to land at Edwards Air Force Base (EAFB), CA.

The deorbit maneuver for the first landing opportunity at EAFB, a dual-engine straight-feed firing, was performed on orbit 250 at 335/20:19:29.3 GMT (15/19:23:50.3 MET). The burn was 174.4 sec in duration with a ΔV of 302.2 ft/sec. The orbit after the deorbit maneuver was 22.1 by 193.0 nmi.

Entry interface occurred at 335/20:53:25 GMT (15/19:57:46 MET). The main landing gear touchdown occurred on the EAFB temporary runway at 335/21:25:07 GMT (15/20:29:28 MET) on November 30, 2008. The drag chute was deployed at 335/21:25:12 GMT. The nose gear touchdown occurred at 335/21:25:20 GMT. The drag chute was jettisoned at 335/21:25:42/1 GMT. Wheels stop occurred at 335/21:26:04 GMT. The rollout was normal in all respects.

The flight duration was 15 days 20 hr 29 min 28 sec. The last APU was shutdown 18 min, 56 sec after landing.

PAYLOADS AND EXPERIMENTS

LAUNCH PACKAGE OVERVIEW

The International Space Station (ISS) Utilization Logistics Flight (ULF) 2 launch package consisted of the Multi-Purpose Logistics Module (MPLM), Lightweight Multi-Purpose Equipment Support Structure Carrier (LMC) and the Space Shuttle Picosat Launcher 5510 (SSPL)/Pico-Satellite Solar Cell (PSSC). The MPLM Flight Module-1 (FM-1) named Leonardo is a pressurized module that carried to orbit seven System/Science racks, six Resupply Stowage Platforms (RSPs), three Resupply Stowage Racks (RSRs), and nine Cargo Transfer Bags (CTBs) attached to the Aft End Cone (AEC) structure. This was a total of 16 racks within the MPLM, the maximum number of racks and cargo carried within the MPLM. The seven System/Science racks included two Crew Quarters (CQ), the Expedite the Process of Experiments-to-Space-Station (EXPRESS) Rack No. 6 (ER-6) plus the crew galley, also the Water Recovery System (WRS) 1 and WRS 2 racks, Waste and Hygiene Compartment (WHC) rack, and the Combustion Integrated Rack (CIR). These System/Science racks, including the Advanced Resistive Exercise Device (ARED) direct-mounted to an RSP, allowed the ISS Program adequate time to check out hardware to support ISS six-crew operations and the ability to support high priority Utilization payload objectives. Additionally, the Cycle Ergometer with Vibration Isolation System (CEVIS) Rack Adapter Bracket (CRAB)/Russian Water Container (EDV) were installed for launch on an RSR and three Zero-G Stowage Racks (ZSRs) were hard-mounted to two RSPs and the ER-6 rack.

CREW ACTIVITY SUMMARY

Highlights of this “extreme home improvement “ mission included single crew rotation, the installation of critical Regenerative Environmental Control and Life Support Structure (ECLSS) system racks necessary for six-crew operations, and four Extravehicular Activities (EVAs) to install and return critical spares located on the LMC and to clean and lubricate the Starboard Solar Alpha Rotary Joint (SARJ).

On Flight Day (FD) 2, the crew performed the Thermal Protection System (TPS) port and starboard wing leading edge (WLE) and nose-cap survey to check for ascent debris damage. A successful rendezvous and docking to the ISS occurred on FD3. Prior to docking, the Orbiter R-bar Pitch Maneuver (RPM) was performed and the ISS crew performed photographic imagery of the Orbiter. Analysis of FD2 TPS inspection and RPM photos indicated that a Focused Inspection (FI) was not required. On FD4, the Space Station Remote Manipulator System (SSRMS) unberthed the MPLM from the Payload Bay (PLB) and successfully berthed the MPLM in the ISS Node 2 Nadir location for the first time. During the docked time-frame, the crew performed four scheduled Extravehicular Activities (EVAs). Numerous Intravehicular Activities (IVA) activations and checkout and remove and replace (R&R) activities, Public Affairs Office (PAO) events, and middeck/consumables transfer operations were also performed. The ISS Reboost was performed on FD 8. The docked mission duration was extended an

additional day on FD11 to accommodate the IVA activities to troubleshoot and process the UPA due to anomalies associated with operating the DA within the Urine Processing Assembly (UPA). On FD13, the MPLM was unberthed from the ISS using the SSRMS and berthing the MPLM in the PLB. Endeavour undocked from the ISS at the beginning of the crew day on FD15. The ISS flyaround was performed using the High Definition Camera System for the first time. On FD15, the Orbiter Boom Sensor System (OBSS) was used to inspect the port and starboard WLE and nose-cap for Micro-Meteoroid/Orbital Debris (MM/OD) damage; no damage was discovered. The vehicle was cleared for entry based on the evaluation of the OBSS late inspection. After undocking, the third separation burn was delayed until post-inspection activities concluded so the Orbiter could avoid a piece of an old, Russian satellite and still perform the PSSC deployment on FD16 as planned. On FD16, prior to stowing the Ku-Band antenna, the PSSC deployment was performed. Poor weather at Kennedy Space Center (KSC) resulted in landing the Orbiter at Edwards Air Force Base on orbit 250 on its third landing attempt of the day.

TRANSFER WEIGHT SUMMARY

TOTAL WEIGHT TRANSFERRED DURING THE MISSION

Parameter	To ISS, lb _m	From ISS, lb _m
MPLM	15,135	3,983
Middeck	1,322	1,160
External Transfers	1,015	1,039
Totals	17472	6182

1. **Water** – The total quantity of supply water transferred was 1345 lbm. A total of thirteen Contingency Water Containers (CWCs) were transferred along with seven Portable Water Reservoirs.
2. **Oxygen** – A total of 22.5 lbm of oxygen was transferred during STS-126; however, 92 lb_m were used for the three EVAs and 29 lb_m were used for the ISS stack maintenance.
3. **Nitrogen** – No Nitrogen was transferred to the Airlock tanks, as the ISS Airlock High Pressure Gas Tanks (HPGT) had less than 15 lbm ullage.
4. **Lithium Hydroxide** – A total of 25 LiOH canisters were transferred to the ISS. A total of 28 LiOH canisters were transferred from the ISS to the Shuttle.
5. **Food** – No food was transferred to the ISS.

SIGNIFICANT FIRSTS

The significant firsts for the STS-126 mission were as follows:

1. The first planned launch pad swap (Pad B to Pad A).
2. The first flight of OI-33 software.
3. The first shuttle crew usage of High Definition video system.

4. The first time MPLM was installed on Node 2.
5. The first delivery and installation of Regenerative Environmental Control and Life Support System (ECLSS) racks to support ISS six-crew habitation; and
6. The first shuttle flight after completion of Linux software deployment in the Mission Control Center (MCC).

SIGNIFICANT ISS ANOMALIES

During the first EVA, a crewlock bag with one of two sets of SARJ cleaning tools was lost. The tools that were lost included:

1. A straight-nozzle grease gun,
2. A J-hook nozzle grease gun,
3. An EVA wipe caddy with EVA wipes (2 wet, 4 dry),
4. A scraper debris container and scraper,
5. A large trash bag,
6. Four Retractable Equipment Tethers,
7. Two Adjustable Equipment Tethers, and
8. Two wire-ties.

Real-time video showed that the bag moved aft/starboard with no ISS or Orbiter contact. The remaining SARJ cleaning tasks were completed using the second set of SARJ cleaning tools. Wet wipes coated with Braycote were used for the cleaning tasks thus minimizing tool sharing. Post-flight, it was determined that an out-of-sequence tool configuration task and a failure to verify tether configurations resulted in the lost EVA crewlock bag.

The UPA activation was started on FD 7. Two hazardous-failure caution annunciations occurred. The first alarm was the result of an overpressure condition caused by a sticky check valve. This caution was erroneously identified as a hazardous-command because of a mapping error in the Caution and Warning (C&W) database. This caution was inhibited. The second alarm was caused by the Distillate Assembly (DA) centrifuge speed being below limits and high motor-currents, which resulted in a shutdown. On FD 8, the UPA was reactivated, ran nominally for two hours, and then exhibited the same DA anomaly. Urine could not be processed, and to achieve adequate samples from the Water Process Assembly (WPA), environmental parameters were adjusted to increase laboratory condensate so that the minimum amount of WPA samples could be obtained during the docked mission. On FD 9, the UPA was reactivated and was run through a process cycle and then a dry down-cycle prior to attempting normal operation. After 2 hr, the system was shut down due to the same DA anomaly. On FD 10, a UPA In-Flight Maintenance (IFM) was performed. The DA was remounted to the Water Recovery System (WRS) rack structure without some of the vibration isolators on the DA mounting plate. It was believed the vibration isolators, used to reduce acoustic noise, could be impacting the DA centrifuge operation. The unit was not vibration tested on the ground with the vibration isolators mounted. After remount and reactivation, the UPA had a liquid sensor error message, which was then disabled by the ground

controller. However, after 2 hr and 53 min of urine processing, the UPA had to be shut down because of the same DA anomaly. An effort began to determine the best options for returning the DA in the Orbiter middeck, if required. On FD 11, two additional hard mounts were installed and all of the fasteners were retorqued. Also, to support additional troubleshooting, a Wireless Instrumentation System (IWIS) Remote Sensor Unit was mounted to obtain accelerometer data when the UPA was activated. The UPA was then deactivated after 15 min because of a high temperature reading at the Moderate Temperature Loop (MTL) inlet. After checking connections, which included re-opening the WRS rack door and noting that the Quick Disconnect (QD) clicked, the ground controller noted that the temperature readings were nominal. The UPA was reactivated and completed a nominal 5 hr of processing. Overnight, it was nominally cooled for 3 hr, followed by a nominal 4.25 hr run. The need to perform this additional IFM activity (and possible additional troubleshooting) lead to the mission being extended an additional docked day. This allowed the UPA to operate long enough to process enough urine so that a highly concentrated sample could be returned to the ground for analysis. On FD 12, the UPA operated nominally for 7 hr, followed by processing that occurred overnight. This was the last planned run for the docked mission, ensuring a highly concentrated urine sample would be returned.

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

Mission priority	Task	Flight Day Task Completed
Category 1		
1	Rotate Expedition 17/18 FE-2 (1J) crewmember with Expedition 18 FE-2 (ULF2) crewmember; transfer mandatory crew rotation cargo per Flight ULF2 Transfer Priority List (TPL) and perform mandatory tasks consisting of the safety briefing, Individual Equipment Liner Kit (IELK) installation, and Sokol suit checkout.	IVA √ FD 3
2	Berth MPLM to ISS Node 2 Nadir Port, activate and check out MPLM.	IVA/SSRMS √ FD 4
3	Perform mandatory water transfers.	IVA √ FD 4-FD 13
4	Transfer critical cargo to ISS per ULF2 TPL.	IVA √ FD 4-FD 13
5	Return MPLM to the Orbiter PLB	IVA/SSRMS √ FD 12

ISS MISSION PRIORITIES COMPLETION STATUS (Continued)

Mission priority	Task	Flight Day Task Completed
6	Transfer and install ISS MPLM racks/items to the ISS. a. WRS1 to LAB1D4 b. WRS2 to LAB1P4 c. WHC to LAB 1P2 d. ER-6 (includes Galley) to LAB1O4 e. ZSR to COL102 f. Crew Quarters to NOD2P5 g. Crew Quarters to NOD2S5 h. ARED to ISS Temp Stow i. ZSR to JPM1A1 j. CIR (PaRIS) to LAB1S3 k. ZSR to JLP1P2	IVA √ FD 5 √ FD 5 √ FD 5 √ FD 5 √ FD 4 √ FD 6 √ FD 6 √ FD 4 √ FD 4 √ FD 4 √ FD 5 √ FD 4
Category 2		
7	Transfer FHRC/FSE IA from the LMC to the ESP-3 site No. 2.	EVA √ FD 5 (EVA1)
8	Return empty NTA/FSE IA from the ESP-3 site No. 2 to the LMC.	EVA √ FD 5 (EVA1)
9	Relocate two Crew Equipment Translation Aids (CETA) carts from Starboard Stbd)-Stbd MT to MT Port-Port configuration.	EVA/ SSRMS √ FD 7 (EVA 2)
10	Perform minimum handover of 12 hours for rotating crewmember (which includes crew safety handover).	IVA √ FD 4- FD 13
11	Transfer cargo items required for mission success per ULF2 TPL. a. Install and return Respiratory Support Pack (RSP) and Radiation Area Monitors (RAM)	IVA √ FD 10
Category 3		
12	Perform ISS daily payload status checks as required.	IVA √ Daily
13	Assemble and activate six-crew system hardware. a. Remove WRS launch restraint and install ORU b. Perform WRS assembly and check out (two racks). Check out is defined as operating Urine Processing Assembly (UPA) and Water Processing Assembly (WPA) through a minimum of one cycle each. c. Perform sampling of WPA (containing Russian Segment (RS) urine processed via UPA. 1. Archival sample 2. Sample for subsequent processing in TOCA2 3. In-flight microbiology sample and analysis d. Perform TOCA2 assembly and checkout. 1. Process sample collected during WPA sampling if crew time permits.	IVA √ FD 6 √ FD 6- FD 10 √ √ FD 11 √ FD 11 √ FD 11 √ FD 9 √ FD 9- FD 11
13.1	Lubricate Port SARJ.	EVA √ FD 11(EVA4)

ISS MISSION PRIORITIES COMPLETION STATUS (Continued)

Mission priority	Task	Flight Day Task Completed
13.2	Perform required ULF2 EVA Activities. a. Lubricate Stbd SARJ. b. R&R TBAs. c. Clean Stbd. Race ring surface. d. Perform EFBM Checkout. 1. Remove Thermal Covers (qty 5). 2. Perform check out and inspection. 3. Re-install center thermal cover. e. Scrape Stbd Outboard race ring canted surface. f. Clean Stbd. Non-race ring surface (skirt and joggles). g. R&R last dirty TBA. h. Perform EFBM contingency berthing mechanism manual operation.	EVA √FD 5,7,9,11 (EVA 1-4) √FD 5,7,9,11 (EVA 1-4) √FD 5,7,9,11 (EVA 1-4) EVA/IVA/ Ground/JEMRMS √FD 5 (EVA1) √FD 8 (IVA) √FD11(EVA4) √FD 5,7,9,11 (EVA 1-4) √FD 5,7,9,11 (EVA 1-4) √FD 11(EVA4) √FD 11(EVA4)
14	Perform ISS payload research operations tasks, Sortie experiment activities, and SDBIs. a. GLACIER b. Human Research Program (HRP)/Integrated Immune c. National Lab Pathfinder (NLP)-Cells-1 d. NLP-Vaccine-2 e. HRP/Sleep Short f. Motion Perception (MOP) g. Low Back Pain-Muscle (MUS)	IVA √ Daily √FD 7,9,11,13,15 √FD 3,6,11,15 √FD 2,3,15 √ ~Daily √ ~Daily √ ~Daily
15	Perform payload operations to support SSPL 5510/PSSC deployment.	IVA/Ground √FD 16
16	Transfer and install NOD2S5 RSR to MPLM for return.	IVA √FD 6
17	Install two JAXA Proximity GPS Antennas on JLP.	EVA √FD 11(EVA4) Only 1 of 2 installed.
18	Lubricate the SSRMS LEE A Snares.	EVA/SSRMS √FD 7 (EVA2)
19	Install and check out ETVCG at CP7.	EVA/Ground √FD 11(EVA4)
20	Transfer remaining cargo items per Flight ULF2 TPL.	IVA √FD 3-FD14
21	Perform maintenance of ISS RS systems.	√IVA

ISS MISSION PRIORITIES COMPLETION STATUS (Continued)

Mission priority	Task	Flight Day Task Completed
22	<p>The following tasks are deemed to fit within the existing EVA timelines; however, may be deferred if the EVA is behind schedule. The EVA will not be extended to complete these tasks.</p> <p>a. IR camera thermal imagery and EVA still camera photography of S1 Radiator delamination and S1 and P1 radiator.</p> <p>b. Eva still camera photography of Zenith MT/TUS cable blemishes.</p> <p>c. EVA still camera photography of SSRMS Boom suspect micrometeoroid damage.</p> <p>d. Release Stbd SARJ aft nadir SLR.</p> <p>e. Secure grounding tabs to clear JEMRMS EE Field of View (FOV).</p> <p>f. Install JEM OIHs and WIFs.</p> <p>g. Close and secure Node 2 Zenith window flap.</p>	<p>EVA</p> <p>FD 11(EVA 4)</p> <p>√ FD 7(EVA 2)</p> <p>√ FD 7(EVA 2)</p> <p>√ FD 5 (EVA 1) FD 11(EVA 4)</p> <p>FD 11(EVA 4) √ FD5 (EVA 1)</p>
23	Transfer Lamp Housing Assemblies (LHAs) and Ballast Baseplate Assemblies (BBAs) from the MPLM to ISS.	<p>IVA</p> <p>√ FD 12</p>
24	<p>Activate and Check out USOS Portable Water Bus (PWB)</p> <p>a. Configure and flush PWB.</p> <p>b. Configure ER-6 for PWD operation.</p> <p>c. Activate and sample PWD.</p>	<p>IVA</p> <p>√ FD 9-FD 13</p>
25	Install/Remove AmiA in the JEM.	<p>IVA</p> <p>√ FD 10-FD 11</p>
Category 4		
26	Transfer N2 from the Orbiter to the ISS High Pressure Gas Tank (HPGT).	<p>IVA</p> <p>FD 4-FD 8</p>
27	Reconfigure PFE/PBA in JPM.	IVA, Defer
28	<p>Perform IVA get-ahead tasks if time permits. The following IVA get-ahead tasks do not fit in the existing timelines; however, the IVA team will be trained and ready to perform should the opportunity arise. MOD has the flexibility to select the tasks to be completed based on scheduling efficiencies associated with scheduled required tasks.</p> <p>a. Cargo Unpack.</p> <p>b. Install hardware command panel (HCP) and cables if not completed during stage 17S (for HTV).</p> <p>c. Reconfigure the Clean Bench chamber.</p> <p>d. Remove JLP Heater Controller (JLP-HCTL) LTA and install JLP Exposed Facility (EF) Drive Unit (EDU).</p> <p>e. Perform JLP Exposed Facility Unit (EFU) Checkout.</p> <p>f. Perform ER-6 laptop deploy.</p> <p>g. Install Node 2 Zenith hatch handle guide ring assembly.</p> <p>i. Remove and replace failed LHAs and BBAs in USOS and International Partner (IP) modules</p> <p>j. Install Solid State Light Module (SSLM) with grounding wire.</p> <p>k. Perform WHC assembly.</p> <p>l. Perform work light touch temperature test.</p>	<p>IVA/ Ground</p> <p>Defer</p> <p>Defer</p> <p>Defer</p> <p>Defer</p> <p>Defer</p> <p>√ FD 9</p> <p>√ FD 10</p> <p>Defer</p> <p>Defer</p> <p>√ FD 5</p>

ISS MISSION PRIORITIES COMPLETION STATUS (Continued)

Mission priority	Task	Flight Day Task Completed
29	Perform 4 additional hours per rotating crewmember of ISS crew handover (16 hours per crewmember total).	IVA
30	Reboost the ISS with the Orbiter if mission resources allow and are consistent with ISS trajectory analysis and planning.	IVA/ Ground √ FD 8
31	Perform payload of opportunity operations to support MAUI and SEITE.	IVA/ Ground
32	Perform imagery survey of ISS exterior during Orbiter flyaround after undock.	IVA √ FD 15
33	<p>Perform EVA get-ahead tasks if time permits. The following EVA get-ahead tasks do not fit in the existing EVA timelines; however, the EVA team will be trained and ready to perform should the opportunity arise. EVA/MOD has the flexibility to select tasks to be completed based on efficiencies gained in the performed scheduled required tasks.</p> <p>a. Imagery of EVA worksites on FGB to support PDGF installation on 15A.</p> <p>b. Deploy S3 upper outboard Payload Attachment System (PAS).</p> <p>c. Disconnect S1/S3 Segment-to-Segment Attach System (SSAS) Umbilicals and Install Caps (Outboard Bolt Bus Controller (BBC)).</p> <p>d. Disconnect P1/P3 SSAS Umbilicals and Install Caps (Outboard BBC).</p> <p>e. Remove S1 FHRC Launch Restraint Bolts.</p> <p>f. Remove P1 FHRC Launch Restraint Bolts.</p> <p>g. Connect P1-P3 Ammonia (NH₃) Contingency Jumper.</p> <p>h. Connect S1-S3 NH₃ Contingency Jumper.</p>	<p>EVA</p> <p>Defer</p> <p>Defer</p> <p>Defer</p> <p>√ FD 7(EVA 2)</p> <p>Defer</p> <p>Defer</p> <p>Defer</p> <p>Defer</p>
34	Perform SDTO 25007-U, Spatial Differences in CO ₂ concentrations on ISS.	Defer
35	Perform SDTO 13005-U, ISS Structural Life Validation and Extension, during ISS reboost (ISS Wireless Instrumentation System (IWIS) required) (only if crew time available).	IVA/Ground √ FD 8
36	Perform SDTO-13005-U, ISS Structural Life Validation and Extension, during ULF2 Orbiter undocking (IWIS highly desired, but not required) (only if crew time available).	IVA/Ground √ FD 15
37	Transfer O ₂ from the Orbiter to the ISS A/L HPGT (as consumables allow).	IVA √ FD 13
38	Perform Station Development Test Objective (SDTO) 13005-U, ISS Structural Life Validation and Extension, during Stbd SARJ Rotations (External Wireless Instrumentation System (EWIS)).	Ground √ FD 5,7,9
39	Perform SDTO 13005-U, ISS Structural Life Validation and Extension, during EVAs related to Port and Stbd SARJ activities (EWIS).	Ground √ FD 5,7,9,11
40	Perform SDTO 13005-U, ISS Structural Life Validation and Extension, during MPLM Berthing (EWIS).	Ground √ FD 4

ISS MISSION PRIORITIES COMPLETION STATUS (Concluded)

Mission priority	Task	Flight Day Task Completed
41	Perform SDTO-13005-U, ISS Structural Life Validation and Extension, during MPLM Unberthing (EWIS).	Ground √ FD 13
42	Perform SDTO 16009-U, Water Vent Imagery, during one of the docked Shuttle water dumps.	IVA √ FD 12

PICO SATELLITE SOLAR CELL EXPERIMENT

On FD 16, prior to stowing the Ku-Band antenna, the Pico Satellite Solar Cell Experiment (PSSC) was launched satisfactorily at 334/20:33:39 GMT (14/19:38:00 MET) on November 29, 2008.

The Aerospace Corporation PICOSAT Program designed, fabricated and tested the PSSC test bed nanosatellite and delivered the PICOSAT to NASA. The PSSC was 5 in. by 5 in. by 10 in, and the weight of the PICOSAT was 6.35 kg. The PICOSAT ground stations at the Stanford Research Institute (SRI) and in El Segundo made initial contact with the satellite minutes after the launch. After three days of contact by both stations, the SRI station was closed and satellite communication was continued only from the El Segundo ground station. Communications have been routine over the initial 39 days with up to four contacts, for several minutes each, with the satellite per day. During that period, more than 6 MB of data and images were downloaded.

VEHICLE PERFORMANCE

SOLID ROCKET BOOSTERS

All Solid Rocket Booster (SRB) systems performed as expected during the launch-countdown and ascent of the STS-126 mission. The SRB pre-launch countdown was nominal. No SRB Launch Commit Criteria (LCC) or Operations and Maintenance Requirements and Specifications Document (OMRSD) violations occurred. No indication of hold-down post hang-up was identified from the analysis of the data. One SRB In-flight Anomaly (IFA) was identified.

Imagery review showed the plunger and compression spring on Hold Down Post (HDP) no. 3 went through the Right-Hand (RH) Aft Skirt Bore Post during lift-off (STS-126-B-001). It was confirmed during the open assessment of the blast container that the plunger was not there. During the Mobile Launch Platform (MLP) -3 inspection, remnants of the compression spring were found, although the plunger has not been found.

Both SRBs were successfully separated from the ET and the deceleration subsystems performed as designed. The SRB's were towed back to Kennedy Space Center (KSC) for inspection and teardown.

Several first-flight design changes were flown on the SRB and these are discussed as follows:

1. The forward propellant segment grain geometry redesign of the transition region increased the factor of safety for horizontal storage.
2. The Intelligent Pressure Transducer (IPT), which is a stand-alone high-sample rate data acquisition system, was flown to collect motor pressure data.
3. The ATK Booster Separation Motor (BSM) was installed on the SRB aft skirt.
4. The Enhanced Data Acquisition System (EDAS) units and signal conditioning hardware was installed on the SRB forward skirt to collect high-fidelity data from one Operational Pressure Transducer (OPT) on each SRB as well as data from accelerometers and strain gages.
5. The Frangible Nut Crossover System (FNCS) was installed on all eight hold-down posts. The redesigned frangible nut incorporated a pyrotechnic crossover assembly, which mitigates the likelihood of a stud hangup resulting from a time skew between cartridge detonations.

The postflight assessment of the SRB after the return to Kennedy Space Center (KSC) was completed and for the most part, the SRBs were in nominal condition. Two non-nominal conditions were noted on the Left-Hand (LH) SRB and are as follows:

1. The HDP no. 5 Debris Containment System (DCS) plunger was partially seated with frangible nut web; and

2. The HDP no. 6 DCS plunger was partially seated with a half-trapped frangible nut.

REUSABLE SOLID ROCKET MOTORS

The STS-126 Reusable Solid Rocket Motor (RSRM) set performed within established and predicted limits (nominal). No RSRM LCC or OMRSD violations were identified. All Ground Environmental Instrumentation (GEI) and Operational Flight Instrumentation (OFI) performed within established requirements.

The motor performance parameters for this flight were within Contractor End Item (CEI) specification limits. Reconstructed performance parameters adjusted to a 60 °F Propellant Mean Bulk Temperature (PMBT) standard are documented in the ATK RSRM-102 Flight Evaluation Team (FET) report, Document No. TR018485-102.

The ambient temperatures recorded during the pre-launch operations of STS-126 varied from 76 to 81 °F. At the time of launch, the ambient temperature was 72 °F.

Igniter joint heaters operated for 14 hr 15 min during the launch countdown. Power was applied to the heating elements 44% (average) of the time during the LCC time frame of the countdown to keep the igniter joints in their normal operating range. Field joint heaters operated for 14 hr 24 min during the launch countdown. Power was applied to the heating elements 32% (average) of the time during the LCC time frame of the countdown. The aft skirt purge operations were for 11 hr 51 min with one conditioning purge required prior to the 11 hr hold.

Propulsion performance data are documented in the ATK RSRM-102 Flight Evaluation Team (FET) report, Document No. TR018485-102. The calculated PMBT was 72 °F at time of launch. The maximum trace shape variation of pressure vs. time during the 62-80 sec time frame was calculated to be 0.24% at 80.0 sec (left motor) and 0.90% at 70.0 sec (right motor). These values were within the 3.2% allowable limits.

All GEI and OFI sensors operated as expected and no significant hardware problems or weather concerns occurred during the successful countdown. All data were recorded, transmitted and analyzed.

EXTERNAL TANK

All STS-126 objectives and requirements associated with the Super Lightweight Tank (SLWT) External Tank (ET) -129 propellant-loading and flight operations were met. No significant oxygen or hydrogen concentrations were detected in the Intertank. All ET electrical equipment and instrumentation operated satisfactorily. Purge and heater operations were monitored and performed properly. Liquid level and Engine Cutoff sensors performed as designed. No ET LCC or OMRSD violations occurred and no IFAs were identified in the data analysis.

ET separation was nominal. Since Main Engine Cut-Off (MECO) occurred within expected tolerances, entry and break-up of the ET occurred within the predicted footprint.

Several first-flight changes were flown on the ET and these are discussed as follows:

1. Changes in Processes affecting the Thermal Protection System (TPS) in the areas of the Liquid Oxygen (LO₂) Ice Frost Ramp and the Longeron Foam applications.
2. The LO₂ feedline camera was changed due to obsolescence issues with the previous camera, with no impact to the functional use of the camera.

The Final Inspection Team (FIT) reported light to moderate condensation was observed on the LH₂ tank with condensate increasing toward the end of the inspection. The LO₂ tank and intertank were observed to be dry. Less than typical ice/frost formations were observed on the umbilicals. Some TPS defects were noted and all were acceptable per established documentation.

SPACE SHUTTLE MAIN ENGINES

All Space Shuttle Main Engine (SSME) parameters were nominal throughout the pre-launch countdown and were typical of previous flights. The Block II engines were 2047, 2052, and 2054 and these were in positions 1, 2, and 3, respectively. No LCC or OMRSD violations were noted, nor were any IFAs identified during the data analysis. 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. The High Pressure Oxidizer Turbo Pump (HPOTP) and High Pressure Fuel Turbo Pump (HPFTP) temperatures were within specifications throughout engine operation. Commanded Max Q throttle down was a one step throttle to 72%, which indicates Adaptive Guidance Throttling (AGT) was not initiated. Propellant dump operations data were normal and the time of MECO time was Engine Start +510 sec. The average SSME specific impulse tag value was 452.16 sec at 104.5% power level.

The review of STS-126 Advanced Health Monitoring System (AHMS) vibration measurements indicates nominal performance. No Failure Identifiers (FIDs) were reported to the Vehicle Data Table (VDT) from start preparation through propellant dump on all engines.

SHUTTLE RANGE SAFETY SYSTEM

The Shuttle Range Safety System (SRSS) closed-loop testing was completed as scheduled during the launch countdown. There were no OMRSD or LCC violations. All SRSS Safe and Arm (S&A) devices were armed and system inhibits were turned off at the appropriate times. As planned, the SRB S&A devices were safed and SRB system power was turned off prior to SRB separation.

ORBITER SYSTEMS

Main Propulsion System

All Main Propulsion System (MPS) systems performed as expected during launch countdown and ascent. No MPS-related LCC and OMRSD violations occurred. The MPS pre-launch countdown was nominal, and two IFAs were identified, and these are discussed in following paragraphs.

Tabulations for 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 database.

Approximately MECO +12 sec, the SSME 1 Liquid Hydrogen (LH₂) prevalve inlet pressure close indication was lost. This is a known condition where surge pressures within the prevalve temporarily lift the close indication off the main seat. This condition has been documented in the Acceptance Test Procedure (ATP), and was also seen during Main Propulsion Test Article (MPTA) testing early in the Space Shuttle Program (SSP). The loss of this indication has occurred on several flights during the SSP. It has been documented as a known condition.

The Gaseous Oxygen (GO₂) fixed orifice pressurization system performed as predicted. Reconstructed data from engine and MPS parameters closely matched the actual ET ullage pressure measurements.

The maximum hydrogen concentration level in the Orbiter aft compartment with the normally elevated system backpressure used for fast-fill was 149 ppm (uncorrected). This value compares favorably with previous data for this Orbiter.

The Gaseous Hydrogen (GH₂) system in-flight performance was nominal with the exception of the anomaly on the GH₂ Flow Control Valve (FCV) no. 2, which is discussed in a following paragraph. Flow control valves no.1 and no.3 performed nominally with 14 cycles for FCV no. 1 and 5 cycles for FCV no. 3. FCV no. 2 did cycle 7 times, but remained failed after the last cycle.

Data from ascent showed a greater than expected pneumatic Helium pressure decay (IFA STS-126-V-09). The helium pneumatic tank pressure on previous flights has dropped approximately 20 psi during ascent. During STS-126, the pressure decay was approximately 140 psi. The leak stopped after ascent and all helium bottle pressures remained stable for the remainder of the mission. The Helium is used for aft compartment and Orbital Maneuvering System (OMS) pod purges as well as MPS propellant manifold repressurization during entry. This anomaly did not impact the flight.

During ascent at 320/00:57:05 GMT [00/00:01:26 Mission Elapsed Time (MET)], the SSME 2 GH₂ outlet pressure stepped down 200 psi without a corresponding ullage

pressure signal conditioner command change (IFA STS-126-V-08 and IFA STS-126-I-004). This occurred after the throttling for Maximum Dynamic Pressure (Max Q) was completed. The differential outlet pressure for this FCV position was 260 psi during previous command changes prior to the throttling operations. There was no mission impact. The GH₂ pressurization system is not active after ascent or for the remainder of the flight.

Hazardous Gas Concentrations

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

HAZARD GAS CONCENTRATIONS AT LAUNCH

Parameter	Peak, ppm	Steady State, ppm
Helium	9800	6600
Hydrogen	125	28
Oxygen	20	8
LD54/55	0	0

Gas Sample Analysis

The measured sample bottle pressures indicate the redesigned Orbiter aft fuselage gas sampler system successfully collected five samples for STS-126. One bottle (RH1) leaked to ambient pressure.

SUMMARY OF BOTTLE PRESSURES AND GAS CONCENTRATION

Bottle No.	Position	Pressure, psia	Helium, %	Measured Oxygen, %	Hydrogen, %
1	RH 1	14.7	N/A	N/A	N/A
2	LH 1	1.41	0.27	2.86	0.04
3	RH 2	1.35	0.38	4.50	0.06
4	LH 2	0.75	0.41	4.60	0.10
5	LH 3	0.16	0.77	1.80	0.29
6	RH 3	0.06	1.66	1.01	0.74

The Ascent Hazard Analysis indicates the maximum hydrogen firing leak rate was 1640 scim. The maximum allowable firing leak rate on ascent is 57,000 scim. Hydrogen concentrations were well below the flammability limit in five of the bottles, as one bottle leaked to ambient pressure. The concentrations are shown in the following table.

HYDROGEN FIRING LEAK RATES

Bottle no.	Position	Hydrogen Firing Leak Rate, scim
1	RH 1	N/A
2	LH 1	1020
3	RH 2	1520
4	LH 2	1640
5	LH 3	1220
6	RH 3	1200

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, %
1128 FLT-1	RH1	760	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1101 FLT-3	LH1	72.8	0.15	16.06	0.27	0.03	0.01	<0.01	3.36	2.86	0.06	0.04
1145 FLT-0	RH2	69.8	0.22	23.55	0.38	<0.01	<0.01	0.01	4.93	4.50	0.06	0.06
1102 FLT-3	LH2	38.6	0.24	25.70	0.41	<0.01	<0.01	0.01	5.38	4.60	0.10	0.10
1126 FLT-1	LH3	8.12	0.13	14.35	0.77	<0.01	0.04	0.01	3.01	1.80	0.29	0.29
1148 FLT-0	RH3	3.01	0.07	7.49	1.66	<0.01	0.13	0.02	1.57	1.01	0.75	0.74

Two oxygen concentrations were right at the flammability limit (right hand no. 2 and left hand no. 2 bottles). Measured argon concentrations indicate air as the source of most of the oxygen concentrations and not a MPS leak. This was the first flight in which all samples had negative values when subtracting O₂ from air from percent of O₂ found. Negative values can occur due to the margin of error of measuring percent of argon in the sample, and using it to determine the quantity of air present.

The highest Helium concentration was 1.66% in bottle right hand no. 3. This was a lower than normal helium concentration, which is not a concern. Due to the low pressures at the time the last bottle acquired its sample and the lack of diluting atmosphere, the last bottle has shown to have the most variation.

Purge, Vent, and Drain System

The Purge, Vent and Drain (PV&D) system performed well during launch. Purge readings and hazardous gas detection system readings were nominal. The following off-nominal observation was made:

The measurement for oxygen concentration in the white room was not available on STS-126. The value did not drop below 20%, however, as a precaution, the forward flow rate was reduced from 86 lb/min to 82 lb/min and vent doors 1 and 2 on the leeward side were opened. Both actions reduced the pressure in the forward fuselage and reduced the Gaseous Nitrogen (GN₂) intrusion into the white room. The vent doors were repositioned to purge after the crew left the white room.

The PV&D system performed nominally during the entry and landing phases. The purge was not initiated within 45 min of touchdown and was not begun until 71 min after landing.

Reaction Control System

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

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, %	79.85	79.06	100.48	100.76	100.48	100.76
Target, pounds	1305	811	1523	962	1523	962
Calculated, %	82.93	82.52	100.63	100.69	100.50	100.69
Advertised, lb	1346.6	840.4	1525.0	961.4	1523.7	961.4
PASS WHI ^a	4.3065	4.2449	4.3766	4.2197	4.3687	4.2486
BFS WHI ^b	N/A	N/A	N/A	N/A	N/A	N/A

Notes:

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

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

All Tyvek covers released at nominal speeds. The Ascent Imagery team identified a piece of light-colored debris passing from the nose region of the Orbiter and over the starboard wing at approximately 29 sec MET (approximately 675 ft/sec = to 460 mph). The ascent Imagery team believes this debris was most probably a remnant of the F4D Tyvek cover left behind when the main cover separated, similar to cover failures on STS-118 and -124; however, the poor lighting conditions of the night launch made it

impossible to confirm the presence of any Tyvek remnant at cover separation. Since such cover remnants releasing prior to 1000 ft/sec have been accepted by the Space Shuttle Program as “expected debris” in NSTS 60559, no Orbiter IFA was taken. Tyvek cover release speeds and vehicle alpha/beta angles at cover release are shown in the following table.

TYVEK COVER RELEASE TIMES, VELOCITIES AND ALPHA/BETA ANGLES

Cover	MET (sec)	Velocity (mph)	Alpha (deg)	Beta (deg)
F1D	4.9	62	-24	11
F3D	5.9	75	-18	9
F2D	5.9	75	-18	9
F4D	6.0	76	-18	9
F1L	8.2	106	-10	6
F3F	9.2	120	-8	2
F3L	9.3	121	-8	2
F4R	9.3	122	-8	2
F2R ^a	9.5	124	-8	2
F1F	9.7	126	-7	2
F2F	9.8	128	-7	1
F1U	9.8	129	-7	1
F2U	10.7	142	-4	-2
F3U ^b	12.6	170	2	-5

Notes:

^a Cover detachment not observed. First view noted aft of windows on starboard side

^b Cover detachment not observed. First view noted over canopy.

Ascent Imagery analysis also identified a flat, light-colored rectangular-shaped debris item that was released from near the left umbilical door on the belly of the Orbiter at approximately 42 sec MET and breaking up into several smaller pieces (IFA STS-126-I-010). Further Imagery analysis found that the F4D cover, after releasing nominally, passed under the Orbiter and was last seen in the vicinity of the umbilical door but was not seen to exit that area. The Ascent Imagery Team believes the cover became hung up on the umbilical door until approximately 42 sec MET when it finally released. No damage to tile occurred. Note that such a cover trajectory is expected at these release conditions and has been predicted by earlier debris transport analyses during Tyvek cover certification.

The RCS window-protect firing of F1U, F2U and F3U was initiated at 320/00:57:44.33 GMT (00/00:02:04.34 MET) for total duration of 2.08 sec. The forward RCS performance was nominal. The window-protect firing is intended to deflect exhaust from the SRB separation motors away from the windows during SRB separation.

The ET separation maneuver was performed at 320/01:04:23 GMT (00/00:08:55 MET) and was a 7.0-sec, 10-thruster translation. The ET Photographic +X maneuver was performed.

The RCS firings, times initiated Differential Velocities (ΔV s), and firing times are listed in the following table.

RCS MANEUVERS AND FIRING DATA

Maneuver/Firing	System	Time of Ignition, GMT	ΔV , ft/sec	Duration, sec
RCS Window Protect	RCS	320/00:57:44	N/A	2.08
ET Separation	RCS	320/01:04:23	N/A	7.0
ET Photo +X	RCS	320/01:04:23	N/A	12.7
NC3	RCS	Cancelled	N/A	N/A
NCC	RCS	321/18:29:06.7	0.3	1.2
MC1	RCS	321/19:46:50.6	0.9	2.6
Out of Plane Null	RCS	321/20:05:44.0	N/A	N/A
MC2	RCS	321/20:23:45	1.6	6.8
MC3	RCS	321/20:40:46	1.6	5.0
MC4	RCS	321/20:50:45.6	0.4	1.0
R-Bar Pitch	RCS	321/21:08:10	N/A	N/A
Docking with ISS	RCS	321/22:01:15	N/A	N/A
ISS Reboost (Maneuver from attitude)	RCS	326/17:09:18	3.09 (1.01)	Approximately 30 min
Undocking from ISS	RCS	333/14:47:39	N/A	N/A
Flyaround the ISS	RCS	333/15:08:46	N/A	N/A
Separation 1	RCS	333/15:55:09	N/A	6.3
Separation 2	RCS	333/16:23:09	N/A	24.24
Separation 3	RCS	333/23:23:39	N/A	21.7
RCS Hotfire	RCS	334/17:08:10	N/A	N/A
Forward Reaction Control System Dump	RCS	335/20:35:14	N/A	29.2

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	
	%	lb	%	lb
Forward Oxidizer	0.2	3	.2	2.7
Forward Fuel	0.2	2	.6	5.1
Left Oxidizer	42.8	578	42.6	575.1
Left Fuel	43.0	366	42.6	362.1
Right Oxidizer	40.8	551	40.8	550.8
Right Fuel	41.8	355	41.6	353.6

Note:

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

The Aft RCS propellant usage during interconnect operations with the OMS is shown in the OMS sections of the report. In addition to the consumption shown below, the RCS also used 503.66 lb of OMS propellants during interconnect operations

RCS PROPELLANT CONSUMPTION

Parameter	Oxidizer, lb	Fuel, lb	Mixture ratio, Oxidizer/Fuel
Forward RCS	1116.9	696.3	1.60
Left RCS	783.4	493.8	1.59
Right RCS	806.4	502.3	1.62

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
	321/22:01:15	Free Drift	Docking / ISS Capture
Orbiter	321/22:51:04	LVLH	
ISS	321/23:00:37	Free Drift	
Orbiter	321/23:01:12	Auto	
ISS	321/23:08:48	Free Drift	
Orbiter	321/23:22:02	Auto	
ISS	321/23:56:52	Free Drift	
Orbiter	324/22:06:49	Auto	Simultaneous Supply and Waste Water Dump
ISS	325/00:24:42	Free Drift	
Orbiter	326/16:38:00	Auto	Reboost Maneuver
ISS	326/19:16:05	Free Drift	
Orbiter	328/22:24:53	Auto	Water Dump
ISS	329/01:05:54	Free Drift	
Orbiter	330/16:11:02	Auto	Water Dump
ISS	330/18:16:21	Free Drift	
Orbiter	333/13:35:15	Auto	Maneuver to Undocking Attitude
ISS	333/14:28:03	Free Drift	
Orbiter	333/14:30:23	Auto	
ISS	333/14:43:27	Free Drift	
Orbiter	333/14:45:28		B/ALT /No Low Z
	333/14:47:39		Undocking

As part of the undocking preparations, thrusters F1U, F2U and F3U were reselected. Undocking was initiated nominally with a +Z pulse at 333/14:47:39 GMT (13/13:52:00 MET). The full flyaround maneuver was initiated with a +X pulse of L3A and R1A at 333/15:08:46 GMT (13/14:13:07 MET), and all thrusters operated properly during the undocking operations.

The RCS Hotfire was initiated at 334/17:08:10 GMT (14/16:12:31 MET). All 38 RCS thrusters were fired at least twice for at least 0.240 sec per pulse. No fail-off or fail-leak problems were detected during the hot fire.

The L3D thruster oxidizer injector temperature did not nominally track the fuel injector temperature during post-firing thermal soak-backs. This behavior occurred throughout the mission whenever the L3D thruster was fired. In all cases, the L3D thruster chamber pressure response indicated nominal valve actuation and no detectable leakage. This condition did not impact the mission operations.

The primary thrusters were fired 3071 times for a total firing time of 957.38 sec. The vernier thrusters were fired 9543 times with a total firing time of 22732.6 sec.

During the post-flight valve test, the forward RCS manifold-5 isolation-valve CLOSE Remote Power Controller (RPC) did not indicate on when the valve was cycled to the closed position. Immediately prior to the end of data, the cockpit switch was thrown to close the forward manifold 5 isolation valves, and, at that time, the expected RPC on indication was observed. It is believed that the RPC is not failed because the valve closed when commanded and because the correct RPC indication was observed during the subsequent operation. The lack of observed RPC indication may be a result of the data sample rate for the RPC and valve positions. The cockpit control switch is a momentary switch that is spring loaded to return to the General Purpose Computer (GPC) position when not depressed. In addition, the sample rate for the RPC and valve positions is once per second and the RPC indication may not have been recorded.

Orbital Maneuvering System

The OMS performed nominally throughout the mission. One IFA was identified and is discussed in a later paragraph in this section.

The OMS configuration is shown in the following table.

OMS CONFIGURATION

Vehicle/ equipment	Flight	Orbital Maneuvering Engine (OME)	Ancillary data
Left Pod (LP) 03	33 rd	S/N 107	3 rd rebuilt flight 19 th flight
Right Pod (RP) 03	29 th	S/N 113	3 rd rebuilt flight 6 th flight

The following table shows the maneuvers that were performed during the STS-126 mission.

OMS MANEUVERS

Maneuver designation	Configuration	Time of ignition, GMT	Firing time, sec	ΔV , ft/sec
Assist	Dual Engine	320/00:57:55.5	103.5	N/A
OMS-2	Dual Engine	320/01:33:58.3	63.4	96.2
OMS-3 (NC1)	Dual Engine	320/04:36:57.4	39.4	60.0
OMS-4 (NC2)	Right Engine	320/17:54:37.8	10.4	7.5
OMS-5 (NH)	Dual Engine	321/17:04:02.6	81.2	125.8
OMS 6 (NC4)	Dual Engine	321/17:43:53.8	60.4	94.3
OMS-6 (TI)	Left Engine	321/19:26:48.2	13.0	9.9
(Deorbit)	Dual Engine	335/20:19:29.3	174.4	302.2

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

INTERCONNECT USAGE, %/POUNDS

Parameter	Total, %	Total, pounds
Left OMS	1.821	235.84
Right OMS	2.068	267.82

The official propellant residuals should be taken from the following table using the aft gage results for the left oxidizer and both right tanks. The burn-time Integration should be used for the left fuel tank. The Shuttle Operational Data Book (SODB) Flow rates are presented for comparison purposes.

PROPELLANT USAGE DATA

Parameters	Left OMS pod		Right OMS pod	
	Oxidizer	Fuel	Oxidizer	Fuel
Loaded, lbm	7050	4254	7051	4254
Residual, lbm (aft gage)	503	1305	464	288
Residual, lbm (burn time integration)	519	259	505	227
Residual, lbm (SODB flow rate)	478	267	467	272

Note: Official residuals use the aft gage results for the left oxidizer and both right tanks and the Burntime integration for the left fuel tank.

The Right Crossfeed Oxidizer Drain Temperature dropped below the expected temperature while operating on the A-string heater system (IFA STS-126-V-05). The System Management (SM) alert was lowered from 50 to 45 °F. The sensor subsequently reached 45.7 °F prior to changing from the OMS crossfeed A heater system to the OMS crossfeed B heater system. The operation on the B-heater system showed nominal cycling. This failure did not impact the nominal operations during the mission.

Auxiliary Power Unit System

The Auxiliary Power Unit (APU) system performance was satisfactory and all required APU operations were met. Two In-flight anomalies were identified from the data analysis and review and these are discussed in later paragraphs in this section.

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 (304)	00:21:34	00:04:56	1:02:47	1:29:17
2 (311)	00:21:50	00:00:00	1:29:14	1:51:04
3 (303)	00:21:57	00:00:00	1:03:06	1:25:03

APU FUEL CONSUMPTION

APU (S/N)	Ascent, lb	FCS Checkout, lb	Entry, lb	Total, lb
1 (304)	54	16	137	207
2 (311)	56	0	168	224
3 (303)	53	0	132	185

The APU 3 Z-axis accelerometer exhibited a slow-start response and brief periods of intermittent dropout to zero g's peak-to-peak beginning at prelaunch APU start and during ascent (IFA STS-V-02). This anomaly did not affect APU performance during the mission. This is a low-vibration APU (less than 15 g's peak-to-peak). During the latter part of ascent, both of APU 303's accelerometers (X- and (Y axis) read nominally. An APU should not be operated for extended periods of time above 100 g's peak-to-peak in either axis as documented in the SODB. The accelerometer did not fail totally, but has shown an intermittent electrical condition during the high-vibration portion of ascent. These measurements are used as a long-term health indicator and are not monitored real-time. There was no impact to safety.

Beginning at approximately 322/14:36 GMT (02/13:41 MET) the APU 1 fuel tank outlet pressure reading appeared to have stopped tracking with tank temperatures (IFA STS-126-V-17). After this point in the mission, the expected data-bit drops resulting from the tank thermal decay were not seen in this pressure reading. The redundant fuel tank pressure (located on the Gaseous Nitrogen side of the tank) reading shows nominal tracking with the tank temperature. This anomaly had no effect on APU performance for this mission.

APU 1 was used for the Flight Control System (FCS) Checkout (C/O) and the APU performed nominally. No water spray boiler cooling was required.

APU 2 was started 5 min prior to ignition for the Deorbit Maneuver. APU 1 and 3 were started at Entry Interface (EI) minus 13 min. All three APUs performed nominally.

Hydraulics/Water Spray Boiler System

The Hydraulic (HYD) and Water Spray Boiler (WSB) system performance during all phases of the STS-126 was nominal and no in-flight anomalies were identified from the data review and analysis. All system pressures and temperatures were maintained within nominal limits.

All three WSB system cores were loaded with 5.0 lb of the additive mixture [53% water; 47% [Propylene Glycol Monomethyl Ether (PGME)]. The initial PGME/Water Tank loading for WSBs 1, 2 and 3 were 133.8 lb. Nominal WSB performance was observed on all three systems during pre-launch, ascent, on-orbit and entry.

During STS-126, the Main Landing Gear (MLG) HYD brake-line heater systems B and C were activated for approximately 5 days 17.5 hr as a test to determine the ability of the heaters to provide thermal conditioning of the MLG tires in cold docked Orbiter/ISS attitudes (high beta and over a larger beta range). The heater string A was not activated since it also includes a heater string on the Nose Landing Gear (NLG) tunnel/extend line which was shown by preliminary thermal analysis to potentially reach temperatures above the 275 °F upper limit for the HYD brake-lines during continuous operations. The brake-line B and C heaters were turned off after undocking. The flight data indicated that use of the brake-line B and C heaters on-orbit warmed the MLG tires by about 13 °F above the temperature the tires would have been with no heater operations.

Prior to FCS Checkout, the WSB 1, 2 and 3 Vent Heaters were activated on Controller B. Nominal heater cycling (144 °F to 186 °F) was observed on all three WSB System "B" vent heaters during the FCS checkout.

Performance on all three WSB systems during entry showed the hydraulic heat exchanger mode operation was first indicated on WSB 1 prior to Terminal Area Energy Management (TAEM). WSB 2 heat exchanger mode operation occurred and WSB 3 occurred after landing.

The WSB (PGME)/Water usage during entry for spray cooling was calculated with the Kennedy Space Center (KSC) off-load correlation method shows that the usage was as follows:

1. System 1 – 24.8 lb (PGME/Water)
2. System 2 – 37.2 lb (PGME/Water)
3. System 3 – 34.5 lb (PGME/Water)

Power Reactant Storage and Distribution System

The Power Reactant Storage and Distribution (PRSD) system performance was nominal during STS-126. The PRSD system supplied the fuel cells with 2446 lb_m of oxygen and 308 lb_m of hydrogen for the production of 3619 kWh of electrical energy.

The average power level for the 380.50-hour mission was 9.5 kW. A 106-hr mission extension was possible at the 12.24 kW average power level with the reactants remaining at touchdown. A 134-hour mission extension capability existed at landing, based upon the PRSD O₂ (the limiting reactant) tank landing quantities at the average fuel cell flight power level of 9.5 kW. No in-flight anomalies were identified during the mission or the post-flight analysis of the data.

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

PRSD TANK QUANTITIES

Oxygen	Tank 1, %	Tank 2, %	Tank 3, %	Tank 4, %	Tank 5, %	Total Mass, lb_m
Loaded	101.4	100.1	101.4	101.8	101.4	3953
Launch	100.1	99.2	100.5	100.5	100.1	3908
Landing	47.5	49.3	39.6	11.6	6.3	1205
Hydrogen	Tank 1, %	Tank 2, %	Tank 3, %t	Tank 4, %	Tank 5, %	Total Mass, lb_m
Loaded	101.9	102.3	101.0	102.3	101.9	486.6
Launch	98.4	98.8	98.8	99.3	98.4	454.2
Landing	46.6	45.8	63.0	2.9	1.5	146.2

The total oxygen supplied to the Shuttle/ISS Environmental Control and Life Support System (ECLSS) was 257 lb_m of oxygen. A total of 22.5 lb_m was transferred to the ISS.

Fuel Cells and Station-to-Shuttle Power Transfer System Operation

The overall performance of the fuel cells was nominal. One IFA was identified from the data during the mission. The anomaly is discussed in a later paragraph in this section.

The average electrical power level averaged 9.5 kW and the total load averaged 305 Amperes (A). During the 380.50 hr mission, the fuel cells produced 3619 kWh of electrical energy and 2754 lb_m of potable water. The fuel cells consumed 2446 lb_m of oxygen and 308 lb_m of hydrogen.

The actual Fuel Cell voltages (200 A load) at the end of the mission were 0.10 Volt (V) below predicted for fuel cell 1, 0.05 V above predicted for fuel cell 2, and 0.10 V above predicted for fuel cell 3. The voltage margins above the minimum performance curves at 200 A at the end of the mission were 1.22 V above minimum for fuel cell 1, 0.90 V above minimum for fuel cell 2, and 0.74 V above minimum for fuel cell 3.

The overall thermal performance of the fuel cell water relief, water line, and reactant purge heater systems was nominal. The system A on the water relief and water line systems was used during launch, ascent, and up to 333:17:58 GMT (13/17:03 MET) and then was reconfigured to system B until the end of mission.

The Fuel Cell Monitoring System (FCMS) was used to monitor individual cell voltages during prelaunch, on-orbit, and postlanding operations. Full-rate on-orbit data were recorded for 12 min 1 sec and no problems were noted.

The fuel cell 1 hydrogen flowmeter measurement began drifting high and became erratic at 320:12:22 GMT (00/11:27 MET) (IFA STS- 126-V-07). At times, the measurement read off-scale high, when the fuel cell was at a low load during Station-to-Shuttle Power Transfer System (SSPTS) operation. When the fuel cell load was increased, during the times when the Orbiter Power Convert Units (OPCUs) were unpowered for Extravehicular Activities (EVAs), the flowmeter measurement came down from off-scale high but was still reading high and erratic. A review of the electrical bus data did not show any anomalous indication at the time of the failure. The measurement did not respond to flow-rate changes during any of the on-orbit purges, but did work nominally during the prelaunch purges.

The primary purpose of the flowmeter is to indicate purge flow. Purge flow can be verified by other parameters (coolant pressure, Hydrogen flow, vent line temperature, fuel cell performance). The flowmeters can also assist in detecting external leakage downstream of the flowmeter. Fuel cell flowmeter failures are a common occurrence. There was no impact to the vehicle/mission, and no crew response was required.

During the fuel cell 2 shut-down sequence at the landing site, the Main Bus B (MNB) ground power supply was lost after fuel cell 2 had been removed from the bus and before it had been stopped. Loss of the bus would cause the FC-40 Coolant and H₂/H₂O Pumps to stop, but the sustaining heater was still enabled. Based on estimates, the sustaining heater would activate in 3-4 min. A total of 6 min elapsed before fuel cell 2 was brought to Stop, which would inhibit sustaining heater operation. Based on the data, Fuel Cell 2 may have had 2-3 min of sustaining heater operation without coolant pump operation. Stagnate FC-40 coolant may have overheated and started to break-down at 392 °F. As a result, the fuel cell was removed and returned to the vendor to determine the extent of the damage.

The SSPTS performed nominally during the STS-126 mission. The SSPTS provided 1498 kWh of power to the Orbiter during the docked period.

When set at maximum output, the SSPTS attempts to regulate Orbiter bus voltage at 31.8 Vdc up to its maximum output of about 6 kW. During SSPTS operation at low power levels, 12-13 kW total Orbiter power, the fuel cell coolant stack exit temperatures were about 185-187 °F. No sustaining heater cycles were observed due to the stack exit temperature not reaching the 183.5 °F turn-on point.

Electrical Power Distribution and Control System

The Electrical Power Distribution and Control (EPDC) system performed nominally during all mission phases of the STS-126 mission. The data review and analysis of all

available EPDC parameters was completed and no anomalous conditions were identified.

As a minimum, the following EPDC parameters are analyzed each mission:

1. Fuel cell voltages and currents;
2. Power Transfer Unit voltages and currents;
3. Essential bus voltages;
4. Control bus voltages;
5. Forward Power Control Assemblies voltages and currents;
6. Mid-Power Control Assemblies (MPCAs) voltages and currents;
7. Aft Power Control Assemblies voltages and currents;
8. AC bus voltages and currents;
9. AC bus Monitor/auto switch status and overload/over-voltage alarm
10. Main bus-to-Control bus Remote Power Controller (RPC) status
11. Forward, Mid and Aft Motor Control Assemblies operational status
12. Fuel cell-to-Essential bus switch status
13. Main bus-to-Essential Bus RPC and switch status
14. Drag chute Pyrotechnic Controller Functions

In addition, during a SSPTS portion of the flight, the following additional parameters are analyzed:

1. Assembly Power Converter Unit (APCU) voltages and currents;
2. Orbital Power Converter Unit (OPCU) voltages and currents;
3. APCU and OPCU temperatures;
4. Main Distribution Control Assembly (MDCA) motor switch status;
5. APCU status bits and trips and
6. OPCU trips.

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 8 min 1 sec, and the avionics hardware was powered for 4 min 48 sec. The system was ready for rendezvous and docking with the ISS.

The application of power for the docking activities was initiated at 321/21:34:36 GMT (01/20:28:57 MET), and the ODS was powered for 1 hr 17 min 54 sec. The initial contact and capture of the ISS occurred at 321/22:01:17 (01/21:05:38 MET). The initial damping was 17 min 54 sec and performance of the "Disable and Release Dampers" procedure was necessary to ensure that any stuck dampers were disengaged.

One distinguishing element of the docking event was how the stuck dampers release procedure was implemented. The procedure is used after capture for releasing clutches in the high-energy dampers. The procedure calls for driving the docking ring in for 5 sec. The ring was driven in for 14 sec. Due to one of the dampers being in a stuck condition, the longer duration of ring drive resulted in a more severe condition for ring misalignment. The ring was in a fixed misaligned state for approximately 13 min. The crew was then given the OK to proceed with the next step in releasing the stuck dampers which is to drive the ring out for 5 sec. However, the ring was driven out for approximately 10 sec. The ring remained misaligned for another 10 min and then went back into alignment. Once the dampers were confirmed released and proper alignment was achieved, the ring was then successfully retracted to the final position and hooks were closed, thus completing the docking event at 321/22:45:28 GMT (01/21:49:19 MET).

In preparation for undocking, the ODS was activated at 333/14:20:04 GMT (13/13:24:25 MET). The undocking and separation from the ISS was completed satisfactorily at 333/14:47:27 GMT (13/13:51:49 MET).

Life Support Systems

Atmospheric Revitalization Pressure Control System

The Atmospheric Revitalization Pressure Control System (ARPCS) performed nominally throughout the mission and all of the scheduled in-flight checkout requirements were satisfied. The Pressure Control System (PCS) 1 was configured and used for the entire mission until after undocking. The PCS was configured to system 2 and checkout of system 2 was completed satisfactorily.

An Orbiter-to-ISS tank-to-tank Oxygen transfer was performed, and the final amount of the offload to the ISS was approximately 22.5 lb. No Nitrogen transfer was performed to the ISS during this mission. The Vestibule was leak checked for docking and undocking operations. There were four Orbiter/ISS stack repressurizations performed prior to undocking using the Orbiter PCS. The repressurizations were performed by opening the payload Nitrogen valves, and the restrictors in the line limited the flow to 7 lb/hr for better cabin air mixing. There was one oxygen repressurization performed prior to docking with the ISS.

Supply and Waste Water System

The Supply Water and Waste Management Systems performed nominally throughout the mission. Supply water was managed through the use of the Flash Evaporator System (FES), water transfer to the ISS and the overboard nozzle-dump system. One supply water nozzle dump at a nominal dump rate of 1.6 % per minute (2.7 lb/min) and two Portable Water Reservoir (PWR) dumps through the supply line were performed. The line heater maintained the supply water dump line temperature between 76 °F and 92° F. Five wastewater simultaneous nozzle dumps were performed at a nominal

average rate of 1.95% per minute (3.21 lb/min). In addition, three Shuttle-condensate bags and one Russian bag condensate (approximately 20 lb) and one leaking Contingency Water Container (CWC) were dumped through the waste line. The waste water dump line temperature was maintained between 60 °F and 77 °F throughout the mission

A total of thirteen CWCs were filled with supply water and transferred to the ISS, for a total of 1197.2 lbm. In addition, 7 PWRs of iodinated water for a total 147.8 lbm were filled and transferred to ISS. One CWC (S/N 1076) was reported leaking after it was filled. The water was processed on ISS and the crew reported approximately 8 lb of residual in the bag which was then transferred back to Shuttle to dump overboard.

The supply water tank “B” quantity sensor exhibited a quantity dropout many times throughout the mission. The same dropouts were recorded during STS-123 on this vehicle (OV-105), and were discussed by the Problem Resolution Team (PRT) after STS-123 mission for possible replacement and the PRT decided to leave the quantity sensor as is. Such dropouts have been experienced during previous flights and the problem is caused by either contamination of the collector bar and/or a surface defect on the collector bar of the potentiometer, which causes an intermittent break in continuity.

At approximately 321/29:55 GMT (01:29:00 MET), data showed that water Tank A was not filling based on the Fuel Cell water production rate. The tank B inlet was closed to isolate water flow through the check valve (A/B) to tank B, and the tank A fill rate increased to match the fuel cell production. The performance of the check valve was monitored until the nominal reconfiguration of the system after all CWCs were filled. Further investigation revealed that A/B check valve cracking pressure was within the Operational Maintenance Specifications and Requirements Document (OMRSD) requirement.

Vacuum vent line temperature was maintained between 76 °F and 60 °F.

Smoke Detection and Fire Suppression System

The Smoke Detection and Fire Suppression (SDFS) system operated nominally with no issues. The Smoke Detection Test was performed of FD 1 and all Smoke detection A and B Sensor circuits operated nominally.

Use of the Fire Suppression system was not required.

Airlock System

The Airlock Systems performed nominally throughout the mission and all of the scheduled in-flight checkout requirements were satisfied. Also, no Orbiter-based EVAs were performed during this mission. All water line and vestibule heaters cycled on all systems. The Airlock structural heater for the upper conic structural temperature and

the internal lower bulkhead did not cycle on the A system. All other structure temperatures cycled on both A and B. The structure temperatures didn't cycle on heater A because of the warm thermal environment as confirmed by the Thermal Control System (TCS) data. These heaters were cycled during the previous flight of OV-105, and there is no indication that these heaters failed to cycle.

Active Thermal Control System

The Active Thermal Control System (ATCS) performed satisfactorily throughout the STS-126 mission. No in-flight anomalies were identified from the review and analysis of the data.

During ascent, the FES exhibited condensate cooling or pre-evaporative cooling prior to the General Purpose Computer (GPC) controller activation. The amount of pre-evaporative cooling was within family. The duct temperatures displayed proper heater control and no excess carryover occurred during this event.

After orbit Insertion, the FES was configured from the Primary A Command controller to Primary B Command controller to support CWC water accumulation requirements. In support of these requirements, the supply water tanks A and B are ganged together while the FES feedline B system draws water from tanks C and D, which are ganged together.

The radiators were not deployed this flight.

At 320/23:57 GMT (06/23:02 MET), the crew was requested to configure the Water Coolant Loop (WCL) 2 bypass valve from Auto to Manual and the valve was positioned to yield approximately 1,200 lb/hr water flow at the interchanger. This change was performed to reduce the Orbiter's humidity control capacity and thereby increase humidity in the stack to satisfy ISS condensate collection requirements. A real-time mission analysis was performed to verify that the configuration would produce the desired result, which increased the dew point or relative humidity of the Orbiter air while having the least impact to cabin temperature. The dew point did increase by about 2 °F after the configuration was implemented.

Crew compartment Partial Pressure Carbon Dioxide (ppCO₂) levels were maintained below 5.38 mmHg through the mission duration. The nominal Lithium Hydroxide (LiOH) canister change-out schedule was adhered to during the flight, and this involved a dual canister change-out during the pre- and post-sleep activity during Orbiter stand-alone operation and a single canister change-out during each pre-sleep period for docked ISS operation. 29 LiOH canisters were spent during the mission.

It was noted for this flight that the Aft Mid-body FES Water Feedline heater A was dithering. Dithering is a phenomenon whereby the controlling thermostat gets into a rapid cycling mode such that the heater is on and off long enough to allow the appearance of constant mid-band temperature. This mode of operation is not

detrimental to the operating system, and should the thermostats useful cycle life be expended and the sensor fail, the system A or B heater can be reactivated.

The Ammonia Boiler System (ABS) tank A and B in-flight leak rate calculation showed approximately 0.02 lbm/day for tank A and 0.01 lbm/day for tank B with the allowable leak rate being no-more-than .0.05 lbm/day.

The ABS system A primary controller was activated at 335/21:33 GMT (15/20:38 MET), about 8 min after landing. Continued ABS operation on system A was terminated after 46 min, when the ground cooling was activated. The full capacity of the tank A was consumed. System B activation was not required because ground cooling was initiated.

Flight Software

The Primary Avionics Software System (PASS) and Backup Flight System (BFS) Flight Software (FSW) performed satisfactorily throughout the mission.

After wheels-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) parameters were completed and the DPS performed all required activities to complete the mission. One IFA was identified, which did not impact the mission, and this anomaly is discussed in the following paragraph.

Shortly after reaching orbit, two issues arose that were ultimately traced back to a single error introduced on OI-33 version of the FSW (IFA STS-126 I-001). The initial attempts to automatically configure the Payload Signal Processor (PSP) were unsuccessful and a work-around was performed with a one-time configuration command uplinked from the ground. Also, the automatic forward-link handovers between the Ku-Band and S-Band antennas were unsuccessful. The condition was also resolved for the flight with a work around, which reverted to using a pre-existing ground-controller manual procedure.

There was a manageable impact to the ground-controller workload during the mission to perform the handovers, and the decision was made that no in-flight fix was desired/required.

Multifunction Electronic Display System

The Multifunction Electronic Display System (MEDS) performed satisfactorily. One anomaly was noted in that double keystrokes of the Commander (CDR) keyboard (the 3 key) during FD 14 and 15 (IFA STS-126-V-15). The anomaly did not impact the mission.

Displays and Controls System

The Display and Controls (D&C) system, including lighting, performed nominally during all phases of STS-126 and no in-flight anomalies were identified from 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 preparations, 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 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 also nominal. Both the Rotational Hand Controller (RHC) and the Translational Hand Controller (THC) were used and exhibited normal channel tracking.

The OMS TVC File IX requirements were met, and OMS TVC actuator rates were normal. Flight control actuator temperatures were also normal. The Rudder/Speed Brake Power Drive Unit (RSB PDU) motor backdrive 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 (TIG) OMS gimbal profile was as expected with the OMS actuator active and standby channels reaching nominal drive rates. All aerosurface actuators 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 during preflight, countdown, orbit, FCS checkout, deorbit preparation, entry, landing and post-landing operations on STS-126. No in-flight anomalies were identified from the results and analysis of the data.

All four ADTAs functioned nominally from power-on until nominal data loss, which occurs at the Lift-off minus-20-min transition on launch day. The ADTA self-tests were performed shortly after power-on and were 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 elevon-park activity.

The ADTA was in the OPS-8 mode for FCS checkout and the 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 the deorbit maneuver 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. The ADTA data were incorporated into Guidance, Navigation, and Control (GN&C) at about Mach 2.6. No ADTA dilemmas or Redundancy Management (RM) failures occurred during deployment through wheels-stop. Entry data was retrieved and reviewed, and no anomalies were observed.

Inertial Measurement Unit and Star Tracker System

The Inertial Measurement Unit (IMU) system performed satisfactorily throughout the STS-126 mission. The IMUs required one adjustment of the onboard IMU accelerometer compensation values during the mission. Also, four adjustments were performed for the IMU drift compensation values.

The Star Tracker (ST) performed nominally during the STS-126 mission in acquiring navigation-stars. However, because of the power-down of various systems, data from the ST was limited for power conservation.

The -Z ST door was closed on FD 4 until after EVA 3 to prevent contamination during the starboard SARJ cleaning activities.

The -Y ST acquired navigation-stars 1153 times, and also missed a navigation-star 1481 times (56.2%) during the mission. Data evaluation showed that 99.1% (1467) of the missed stars belonged to navigation star 106. This condition did not impact the mission.

The –Z ST acquired a star 59 times and missed a star 32 times (35.1%). Data showed that most of these stars were missed during the docking and undocking activities. This condition also did not impact the mission.

The cause of the missed stars in both the –Y and –Z ST was Orbiter attitude, docking and undocking orientation, and bright objects in the field of view. This response is considered nominal operation.

Global Positioning System Navigation

The Global Positioning System (GPS) operation on STS-126 was nominal. All three GPS strings were powered prior to launch. During the power-up sequence, the Miniature Air-to-Ground Receiver (MAGR) receivers were powered prior to the GPS Input/Output (I/O) being activated. This sequence is now standard for day of launch power-up as this procedure eliminates any potential time-out errors which could have been generated by the GPCs polling unpowered MAGR receivers.

GPS no. 1 and GPS no. 3 were powered OFF as part of the Group B Powerdown about 2 hr 22 min into the mission. These two receivers were powered up just before the FCS C/O the day before landing.

Beginning with FCS C/O, all three GPS receivers remained ON until 14 min after touchdown. During entry, the GPS high Figure of Merit (FOM) period usually encountered in the Plasma region cleared on two of three receivers before GPS incorporation into PASS/BFS navigation. The third receiver (GPS no. 1) was delayed due to a roll maneuver but cleared shortly thereafter. No Data Invalid or FOM Chimneys occurred during the critical phase of Entry (below 140,000 ft altitude), where the GPS satellite geometry is less dynamic. After performance confirmation with high-speed C-band tracking, the GPS state vector was set to incorporate in both the PASS and BFS, which is a standard operational procedure for both 3-string and single-string GPS. This occurred 19 min 48 sec after Entry Interface, at approximately 163,000 ft altitude. The effect was that the PASS and BFS navigation state vector residuals were reduced significantly. After GPS incorporation, navigation errors were reduced from approximately 4500 feet to less than approximately 100 feet. The PASS navigation state vector residuals remained consistently low from GPS incorporation through Microwave Landing System (MLS) incorporation at approximately 18,600 ft altitude.

Communications and Tracking System and Navigation Aids

The Communications and Tracking System met all mission requirements. Two Ku-Band anomalies occurred during the mission; however, the anomalies did not impact the successful completion of the mission. These are discussed in later paragraphs in this section.

The Navigation Aids (NAVAID) subsystem performed satisfactorily and met all File IX requirements. In addition, the S-band system operated satisfactorily for over 24 hr, which was the required time to meet the File IX requirements.

From the initial Ku-Band lock-on to the Tracking and Data Relay Satellite (TDRS) after configuring to the Communications (COMM) mode, the Ku-Band antenna did not remain locked in the GPC Acquisition (ACQ) mode (IFA STS-126-V-03). Angles appeared to drift off until the forward-link lock was lost, after which the Ku-Band antenna repointed to the designated angles and reacquired the forward link. This condition repeated each time that the GPC ACQ mode was selected and on both TDRS satellites. When the GPC DESIG mode was selected by the controllers, the Ku-Band antenna forward link remained locked.

At times during the mission, the Ku-Band 216-kbps forward-link frame synchronization parameter was low even though the Data Present signal remained high and the signal strength was maintained (IFA STS-126-V-19). The high signal strength indicates good frame synchronization. The 216-kbps forward link frame synchronization parameter is created in the Ku-Band Signal Processor Assembly (SPA), routed to the Electronic Assembly 1 (EA-1), and included in a status word sent from EA-1 through PF-1 to the System Management (SM) GPC. The 216-kbps forward link frame synchronization dropouts have occurred in the GPC (Acquisition (ACQ) and GPC Designate (DESIG) modes. There was no impact to operations.

During the post-undocking timeframe, the Ku band was taken to RADAR mode. The RADAR was in a proper configuration for this procedure. However, when powered up in the RADAR mode, the data for range and range rate was erratic and unusable (IFA STS-126-V-20). The crew took the pointing mode from GPC to GPC DESIG to check for range and range-rate data improvement. The RADAR did not lock on the ISS. The crew took the pointing mode back to GPC. The same results as the previous GPC mode were seen with very erratic range and range rate data. During this entire period, the SM GPC data did not show the RADAR had detected the ISS, but it did show that the RADAR was tracking the station.

Operational Instrumentation/Modular Auxiliary Data System

The Operational Instrumentation/Modular Auxiliary Data System (OI/MADS) systems performed nominally throughout the STS-126 mission. 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 and sent to the ground for evaluation. The MADS PCM performed nominally with no problems identified from the review of the data. Based on a review of the ascent and entry telemetry data, the MADS recorder and Master Measurement Unit (MMU) performed nominally during all phases of the STS-126 mission.

Mechanical and Hatches System

All mechanical and hatch systems performed within the specification limits. The vent door operations prior to lift-off were nominal. No mechanical systems were active during ascent. Following orbital insertion, the closing of the ET doors and Star Tracker door opening were nominal.

The -Z ST door was closed on FD 4 until after EVA 3 to prevent contamination during the starboard SARJ cleaning activities. The door was closed using a single motor per the established procedure.

In preparation for entry, the vent door repositioning was nominal. The star tracker door closing was nominal, with the exception of the observation in a following paragraph.

During -Z Star Tracker Door closure, motor 2 ran for approximately 0.4 sec longer than motor 1 due to a delayed CLOSED 2 limit switch indication; however, the -Z Star Tracker door closure was well within dual motor time. A similar condition was noted during the STS-123 processing flow in 2007; however, the problem was not repeatable and did not occur during the STS-123 mission.

The vent door repositioning for Entry Interface (EI) and after EI was nominal. The Air Data probe deployment was nominal. The ET door opening and vent door repositioning on the runway was nominal.

Landing and Deceleration System

The landing system performance at the Edwards Air Force Base (EAFB) temporary runway was nominal. This is the first Orbiter landing at the temporary asphalt runway. The primary concrete runway 22/04 has been closed for refurbishment and will be activated for use prior to STS-119. This assessment includes all events from landing gear deployment, main gear touchdown, nose gear touchdown, through roll out, and including drag chute deployment and brake/deceleration.

It was the first flight of the nose landing gear tires. The tires were in good condition and performed nominally. The main landing gear tires appeared nominal. Normal appearance of tread cord materials on areas of the tire's surface is a known and expected condition characteristic of the new tire design. Due to the landing taking place at EAFB, the postflight inspection of the drag parachute hardware at the KSC Parachute Refurbishment Facility was performed as soon as the flown hardware was delivered to KSC. However, analysis of the post flight imagery from the STS-126 landing indicates the drag parachute deployment was as expected and no signs of anomalous conditions for hardware performance exist.

The landing parameters for the STS-126 mission are shown in the following table

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	2,172.4	0.0	210.3	218.4	-1.62	N/A
Drag Chute Deployment	4407.7	6.44	189.2	195.6	N/A	N/A
Drag Chute Disreef	5994.16	11.53	171.5	172.2	N/A	N/A
Drag Chute Jettison	10603.4	36.52	OSL	54.0	N/A	N/A
Wheels Stop	11,385.7	56.76	0	0	N/A	N/A
Parameter			Data			
Brake Initiation Speed, keas			115.9			
Brake On Time, sec			36.03			
Rollout Distance, ft			9213.3			
Rollout Time, sec			56.76			
Runway Location, Surface and Degrees			EAFB Temporary Asphalt/04			
Orbiter Weight at Landing, lb			221979.8			
Parameter	Maximum Brake Pressure, psia		Total Brake Energy, Mft/lb			
Left inboard	900.3		23.60			
Left outboard	971.5		25.61			
Right inboard	877.6		18.36			
Right outboard	767.5		16.56			

^aKnots equivalent air speed

Aerothermodynamics, Integrated Heating and Interfaces

Visual reports indicated overall Orbiter TPS looked normal. The lower structural temperature data indicated normal entry heating. The recorded structure temperatures are within the flight experience of OV-105. However, sensors at location P4 (Tmax = 83 °F) and RP (Tmax = 83 °F) experienced the most temperature rise for the OV-103 vehicle. From MADS surface thermocouples and the Best Estimated Trajectory (BET), Boundary Layer Transition (BLT) onset time was 1283 sec after entry interface and occurred at Mach 6.6 and located at XL= 0.6. The thermal sensor data indicated a symmetrical BLT.

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	123.9
Lower fuselage forward left-hand (B2)	182.5	179
Lower fuselage forward mid left-hand (B3)	153.5	170.4
Lower fuselage mid center (B4)	137.7	139.4
Lower fuselage mid aft center (B5)	174.5	171.1
Lower fuselage aft center (B6)	179.8	153.4
Left-wing center (LW)	106.4	135.9
Right wing center (RW)	119.4	136.8
Port side FRCS forward (P1)	140.4	121.6
Port side fuselage forward center (P2)	96	105.3
Port side fuselage forward mid center (P3)	80.5 ^c	87.2
Port side fuselage mid aft center (P4)	72.7	89.6
Port side fuselage aft center (P5)	77.9	69.3
Starboard side FRCS Forward (S1)	153.5	132.2 ^b
Starboard side fuselage forward center (S2)	132.5	126.5
Starboard side fuselage forward mid center (S3)	103.8	82.5
Starboard side fuselage mid-aft center (S4)	98.6	77.3
Starboard side fuselage aft center (S5)	90.8	67
Left-hand OMS pod side forward (LP)	80.5	69.4
Right-hand OMS pod side forward (RP)	70.1 ^a	56.5 ^a
Lower body flap center	119.4 ^a	87.9 ^a
Right-hand OMS pod side forward	70.1 ^a	56.5 ^a
Left-hand OMS pod side forward	80.5	69.4
Right-hand PLBD forward	64.9	102.1
Left-hand PLBD forward	59.8 ^a	112.0 ^a
Right-hand PLBD aft	80.5	110
Left-hand PLBD aft	80.5	117.6
Right wing upper center	88.2 ^a	110.2 ^a
Left wing upper center	75.3 ^a	112.4 ^a
Forward RCS center	85.6	74.5
Forward fuselage upper center	70.1	92.1

Notes

^a Maximum temperature occurred 30 min after wheel stop.

^b Maximum temperature ever experienced on the OV-105 vehicle.

Thermal Control System

The Thermal Control System (TCS) performed satisfactorily during the STS-126 mission and all passive TCS temperatures were maintained within acceptable limits. One IFA was identified during the mission and it is discussed in a following paragraph.

Flight data for the MLG brake-line heater operation matched model predictions well. This was done to acquire flight data to support the study to alleviate switching attitudes

while docked in cold attitudes. Postflight analysis confirmed the MLG brake line heaters benefit to be at least 13 °F compared to no heaters for both warm and cold exposure.

The Starboard OMS crossfeed oxidizer drain temperature dropped below the expected temperature while operating on the A-string heaters (IFA STS-126-V-05). The SM alert temperature was lowered from 50 to 45 °F. The sensor subsequently reached 45.7 °F prior to changing from the A string to the B heater string. The B-string heater cycled nominally for the remainder of the mission.

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	74
Upper Surface/Window	0	3
Right OMS pod	4	8
Left OMS pod	2	12
Totals	14	97

A post landing walk-down of the runway was performed. No unexpected flight hardware was found. All components of the drag parachute were recovered. The drag parachute hardware and components appeared to have functioned nominally. Both reefing line cutter pyrotechnic devices were expended.

The Orbiter nose cap appeared to be in nominal condition. The Left-Hand (LH) and Right-Hand (RH) Reinforced Carbon-Carbon (RCC) panels both had black external contamination on them. The RH side was panel 7 and both adjacent T-seals. The LH panel was panel 14 and the adjacent aft T-seal.

The SSME Dome Mounted Heat Shield (DMHS) blankets all appeared to be in nominal condition with low fraying.

The LH₂ and LO₂ umbilicals both appeared to be nominal. The ET/Orbiter (EO) doors 2 and 3 both had two missing clips around the perimeter of the salad bowl.

The window 6 damage that was reported on orbit did not appear to have propagated any further. The windows did not appear to have any hazing on them.

A protruding gap filler was observed on the right inboard elevon. The protruding gap fillers on the left OMS pod that had been noticed during the flight do not appear to have

moved from their on-orbit positions. An additional protruding gap filler on the left OMS in the black tiles is sticking out about 1 in.

At the Mate/Demate device, the left outboard MLG tire was noted to have a small puncture in the tread. This was not seen during the runway inspection. The other nose and MLG tires appear nominal.

The nose landing gear door and the MLG doors did not have any corner tile chips.

An interesting tile defect was observed on the Orbiter body flap. The ceramic coating appears to have been rolled back from an impact and has formed a scroll-type shape. The following photograph shows the extent of the damage.



Impact Damage to the Body Flap

Tile and Blanket Flight Assessment

The Imagery Integration Team noted a single-debris release prior to the 135 sec Aerodynamic Sensor Transport Time (ASTT) aft of the vehicle at 33 sec based on available ascent imagery from ground cameras and the ET feedline camera. One anomaly (IFA STS-126-V-01) covers all of the tile and blanket items noted.

One additional debris release was noted after ASTT. No potential vehicle impacts from any of the observed events were identified.

The ascent imagery of the port T-0 area showed what was initially thought to be a loss of a Flexible Reusable Surface Insulation (FRSI) blanket. As a result, the team requested additional imagery of this location. During the Port RCC Survey, the crew zoomed onto the OMS Pod/T-0 umbilical carrier panel interface and determined that the FRSI was in place. Additional Launch Pad imagery was reviewed and the debris source was determined to be ice.

All RPM imagery was downlinked and was reviewed by the Damage Assessment Team (DAT). The Orbiter Project Office (OPO) cleared the starboard side of the vehicle to allow for MPLM installation on Node 2 on FD 4. The Thermal Protection System (TPS) DAT had no Focused Inspection (FI) candidates on the starboard side. There were some protruding gap fillers at various locations, tile coating damage near the LH ET door tile with shallow damage, and a broken DMHS tile (IFA STS-126-V-01).

Images of a Micro Meteoroid/Orbital Debris (MM/OD) strike on Window 6 were downlinked for ground review. The window 6 MM/OD impact assessment was presented and cleared for entry at the Mission Management team meeting.

RCC Flight Assessment

After processing the downlinked Wing Leading Edge (WLE) ascent data, it was discovered at 320/15:15:00 GMT (00/14:19:21 MET) that all three channels of WLE Sensor Unit 1163 (on the Starboard wing) were scaled higher (approximately 7 times) than all other sensors (IFA STS-126-V-04). The data collected was still analyzed, but the unit was not used for on-orbit sensor Group 2 operations. As a result, the RCC panel 4 was monitored with two horizontal sensors rather than the nominal diagonal sensor.

Based on the processed WLE ascent data, there were three indications above the 1 Gravity root mean square (Grms) reporting threshold. All three indications were later cleared by the Orbiter Boom Sensor System (OBSS) surveys of the RCC.

The OBSS surveys of the starboard RCC, nose-cap RCC and port RCC were completed and the data were downlinked for analysis. It was noticed during the surveys that the tilt angle had a greater offset than is usually seen (as much as 14 deg). This tilt offset did not adversely affect the collection of the survey data. Also, the hand-held imagery of the OMS pod and tail were downlinked successfully.

The WLE sensor system collected data for approximately 6 hr, and the completed analysis showed no new reportable indications.

The RCC Leading Edge Subsystem (LESS) DAT identified no FI requirements for the starboard or port wings or the nose-cap.

The Late Inspection started with the starboard survey at 333/18:30:00 GMT (13/17:34:21 MET) and ended with the port survey at 333/22:00:00 GMT (13/21:04:21 MET). During the port wing survey, the Laser Dynamic Range Imager (LDRI) video intermittently went blank and flashed (IFA STS-126-V-14). This behavior occurred at approximately 333/20:56 and 333/21:54 GMT (13/20:01 and 13/20:59 MET). Scan overlap from another sequence and data received despite the intermittent behavior were sufficient to obviate the need for additional scans.

The Late Inspection data review was completed, and the vehicle was cleared for entry.

Windows

The windows performed satisfactorily throughout the mission. The only problem reported is discussed in the following paragraphs.

The crew reported a MM/OD impact on thermal window no. 6. The estimated diameter of the defect was 0.5 in. The research collected over the life of the Space Shuttle Program (SSP) as well as from the ISS, resulted in the development of a "rule of thumb" ratio for estimating MM/OD depth as 10:1. The estimated depth was used for residual-strength predictions and the subsequent Margin- of-Safety (MS) calculation. Applying the 10:1 dia/depth ratio, the estimated damage depth was 0.050 in. Using the trajectory consistent load case, the side window no. 6 descent capability is 0.0051-in [Mach 0.7, Differential Pressure (Δp) = 2.04]. The maximum thermal stress during the peak heating zone is 325-psi stress, which was equivalent to an allowable flaw size depth of 0.140-in. The determination was made that the thermal pane would perform as designed through the peak heating, which enveloped the on-orbit thermal cycles.

The highest potential for window failure would occur at peak descent burst loads, with a Δp across the pane of 2.04 psid [Mach 0.70, MS = -0.7, Factor of Safety (FS) = 1.4], for the trajectory consistent load-case. However, flight experience supports the fact that no flaw propagation has been experienced on any of the previously reported MM/OD impacts, indicating the low probability of flaw propagation during the entry phase and landing. At this low pressure, flaw propagation may manifest itself in the form of cracks radiating out from the defect site. At a $\Delta p = -0.3$ psi estimated flaw size maintains a MS = 0, but degrades as Mach number decreases and ΔP increases. Based on previous testing, if a crack should occur, it is highly likely that the window pane will remain intact (one piece with no missing pieces), and retained. No liberation of glass pieces was expected. The peripheral view across the window would not be detrimentally affected.

Waste Collection System

The Waste Collection System operated properly with no reported problems.

EXTRAVEHICULAR ACTIVITY

The crew performed four Extravehicular Activities (EVAs) on STS-126 in a total EVA time of 20 hr, 32 min. Space Shuttle Mission Specialists Heidi-Stefanyshyn- Piper Steve Bowen and Shane Kimbrough, who were designated as EV1, EV2 and EV3, respectively,

The primary EVA mission objectives were as follows:

1. Transfer the flexible hose rotary coupler from the Lightweight Multi-Purpose Experiment Support Structure Carrier (LMC) to the External Stowage Platform (ESP) 3.
2. Return the empty Nitrogen Tank Assembly (NTA) flight support equipment from the ESP 3 to the LMC.
3. Relocate two Crew and Equipment Translation Aid (CETA) carts from the starboard-starboard to port-port.
4. Perform starboard Solar Alpha Rotary Joint (SARJ) activities.

The Airlock campout prebreathe protocol was utilized in preparation for all of the EVAs.

FIRST EXTRAVEHICULAR ACTIVITY

The first EVA was performed by the EV1 and EV2 crewmembers, and all planned tasks were completed. The EVA duration was 6 hr 52 min. The crew transferred the Nitrogen Tank Assembly (NTA) from the ESP 3 to the bottom of the LMC in the Shuttle Payload Bay. The crew then removed the Fluid Hose Rotary Coupler (FHRC) from the top of the LMC and transferred the coupler to ESP 3. Once the transfer was completed, the EV2 crewmember then removed the Multi-Layer Insulation (MLI) blankets from the External Facility Berthing Mechanism (EFBM). The four small blankets were removed and the center blanket was temporarily stowed on the Japanese Experiment Module (JEM).

The EV2 crewmember then joined the EV1 crewmember on the Starboard SARJ maintenance tasks, which included cleaning and lubricating the Starboard SARJ race ring and changing the SARJ Trundle Bearing Assemblies (TBAs). Two TBAs were removed and replaced on EVA 1 and one was left off as planned until EVA 2. The crew performed a get-ahead task to remove the SLR 4A. Despite loss of a crew-lock bag on EVA 1, the crew was able to complete all planned objectives.

During the first EVA, a crewlock EVA bag was accidentally released when it was removed from a large Orbital Replacement Unit (ORU) bag. Two grease guns were lost along with ancillary hardware for applying grease to the SARJ. The ground personnel requested one of the two Manual Crack Repair Guns (MCRG) was needed to support grease operations on the third and fourth EVAs. The grease guns and the MCRGs have similar designs; however the grease gun has a different nozzle tip (1/8-in.diameter Teflon vs. 3/8-inch diameter aluminum). Only one MCRG is required to perform a Non-

Oxide Adhesive Experimental (NOAX) repair; however RCC repair is a Critical 1 task and redundancy is preferred for the EVA.

SECOND EXTRAVEHICULAR ACTIVITY

The second EVA was performed by the EV1 and EV3 crewmembers. The second EVA duration was 6 hr 45 min. The EVA was terminated near the end of the nominal EVA activity due to elevated levels [greater than 3.2 millimeters of Mercury (mmHG)] of carbon dioxide (CO₂) for EV3. Once EV3 returned to the airlock, the CO₂ levels dropped to acceptable levels. The crew completed all planned tasks.

The crew relocated the two Crew and Equipment Translation Aid (CETA) carts from the starboard to the port side. In addition to the planned tasks, the crew photographed and commented on the two Trailing Umbilical System (TUS) blemishes and the Space Station Remote Manipulator System (SSRMS) blemish, which were get-ahead tasks added to the mission. The crew completed the get-ahead-task for the Segment-to-Segment Attachment System (SSAS) Bus Bolt Controller reconfiguration from P1 to P3. After the CETA Cart relocation, the EV3 crewmember performed the SSRMS Latching End Effector (LEE) A snare lubrication task and then joined the EV1 crewmember at S3 to continue with the S3 maintenance tasks. Two TBAs were removed and replaced and the one left off on EVA 1 was installed and another TBA was removed. The TBA in slot 11 was over-torqued and it was removed and another TBA was installed. As planned, TBA covers 15 and 16 were tied-down between EVA 2 and 3.

THIRD EXTRAVEHICULAR ACTIVITY

The third EVA was performed by EV1 and EV2 crewmembers, and all planned tasks were completed. The EVA duration was 6 hr 57 min. The entire EVA was dedicated to S3 SARJ Maintenance tasks. A total of five TBAs were removed and replaced and one TBA and a set of MLI covers were left off as planned.

FOURTH EXTRAVEHICULAR ACTIVITY

The fourth EVA was performed by EV2 and EV3 crewmembers, and all but three planned tasks were completed. The three planned tasks were deferred to STS-119. The EVA duration was 6 hr 06 min. The crew completed the Starboard SARJ maintenance tasks and lubrication of the Port SARJ. A total of 11 TBAs were removed and replaced during the first 3 EVAs.

In addition, the EFBM Contingency Task (structural latch no. 1) was performed successfully and the EFBM Center Cover was reinstalled. The EV3 crewmember completed the External Television Camera Group (ETVCG) installation and EV2 completed the installation of Global Positioning System (GPS) Antenna A Installation.

At the end of the EVA, the EV3 crewmember had high CO₂ levels and the EVA was terminated as the EV3 crewmember was entering the airlock. Due to Metal Oxide

(METOX) management, the EVA had been planned to end at 6 hr Phased Elapsed Time (PET), so no impact to EVA operations occurred.

REMOTE MANIPULATOR SYSTEM AND ORBITER BOOM SENSOR SYSTEM

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

STS-126 was the 80th flight of the SRMS, the 20th flight of SRMS Serial Number (S/N) 201, the 11th flight of the Orbiter Boom Sensor System (OBSS), and the 4th flight of Inspection Boom Assembly (IBA) S/N 202.

The SRMS on-orbit Initialization began at 320/03:41 GMT [00/02:46 Mission Elapsed Time (MET)] on Flight Day (FD) 1. The port and starboard Manipulator Positioning Mechanisms (MPMs) were deployed and the SRMS shoulder brace was released. The SRMS Checkout began at 320/05:43 GMT (00/04:48 MET) and completed 49 min later.

On FD 2, the SRMS maneuvered to the OBSS Pre-Grapple position at 320/18:05 GMT (00/17:10 MET). The SRMS unberthed the OBSS in preparation for the Thermal Protection System (TPS) surveys, which began at 320/19:17 GMT (00/18:22 MET) and were completed at 321/00:43 GMT (00/23:48 MET). During the Port Reinforced Carbon-Carbon (RCC) survey, the SRMS was maneuvered to inspect the left Orbital Maneuvering System (OMS) pod for Felt Reusable Surface Insulation (FRSI) material believed to be liberated seconds after launch. The SRMS then re-berthed the OBSS into the starboard MPMs and maneuvered to the Pre-Cradle position.

On FD 3, the Orbiter docked with the International Space Station (ISS) while the SRMS was in the pre-cradle position. After docking, the SRMS was maneuvered to the OBSS pre-grapple position. The Space Station Remote Manipulator System (SSRMS) grappled, unberthed, and maneuvered the OBSS to the handoff position where the SRMS grappled the OBSS. The SRMS maneuvered the OBSS to the Multi-Purpose Logistics Module (MPLM) viewing position at 322/02:53 GMT (02/01:58 MET).

On FD 4, the SSRMS performed the MPLM unberthing and installation, while the SRMS remained in the MPLM Viewing position.

On FD 5, the SRMS was maneuvered to the Solar Alpha Rotary Joint (SARJ) Cleaning position at 323/20:14 GMT (03/19:19 MET).

On FDs 6 through 11, the SRMS remained in the SARJ Cleaning position.

On FD 12, the SRMS with the OBSS was maneuvered to the MPLM Viewing position at 330/17:15 GMT (10/16:20 MET) and remained there on FD 13.

On FD 14, the SRMS maneuvered from the MPLM Viewing position to the OBSS Undocking position at 332/20:23 GMT (12/19:28 MET).

Discovery undocked on FD 15, after which the SRMS and OBSS performed a Late Inspection which started at 333/17:31 GMT (13/16:36 MET) and completed approximately 4½ hr later. The OBSS was moved to the OBSS Hover position and was berthed and latched at 333/22:41 GMT (13/21:46 MET). The SRMS was then maneuvered to the Pre-Cradle position.

On FD 16, the SRMS was maneuvered to Cradle and was latched at 334/14:26 GMT (14/13:47 MET). The Port MPMs were stowed. The Starboard MPMs were stowed following the deployment of the PicoSat.

WING LEADING EDGE IMPACT DETECTION SYSTEM

ASCENT MONITORING

All units triggered and began recording main engine data recording within 0.24 sec of each other with the exception of units 1202 and 1203, which both triggered 0.67 sec early. As a result, a time shift was added to data from these two units so there was no impact to the ascent analysis. The MET was set to 9.201 sec behind the Data Elapsed Time (MET = DET – 9.201 sec) for both the port and starboard wing units.

All ascent summary files were downlinked nominally and were received by 9:44 hr Mission Elapsed Time (MET). By 11:49 hr MET, the Wing Leading Edge (WLE) had received 25 half-second windows of ascent data. At Launch (L) +14 hr, the ascent analysis was completed. A total of 3 impact indications above 1.0 Grms were found with a damage likelihood being less than 1/1000 (Category I). Automatic scanning of the post-flight data yielded no additional indications above 1.0 Grms.

SUSPECTED ASCENT DEBRIS IMPACTS ABOVE 1.0 GRMS

Times ^a		Location			Magnitude		Criteria				Impact ^b	
MET, Hr	DET, hr	Wing	RCC	Unit-Channel	Max. Grms	Max. G	Transient	Local	Spectral	Shock	In-Flt	Post-Flt
93.3	102.5	Stbd	10	1185-J2	1.9	8.10	+	+	+	+	P	P
88.1	97.2	Stbd	1U	1161-J1	0.50	8.87	+	+	+	+	P	P
106.1	115.2	Port	2/3L	1230-J2	0.66	5.52	+	+	+	+	P	P

^aAdjusted to correct for known differences between the onboard laptop and actual GMT times.

^bP = Probable

ORBIT MONITORING

No Micro-Meteoroid/Orbital Debris (MM/OD) impact indications were reported during this flight. For this mission, the Wing Leading Edge Impact Detection System (WLE IDS) system triggered 5 times. The first two triggers were data anomaly spikes. The third trigger did not meet the new multi-sensor and trapped-wave criteria. The fourth and fifth triggers belonged to the same event and did not meet the multi-sensor and trapped-wave criteria.

ANOMALIES

No ascent data spike anomalies were found during the mission. Automatic scanning of post-flight ascent data revealed no additional ascent anomalies.

Two data spike anomalies were detected and reported during on-orbit monitoring. The specifics of these on-orbit data anomalies are shown in the following table. Automatic scanning of post-flight data revealed no additional on-orbit anomalies.

ON-ORBIT DATA ANOMALIES

Time	Location			Magni- tude	Criteria							Impact†	
GMT	Wing	RCC	Unit- Chan- nel	Mea- sured G, Peak	Tran- sient	Loc- al	Spec- tral	Shock	Damp- ing	Multi- sen- sor	Trap- ped Wave	In- flight	Post- flight
320/20:49:04	Stbd	13/14	1202-J1	1.13	+	+	-	-	+	-	+	P	P
320/21:05:29	Port	17/18	1187-J2	1.09	+	+	-	-	+	-	+	P	P

^aAdjusted to correct for known differences between the onboard laptop and actual GMT times.

^bP = Probable

Unit 1163 was not used for on-orbit monitoring because all three channels measured high noise levels during ascent monitoring. The Wireless Instrumentation System Government Furnished Equipment (WIS-GFE) team investigated and resolved this issue post-flight. During post-flight data downloads, Units 1163 and 1165 did not register as the correct serial unit Identification (ID) in the software. This was due to a firmware swap between units 1163 (starboard inboard RCC panels) and 1165 (starboard chine area). A post-flight check of the data confirmed the higher noise levels on unit 1163 are the expected levels for the chine area sensor. Prior to the next flight of OV-105, the correct firmware will be loaded onto these two units. The sensor units on OV-103 and OV-104 will be checked prior to there next flights.

CONCLUSIONS

The WLE IDS system performed well for ascent impact monitoring, allowing an initial ascent report to be published at L +14 hr. During the mission, three ascent impact indications above the 1.0 Grms reporting threshold with damage likelihood being less than 1/1000 (Category I) were reported. Post-flight review of the data found no additional ascent indications.

No MM/OD impact indications were detected during MM/OD monitoring using the improved MM/OD impact criteria.

Based on the ascent findings from all systems including WLE IDS, the Orbiter Project Office (OPO) recommended that a focused WLE RCC inspection was not required.

The late mission OBSS survey visually inspected the WLE after Orbiter undocking and prior to entry and no damage was found.

GOVERNMENT FURNISHED EQUIPMENT/FLIGHT CREW EQUIPMENT

The overall performance of the Government Furnished Equipment (GFE) and Flight Crew Equipment (FCE) was nominal throughout the prelaunch and flight operations. Four in-flight anomalies were identified and none of them impacted the successful completion of the mission. These anomalies are discussed in the following paragraphs.

The Wing Leading Edge (WLE) sensor unit 1163 exhibited amplified Grms readings (IFA STS-126-V-04). All three channels of data from this sensor were scaled approximately 7 times higher than all other sensors. As a result, panel 4 was monitored using the two horizontal sensors rather than the nominal two diagonal sensors. This condition resulted in lowering the level of confidence for discernment of Micrometeoroid Orbital Debris (MM/OD) indications. The decision was made to discontinue use of this sensor unit for MM/OD monitoring throughout the remainder of the mission.

The crew reported that the Closed Circuit Television (CCTV) elbow camera Image was black in the Automatic Light Control (ALC) average mode (IFA STS-126-V-06). When using the manual iris control mode, a normal picture was obtained. This was the first flight of this camera after being returned to the field. In-flight testing from the ground controller determined that when activating the elbow camera, an additional ALC menu command to take it to the All-Off menu resulted in the camera picture returning with a good image, good Vertical Interval Data Decoder (VIDD) data, and proper ALC operation.

The downlink of the CCTV elbow camera color had a magenta hue at 325/19:30 GMT (05/18:35 Mission Elapsed Time (MET) (IFA STS-126-V-10). At 326/02:29 GMT (06/01:34 MET), the ground controller powered on the elbow camera during a camera temperature status check, and the image video appeared normal with no color shift. Later downlinked images from the camera in low-light conditions showed a green hue in the low-light video portions of scene. With full lighting, the image appeared normal with no color shift noted. This is the same camera with the ALC problem described by IFA STS-126-V-06, which is discussed in a previous paragraph in this section.

At GMT 329/10:54 (09/09:59 MET) while CCTV camera A was downlinking earth views, the video suddenly shifted toward yellow (IFA STS-126-V-11). The ground controller power-cycled the camera approximately 2½ min later, but the yellow hue was still noticeable. Image quality was otherwise unaffected. This phenomenon has been observed before and there is no in-flight remedy to correct the anomaly. The picture was not lost. However, false color may have been noted.

Buffer errors were seen with High Definition Television (HDTV) downlink on Digital Television (DTV) Multiplexer (MUX) Channel 2 (IFA STS-126-V-13). The DTV Multiplexer power was cycled, which temporarily cleared the errors. The errors returned during subsequent HDTV downlinks and could not be cleared. As a result, Standard Definition was used for all remaining video downlinks.

DEVELOPMENT TEST OBJECTIVES AND DEVELOPMENT SUPPLEMENTARY OBJECTIVE

DTO 805 - CROSSWIND LANDING PERFORMANCE

This Development Test Objective (DTO) of opportunity was not attempted during landing due to lack of crosswind at Edwards.

DTO 900 - SHUTTLE SRB CHAMBER PRESSURE, STRAIN GAUGE, AND ACCELERATION RATES DATA COLLECTION

Measurements were taken during ascent to support future exploration initiatives.

DSO - 500 SPACE FLIGHT-INDUCED REACTIVATION OF LATENT EPSTEIN BARR VIRUS (Pre/Post Flight Only)

This Development Supplementary Objective (DSO) was performed by collecting blood and urine samples during the pre-flight and post-flight period.

POST-LAUNCH PAD INSPECTION

The post-launch inspection of the Mobile Launch Platform (MLP) -3, Pad A Fixed Service Structure (FSS), and the Pad A apron was conducted on November 14, 2008, from Launch +1 hr 20 min to 4 hr 50 min. The entire Launch Pad, FSS and MLP were inspected.

No flight hardware was found other than minimal Solid Rocket Booster (SRB) nozzle throat plug foam and minimal SRB water bag material was present.

The Orbiter lift-off lateral acceleration data indicated a maximum of 0.11g. The Hold-Down Post (HDP) stud hang-ups are typically noted with lateral accelerations above 0.19g.

Inspections of the Solid Rocket Booster (SRB) Holddown Posts (HDPs) were performed and the following observations are discussed;

HDP no. 1 – The poured sidewalls experienced some acceptable pitting in the West and South sidewalls. The Phenolic shim were nominal and both firing lines were present (2 ft and 20 in). No galling or chatter marks were noted in the chamfer of the through-hole and the stud was set down.

HDP no. 2 – The poured sidewalls were nominal with acceptable minor pitting on all four sides. The Phenolic shim was nominal and both firing lines were present (20 in and 20 in). Approximately 3 ft of Range Safety System (RSS) cable remained. 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 more-than nominal indications of erosion on the Room Temperature Vulcanizing (RTV) -coated blast shield with proper closure.

HDP no. 4 – This HDP showed nominal indications of erosion on the RTV-coated blast shield with proper closure.

HDP no. 5 – The EA934 poured sidewalls were nominal with acceptable minor pitting on the West wall. The Phenolic shim was nominal with typical erosion and 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. The Phenolic shim was nominal and 1 of 2 firing lines were present (approximately 1 ft remained). No galling or chatter marks were noted in the chamfer of the through-hole and the stud was set down.

HDP no. 7 - This HDP showed nominal indications of erosion on the RTV-coated blast shield with proper closure.

HDP no. 8 - This HDP showed nominal indications of erosion on the RTV-coated blast shield with proper closure and the RSS cable was missing.

Inspections of the GN₂ purge lines were performed and the observations were as follows:

The Left Hand (LH) probe was erect and slightly bent to the South with about 75% of the protective tape layering remaining with no exposed braiding. The O-ring was not present.

The Right Hand (RH) probe was erect and slightly bent to the Southeast with about 75% of the protective tape layering remaining with no exposed braiding. The O-ring was present.

Inspections of the SRB T-0 Ground Carrier Assemblies (GCAs) were performed and the observations are as follows:

The LH SRB T-0 GCAs appeared to be in nominal condition with proper demating. The RH SRB T-0 GCAs appeared to be in nominal condition with proper demating, but the one connector (4J1) experienced a cracked backshell and another connector (2J1) was slightly bent to the Southeast.

The Liquid Oxygen (LO₂) and Liquid Hydrogen (LH₂) Tail Service Masts (TSMs) appeared to be undamaged and both bonnets appeared to have closed properly. The LO₂ access door was ajar.

The MLP deck was in nominal condition. Typical blast erosion was observed in and around the SRB flame holes with some indication of a Northerly ascent. All sound-suppression pipe-support shims appeared to be in place.

The Orbiter Access Arm (OAA) (located at the 195-ft level) was inspected because of the pre-launch issue with the door seal not being latched and secured properly. The OAA was retracted and secured. The white room air conditioning vent louvers were loose and some were scattered throughout the white room and the PAD surface. The seal door had free motion, but the weather seal at the bottom of the door was damaged. The storage container cover located on the right side upon entrance into the white room seemed to be loose and shifted during launch with no pins engaged. A bolt, washer and tie-wrap were also retrieved from the white room.

All slidewire baskets were still secured at the 195-ft Level with no evidence of damage. Basket signs had various PIP pins not engaged but all pins were present.

The GH₂ vent line on the Ground Umbilical Carrier Plate (GUCP) at the (215-ft level) was latched on the seventh tooth (of eight) on the latching mechanism. The vent line was in between the gimbal struts and slightly South of center in the latching mechanism as seen from the FSS. The External Tank (ET) GUCP 7-inch GH₂ Quick-Disconnect (QD) probe was accessible for inspection and appeared to be undamaged. Both the QD probe sealing surface and the poppet valve assembly were in good condition with minor SRB plume speckles on the poppet probe. The ET GUCP exhibited typical blast damage and the pyrotechnic bolts fired nominally.

The GO_2 vent arm at the 255-ft level, as well as the vent hood, windows and structure appeared to be in nominal condition and the latch mechanism locked properly. Both flexible duct blankets were nominal, although the paint was peeling on the LH duct assembly.

Numerous items were found but, the PAD facility was found to be in good condition while the SRB flame trench experienced nominal erosion and the repair areas are intact. One brick was missing near the repair area on the West sidewall. The debris items found were not remarkable.

A large triangular-shaped fondue fyre from the SSME flame deflector, which was located inside the SSME flame trench, appeared to be from a previous (old) rectangular repair area. Additionally, the LO_2 TSM access door was open. At the 275-ft level antenna, the GN_2 regulator panel door was broken off at the hinge and had dropped onto the grating.

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

Orbiter and External Tank During Ascent

Evaluation of the -100 sec, External Tank (ET) Thermal Protection System (TPS) loss determined that the loss was caused by the Gaseous Oxygen (GO₂) vent arm retraction

At approximately 26 sec MET, a light-colored piece of debris was observed near Xt 1269 falling along the LO₂ feedline. The exact source of the debris is unknown. No Orbiter impact observed.

At, 26.696 sec Mission Elapsed Time (MET), multiple pieces of debris were observed to liberate from the opening between the Liquid Hydrogen (LH₂) T-0 umbilical and port Orbital Maneuvering System (OMS) pod. No secondary Orbiter impact was observed. The real-time observations from the Focused Inspection (FI) using the Orbiter Boom Sensor System (OBSS) and the Intensified Television Camera (ITVC) on Flight Day (FD) 2 did not show any apparent residual damage or artifacts. The Flexible Reusable Surface Insulation (FRSI) in the area appeared intact. Additional data has shown that the most likely material was a piece of ice. This area in question was inspected on-orbit by the ITVC on the OBSS and the FRSI blankets beneath the OMS pod were found to be intact.

At approximately 29 sec MET, debris was observed coming from forward of the Orbiter crew compartment and travelled down the fuselage and over the starboard wing. No Orbiter impact observed. The exact source and composition of material was unknown at the time of the evaluation.

At approximately 42 sec MET, several pieces of debris were observed near the LH₂ (port) ET/Orbiter umbilical and were entrained in the turbulent airflow in the area. No Orbiter impact observed.

At 54.76 sec MET, contact (debris) is first observed at release from the vehicle, and the debris travelled for 11 ft, ending with a velocity of 190 ft/sec. The contact is visible for 0.1 sec. The velocity profile and geometry indicate a mid-body release location seen through the gap between the Orbiter and External Tank (ET). The contact is most likely ice with an approximate size of 2 in.

At 64.880 sec MET, radar contact is first observed with a separation velocity of 140 ft/sec, and travelled for 55 ft and is visible for 0.2 sec. The Radar contact's non-ballistic

motion indicates motion in the vicinity of the vehicle. Object composition is most likely ice at least 1 in. in size.

At 68.580 sec MET, a simultaneous release of two bright debris objects was observed for a short duration. The signature indicates ice or an ice-foam mix for both objects. Velocity profiles and geometry indicate a mid-body release location seen through the gap between the Orbiter and ET. The tumble signature indicates a mostly regular shape. The objects were observed from the release point over a travel distance of 10 ft where the object's tracks abruptly end, most likely from body blockage at the aft end of the vehicle. The final observed velocities were 275 ft/sec and 500 ft/sec, respectively.

At 104.02 sec MET, the contact was observed with initial Shuttle relative velocity of 1900 ft/sec. The contact is most likely foam-ice greater than 1 in. in size. The initial contact was likely detected aft of the stack.

At 104.71 sec MET, the contact was observed at which time the initial Shuttle relative velocity was 420 ft/sec. The contact experienced a Doppler shift mid-track that suddenly changes its Shuttle relative velocity from 850 to 750 ft/sec. The contact is most likely ice greater than 1 in. in size. Over the length of the track, the contact travels approximately 310 ft.

At approximately 132 sec MET a dark piece of debris was observed between the ET and the Orbiter on the port side. No Orbiter impact observed.

At 161.34 sec MET, the contact is a single large object that was confirmed to have originated from the Orbiter/ET stack. The signature indicates an irregularly shaped piece of ice with largest dimension estimated at 7 to 13 in. The contact is observed with an initial separation velocity of 338 ft/sec, is visible for 8.5 sec and travelled a distance of 9000 ft relative to the Shuttle. The velocity profile exhibits non-ballistic behavior.

On-Orbit

The initial report of the screening of the OBSS Laser Dynamic Range Imager (LDRI) Survey data was completed on Flight Day (FD) 3, and no major Reinforced Carbon-Carbon (RCC) anomalies were observed.

The crew hand-held photography of the vertical stabilizer and OMS pods was screened. Some protruding gap fillers were observed on the port OMS pod. The Debris Assessment Team (DAT) initiated an evaluation of these findings.

As of FD 3, the WLEIDS data identified three small indications (less than 2 Grms) all of which had a probability of damage of less than 1 in 1000. Also, screening of all other Thermal Protection System (TPS) data from on-orbit observations was completed with no remarkable observations.

The DAT reported on FD 6 that the assessments of the OBSS and RPM imagery had been completed and no areas of the TPS were considered suspect. As a result, no focused inspections were required.

LAUNCH PAD OBSERVATIONS

At -3.412 sec, debris (possibly gap filler) was observed originating near base heat shield of the port OMS engine.

At -3.613 sec, the LH₂ Tail Service Mast (TSM) lighting failed and went out. A flash was seen as the lights went out.

At -4.020 sec, facility debris was noted near the Liquid Oxygen (LO₂) TSM that was possibly larger than the allowable criteria.

In the time period between 0.060 - 0.217 sec MET, debris was observed ejecting from Debris Containment Systems (DCS) for Hold-Down Post (HDPs) 1, 2, 5, 6, and 7 at NASA Standard Initiator (NSI) firing.

At 0.683 sec MET, the HDP 3 plunger (from DCS) was seen extended during lift-off. The spring was extending out from the aft skirt as the vehicle lifted off. The spring released from the aft skirt and stayed on the ground when the blast shield released the aft skirt. The blast shield appears not to close completely. Debris was seen falling from the HDP aft-skirt hole aft the spring separated from the aft skirt. The post-launch walkdown found the spring. The plunger was still missing.

At 2.796 sec MET, facility debris was visible in the field of view that may be larger than allowable.

At 3.160 sec MET, the Fixed Service Structure (FSS) water flow protecting the Gaseous Hydrogen (GH₂) vent arm appears to be inadequate.

At 3.228 sec MET, debris was observed originating near the LH₂ TSM. The object may be larger than allowable size. No observed vehicle impact.

At 4.572 sec MET, the LO₂ starboard TSM access door was open and swinging back and forth. The door first opened at 4.061 sec MET and appears to bounce off of a box on the TSM and flexes as it swings open.

At 4.627 sec MET, a ring-like piece of debris was observed in the field of view during lift-off. The source of the debris is unknown.

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APPENDIX A
STS-126 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	320/00:50:50.117 320/00:50:51.841 320/00:50:53.604
SRB HPU Activation	LH HPU System A Start Command LH HPU System B Start Command RH HPU System A Start Command RH HPU System B Start Command	320/00:55:11.056 320/00:55:11.216 320/00:55:11.376 320/00:55:11.536
Main Engine Start	SSME-3 Start Command Accepted SSME-2 Start Command Accepted SSME-1 Start Command Accepted	320/00:55:32.448 320/00:55:32.560 320/00:55:32.688
SRB Ignition	SRB Ignition Command	320/00:55:38.996
Throttle Up 104.5 Percent	SSME-2 Command Accepted SSME-3 Command Accepted SSME-1 Command Accepted	320/00:55:42.956 320/00:55:42.965 320/00:55:42.985
Throttle Down to 72 Percent	SSME-2 Command Accepted SSME-3 Command Accepted SSME-1 Command Accepted	320/00:56:15.277 320/00:56:15.286 320/00:56:15.305
Throttle Up to 104.5 Percent	SSME-2 Command Accepted SSME-3 Command Accepted SSME-1 Command Accepted	320/00:56:28.397 320/00:56:28.406 320/00:56:28.426
Maximum Dynamic Pressure (Max Q)	Derived Ascent Dynamic Pressure	320/00:56:39
Both SRMs to less than 50 psi	RH SRM Chamber Pressure LH SRM Chamber Pressure	320/00:57:39.356 320/00:57:40.436
End SRM Action	RH SRM Chamber Pressure LH SRM Chamber Pressure	320/00:57:41.596 320/00:57:42.596
SRB Separation Command	SRB Separation Command Flag	320/00:57:45
SRB Physical Separation	LH APU A Turbine Loss of Signal LH APU B Turbine Loss of Signal RH APU A Turbine Loss of Signal RH APU B Turbine Loss of Signal	320/00:57:45.236 320/00:57:45.276 320/00:57:45.276 320/00:57:45.316
OMS Assist Ignition	R Engine Bipropellant Valve Position L Engine Bipropellant Valve Position	320/00:57:55.5 320/00:57:55.6
OMS Assist Cutoff	L Engine Bipropellant Valve Position R Engine Bipropellant Valve Position	320/00:59:39.0 320/00:59:39.1
3G Acceleration	Total Load Factor (g)	320/01:03:02.3
Throttle Down for 3g	SSME-2 Command Accepted SSME-3 Command Accepted SSME-1 Command Accepted	320/01:03:02.325 320/01:03:02.336 320/01:03:02.352
Throttle down to 67 percent for Cutoff	SSME-2 Command Accepted SSME-3 Command Accepted SSME-1 Command Accepted	320/01:03:55.766 320/01:03:55.777 320/01:03:55.793
SSME Shutdown	SSME-2 Command Accepted SSME-3 Command Accepted SSME-1 Command Accepted	320/01:04:01.966 320/01:04:01.977 320/01:04:01.993
Main Engine Cutoff (MECO)	MECO Command Flag MECO Confirmed Flag	320/01:04:02 320/01:04:03
ET Separation	ET Separation Command Flag	320/01:04:24

APPENDIX A

STS-126 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	320/01:12:21.537 320/01:12:40.911 320/01:12:48.634
OMS 1 Ignition	L Engine Bipropellant Valve Position R Engine Bipropellant Valve Position	Not Required
OMS 1 Cutoff	L Engine Bipropellant Valve Position R Engine Bipropellant Valve Position	Not Required
OMS 2 Ignition	R Engine Bipropellant Valve Position L Engine Bipropellant Valve Position	320/01:33:58.3 320/01:33:58.4
OMS 2 Cutoff	R Engine Bipropellant Valve Position L Engine Bipropellant Valve Position	320/01:35:01.7 320/01:35:01.8
Payload Bay Doors Open	Right Payload Bay Door Open 1 Left Payload Bay Door Open 1	320/02:24:47 320/02:26:08
OMS 3 Ignition	L Engine Bipropellant Valve Position R Engine Bipropellant Valve Position	320/04:36:57.4 320/04:36:57.4
OMS 3 Cutoff	L Engine Bipropellant Valve Position R Engine Bipropellant Valve Position	320/04:37:36.8 320/04:37:36.8
OMS 4 Ignition	L Engine Bipropellant Valve Position R Engine Bipropellant Valve Position	320/17:54:37.8
OMS 4 Cutoff	L Engine Bipropellant Valve Position R Engine Bipropellant Valve Position	320/17:54:48.2
OMS 5 Ignition	L Engine Bipropellant Valve Position R Engine Bipropellant Valve Position	321/17:04:02.6 321/17:04:02.6
OMS 5 Cutoff	L Engine Bipropellant Valve Position R Engine Bipropellant Valve Position	321/17:05:23.8 321/17:05:23.8
OMS 6 Ignition	L Engine Bipropellant Valve Position R Engine Bipropellant Valve Position	321/17:43:53.8 321/17:43:54.0
OMS 6 Cutoff	L Engine Bipropellant Valve Position R Engine Bipropellant Valve Position	321/17:44:54.2 321/17:44:54.2
OMS 7 Ignition	L Engine Bipropellant Valve Position R Engine Bipropellant Valve Position	321/19:26:48.2
OMS 6 Cutoff	L Engine Bipropellant Valve Position R Engine Bipropellant Valve Position	321/19:27:01.2
Docking	Capture	321/22:01:17
Undocking	Undocking Complete	333/14:47:25
Flight Control System Checkout – APU 1 Start	APU-1 Gas Generator Chamber Pressure	334/16:08:51.757
APU 1 Stop	APU-1 Gas Generator Chamber Pressure	334/16:13:44.757
Payload Bay Door Close	Left Payload Bay Door Close Right Payload Bay door Close	335/16:21:06 335/16:23:01
APU Activation	APU-2 Gas Generator Chamber Pressure APU-1 Gas Generator Chamber Pressure APU-3 Gas Generator Chamber Pressure	335/20:14:32.071 335/20:40:49.607 335/20:40:58.334
Deorbit Maneuver Ignition	L Engine Bipropellant Valve Position R Engine Bipropellant Valve Position	335/20:19:29.3 335/20:19:29.3
Deorbit Maneuver Cutoff	L Engine Bipropellant Valve Position R Engine Bipropellant Valve Position	335/20:22:23.7 335/20:22:23.7
Entry Interface	Orbital Altitude Referenced to Ellipsoid	335/20:53:25
Blackout End	Data Locked (High Sample Rate)	NO BLACKOUT

APPENDIX A
STS-126 MISSION EVENTS

EVENT	DESCRIPTION	ACTUAL GMT
Terminal Area Energy Management (TAEM)	Major Mode Code (305)	335/21:18:41
Main Landing Gear Contact	Main Landing Gear Left Hand Tire Pressure Main Landing Gear Right Hand Tire Pressure	335/21:25:06 335/21:25:06
Main Landing Gear Weight on Wheels	Main Landing Gear Right-Hand Weight on Wheels Main Landing Gear Left Hand Weight on Wheels	335/21:25:07 335/21:25:08
Drag Chute Deployment	Drag Chute Deploy 1 CP Volts	335/21:25:12.0
Nose Landing Gear Contact	Nose Landing Gear Left Hand Tire Pressure 1	335/21:25:20
Nose Landing Gear Weight on Wheels	Nose Landing Gear Weight on Wheels	335/21:25:20
Drag Chute Jettison	Drag Chute Jettison 2 CP Volts	335/21:25:42.1
Wheels Stop	Velocity with respect to Runway	335/21:26:04
APU Deactivation	APU-1 Gas Generator Chamber Pressure APU-2 Gas Generator Chamber Pressure APU-3 Gas Generator Chamber Pressure	335/21:43:34.127 335/21:43:43.771 335/21:44:02.944

APPENDIX B STS-126 IN-FLIGHT ANOMALIES

INTRODUCTION

This appendix contains listings and discussions of each of the In-Flight Anomalies (IFAs) that were identified for the STS-126 mission.

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

APPENDIX B STS-126 IN-FLIGHT ANOMALIES

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IFA Number	Title	Comments
STS-126-V-01	TPS Tile and Blanket Anomalies	<p>A total of 13 TPS items were identified that exceeded pre-defined screening criteria and were entered into the TIIMS Database. An additional 8 items were cleared using standard procedures/tools, and the following 5 items required additional analysis: D-126-AFD-540-001 - Tile is Damaged on Right Orbital Maneuvering System (OMS) Pod D-126-AFD-540-002 - Tile is Damage on Right OMS Pod D-126-AFD-550-002 - Gap Filler Protruding on Left OMS Pod D-126-RPM-210_3-001 - Tile with Small SIP Footprint is Damaged D-126-RPM-700_2-001 - Tile is Damaged Forward of Left (Port) ET Door</p> <p>No focused inspection was required based on the data available from Flight Day (FD) 3 R-Bar Pitch Maneuver (RPM) images and FD 2 inspections. The remaining TPS tile damage sites (listed above) were cleared based on additional analysis.</p> <p>Post-flight Status: All OMS leading edge gap fillers (260) were subjected to detailed post-flight inspection for fraying/protrusion, and 34 discrepant gap fillers were removed. All new installations utilized improved fabrication techniques and more robust pull test of 10 lbs. Improved techniques and higher pull test will be incorporated into processing specification. All suspect tiles replaced or repaired.</p>
STS-126-V-02	APU 3 Z-Axis Accelerometer Erratic	<p>The Auxiliary Power Unit (APU) 3 (S/N 303) Z-axis accelerometer exhibited a slow-start response and brief periods of intermittent dropout to zero g's peak-to-peak beginning at prelaunch APU start and during ascent. During the latter part of ascent, both of APU 303's accelerometers read nominally. Per SODB, an APU should not be operated for extended periods of time above 100 g's peak-to-peak in either axis. The accelerometer has not failed hard, but has shown an intermittent electrical condition, particularly during the high-vibration portion of ascent. A hard-failure of the accelerometer did not occur, but the sensor has shown an intermittent electrical condition, particularly during the high-vibration portion of ascent. These measurements are used as a long-term health indicator and are not monitored real-time. This signature is a known condition that occurred during this APU's confidence run on this Orbiter and was reviewed and coordinated with the APU Problem Resolution Team (PRT) with no action required.</p> <p>Post-flight Status: Troubleshooting looked at both the failed sensor and a good one. Time Domain Reflectometry (TDR) tests of both sensor runs were identical and injections into the Vibration Monitoring System (VMS) had identical results. The sensor was replaced.</p>

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IFA Number	Title	Comments
STS-126-V-03	Ku Band Not Maintaining Track In Communications Mode	<p>From the initial Tracking and Data Relay Satellite (TDRS) lock after configuring to the COMM mode, the Ku-Band was not staying locked in General Purpose Computer (GPC) Acquisition (ACQ) mode. Angles appeared to drift off until the forward link lock was lost, after which the Ku-Band re-pointed to the designated angles and reacquired forward link. This condition occurred whenever the GPC ACQ mode was selected on both TDRS West 171 and TDRS Spare 046. The impact was that the Ku-Band forward and return link would be intermittent during COMM operations in the GPC mode. The RADAR performance during rendezvous was not impacted. A workaround existed when the ground controller selected the GPC Designate (DESIG) mode, the Ku-Band forward link stayed locked. However, a momentary hit was expected any time the Ku-Band azimuth angle crossed ± 90 deg. From Flight Day (FD) 1 to after undocking, the Ku-Band was operating nominally with GPC DESIG mode. At 333/18:24 GMT (13/17:28 MET), a handover from TDRS W171 to TDRS S046 (rev 217) occurred. At reacquisition after the handover, the Ku-Band did not have DETECT/TRACK indications and Ku-Band forward and return link data were not available. Ku-Band telemetry indicated no forward link signal strength. Ku-Band telemetry indicated the Ku-Band was radiating, but the TDRS network was not seeing a Ku-Band return link signal. A number of attempts were made by the ground controller with no satisfactory operation observed. A Ku-Band search was started, and the angles changed about 1 deg, and the Ku-Band locked up on the forward link. However, the return link was not working until INCO commanded Modulation back to AUTO1. Following this acquisition, the Ku-Band operated nominally in GPC ACQ mode (other than 216 kbps Forward Link Frame Sync telemetry was still dropping out). At 334/13:15:43 GMT, the ground controller retested the GPC DESIG mode and it is working again. The ground controller also tried the Modulation ON in both GPC DESIG and GPC ACQ, but lost the return link until Modulation AUTO was reselected.</p> <p>Post-flight Status: Angle track did not work during COMM mode operations in GPC ACQ or AUTO TRACK (repeat of IFA STS-126-V-03 problem). TRACK IF signal from DA through wiring appeared good. Alpha/beta error signals from EA-1 test port did not change as expected when angles were drifting off bore sight. Angle track worked nominally during radar mode ops in GPC ACQ and AUTO TRACK. GPC DESIG operations nominal. Return link modulation operations were nominal in ON, OFF, and AUTO. EA-1 was replaced and retested with no issues.</p>

APPENDIX B STS-126 IN-FLIGHT ANOMALIES

ORBITER ANOMALIES

IFA Number	Title	Comments
STS-126-V-04	Wing Leading Edge (WLE) Sensor Unit 1163 Amplified Grms Reading	<p>All three channels of WLE Sensor (1163) are scaled higher than all other sensors (approximately 7 times). Panel 4 will be monitored with two horizontal sensors rather than the nominal two diagonal sensors, lowering the level of confidence for discernment of MM/OD indications. The sensor remained stable in a idle-mode setting to prevent other sensors from not performing nominally. Troubleshooting of the anomaly was performed during the mission. The team conducted a 2 sec timed data take on FD 3. The noise levels collected during the 2 sec data take appeared to be nominal when comparing the data against a known good sensor (1162) that monitors in the near vicinity of Sensor 1163. The decision was made to discontinue use of Sensor Unit 1163 for Micrometeoroid/Orbital Debris (MM/OD) monitoring throughout the remainder of the mission.</p> <p>Post-Flight Status: Further troubleshooting on the ground revealed that the firmware installation of units S/N 1163 and S/N 1165 were swapped with each other accidentally, hence unit S/N 1163 responded as unit S/N 1165 and vice-versa. The "chine" location of unit S/N 1165 typically registers higher readings than the other locations such as the location of S/N 1163 and, therefore, when data for S/N 1163 was downloaded during the mission, analysts were looking at data from the "chine" location of S/N 1165. It was also confirmed that the lower levels of data from S/N 1165 matches the expected data from the location of S/N 1163 and is in family. In response to this, KSC INS has loaded the correct firmware files for each of the sensors.</p>
STS-126-V-05	OMS Right Oxidizer Cross-Feed Drain Line Heater A Failed Off	<p>The Right OMS Crossfeed Oxidizer Drain Temperature dropped below the expected temperature while on the A-string. The System Management (SM) Alert was lowered from 50 to 45 °F by a Table Maintenance Block Update (TMBU). The sensor subsequently reached 45.7 °F prior to changing from the OMS Cross-feed A to OMS Cross-feed B heater string. Once on the B-string, the heater was observed to cycle nominally. During in-flight troubleshooting prior to docking, the flight control team switched back to the A string and lowered the Fault Detection and Annunciation (FDA) limits to prevent alarms. The temperature dropped from approximately 68 °F to approximately 35°F and no heater activation was seen. The heater was considered failed for the remainder of the mission.</p> <p>Post Flight Status: Initial visual inspections showed no anomalies. Fuse removal/inspection was performed with no anomalies noted. Wire inspections and vehicle wiring splice inspections were performed with no anomalies noted. Further troubleshooting on the thermal switch found a broken vendor lead on the heater. A replacement heater was installed.</p>

APPENDIX B STS-126 IN-FLIGHT ANOMALIES

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IFA Number	Title	Comments
STS-126-V-06	CCTV Elbow Camera Image Black in the ALC Mode	<p>The Crew reported that when they selected the Closed Circuit Television (CCTV) elbow camera Automatic Light Control (ALC) average mode, the picture went black. When using the manual iris control mode, a normal picture was obtained. After STS-117, this camera was returned to the vendor for repair. During the reacceptance TVAC testing, the camera failed to respond to the ALC command. Following the otherwise successful conclusion of the TVAC test, the ALC performed properly during ambient conditions. It further continued to perform properly during at least 3 additional TVAC tests and additional ambient tests. Since nothing could be identified to repair, this was finally judged to be an unverified failure (UVF) and the vendor was directed to ship the camera back for future use. This was the first flight of this camera after being returned to the field. After testing from the ground via the Ku-Band, the ground controller determined that when activating the elbow camera, an additional ALC menu command to take it the "All Off" menu results in the camera picture coming back with a good image, good VIDD (Vertical Interval Data Decoder) data, and proper ALC operation.</p> <p>Post Flight Status: Camera was returned to Lockheed for Maintenance and Repair. To date, the problem has not repeated. Troubleshooting is ongoing.</p>
STS-126-V-07	Fuel Cell (FC) 1 Hydrogen (H ₂) Flowmeter Failed-Off Scale High (320/12:36 GMT)	<p>The Fuel Cell 1 Hydrogen flowmeter measurement began drifting high and erratic. At times, the measurement was reading off-scale high. The FC1 H₂ Flowmeter was considered failed by the flight control team and the on-board class 3 FDA limit was inhibited. A review of the electrical bus did not show any anomalous indication at the time of the failure. When SSPTS was turned off for EVA 1, the flow meter went from off-scale high back to erratic. When SSPTS was turned back on, the H₂ flow meter returned to off-scale high.</p> <p>Post-Flight Status: Post-flight fuse inspections found no issues. Circuit checkout found no other anomalies. Performed "MR" cap & stow of Main A power to the flowmeter at terminal board 40TB29. Flowmeter has been isolated from the system. Exception EK10696 written to cover the OMRSD violation (loss of flow meter data during purge Ops) was approved by the ERB on 3/27/2009.</p>

APPENDIX B STS-126 IN-FLIGHT ANOMALIES

ORBITER ANOMALIES

IFA Number	Title	Comments
STS-126-V-08 (Also STS-126-I-004)	Main Propulsion System (MPS) Engine 2 GH ₂ Pressure Flow Control Valve 2 Opened With No Command	<p>During ascent and after the thrust lowered for Max Q (thrust bucket), the Engine 2 GH₂ outlet pressure had a 200-psi step down without a corresponding ullage pressure signal conditioner command change. The differential outlet pressure for this Flow Control Valve (FCV) position was 260 psi during previous command changes before the thrust bucket. The GH₂ pressurization system is not active after ascent or for the remainder of flight.</p> <p>Post-Flight Status: X-rays and valve removal showed a portion of the valve poppet was missing. All three FCVs were removed from the vehicle for inspection. Inspection of the braze joint upstream of the FCV noted a "blob" of braze material due to overflow of the initial braze. The suspect joint and GH₂ filter was replaced. Inspection downstream of LV57 found minor damage to elbow believed to be from poppet fragment impact. Damaged elbow was replaced with the same configuration. FCVs with full NDE screening are installed.</p>
STS-126-V-09 (Also STS-126-I-009)	MPS Pneumatic Helium Pressure Decay Greater Than Expected On Ascent	<p>During MPS post-ascent data reviews, greater-than-expected pressure decay was observed. The helium pneumatic tank pressure normally (previous flights) drops about 20 psi during ascent. On STS-126, it was approximately 140 psi. Leak stopped and all helium bottle pressures were stable. Helium is used for aft compartment and OMS pod purges as well as MPS propellant manifold repressurization during entry. For Entry, the flight control team recommended nominal entry configuration with observed calculated leak rate (approximately 0.008 lb/sec).</p> <p>Post-Flight Status: Post-flight troubleshooting isolated the leak to CV4, which was replaced and retested. Failure analysis of the removed CV4 revealed a small manufacturing defect (sliver of metal on poppet). Check valve was replaced and passed all functional tests.</p>
STS-126-V-10	CCTV Elbow Camera Color Off-Nominal	<p>A magenta hue was noticed on the downlink of the Shuttle Remote Manipulator System (SRMS) elbow camera image. At 326/03:25 GMT (06/02:30 MET), the ground controller powered on the elbow camera during a camera temperature status check, and the video image appeared normal (no color shift). Later downlinked images from the camera in the low-light conditions showed a green hue the in low-light portions of video scene. With full lighting, the image appeared normal (no color shift noted).</p> <p>Post-Flight Status: Camera was returned to Lockheed for M&R. Lockheed thinks it may need the delay line module bypass kit to be installed, but troubleshooting is ongoing.</p>

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IFA Number	Title	Comments
STS-126-V-11	CCTV Camera A Had a Yellow Hue	<p>At 329/10:54 GMT (09/09:59 MET), while downlinking earth views using CCTV camera A, the video suddenly shifted toward yellow. The camera was power by the ground controller 2 min later, but the yellow hue was still noticeable. Image quality was otherwise unaffected.</p> <p>Post-Flight Status: The camera has been PIA tested at KSC with no repeat of the problem. The camera will retained for use on future missions. Camera will fly as Camera A on STS-127. As a result, the classification with the Problem Tracking Database was changed to Future Trending (4/3/2009).</p>
STS-126-V-12	GNC Bypass of Ku-Band Radar Data	<p>The Guidance, Navigation and Control (GNC) General Purpose Computer (GPC) 1 annunciated two consecutive Input/Output (I/O) Errors on Flight Forward (FF) 3 Multiplexer/Demultiplexer (MDM), Serial Interface Card 3, Channel 3, and telemetry indicated a "Radar Bypass" indication. Similar data is provided to the Systems Management (SM) GPC via Payload 1 MDM, however the SM GPC did not issue either of the I/O errors or the bypass bit. Telemetry indicated the GNC GPC I/O errors and the subsequent bypass were caused by the setting of the E-bit in the first word from the Ku-Band Radar. As part of anomaly troubleshooting, an MDM BITE4 Read was performed and both return words were nominal indicating a good data path. (Note the BITE4 Read cannot test all functionality of the MDM). Subsequent to the BITE4 Read, a GNC I/O reset was performed and resulted in the Ku-Band radar being upmoded, with no I/O errors re-annunciated or the bypass bit being reset. This indicates a transient condition that cleared (no subsequent bypass). In addition, there were subsequent I/O errors encountered in a non-consecutive fashion and did not result in a Radar Bypass indication.</p> <p>Post-Flight Status: Troubleshooting repeated the anomaly. A Break Out Box was installed at EA1 for additional troubleshooting (MDM FF3 to EA1 interface testing). The MDM checked out good. The problem appears to be in EA-1. EA-1 was replaced and retested with no issues.</p>

APPENDIX B STS-126 IN-FLIGHT ANOMALIES

ORBITER ANOMALIES

IFA Number	Title	Comments
STS-126-V-13	DTV Multiplexer Channel 2 Buffer Errors	<p>While trying to playback previously recorded video, as well as live downlink, the crew and ground controllers were seeing buffer errors on the DTV MUX and dropouts in the downlink video. On FD 3, at approximately 322/03:30 GMT (02/02:35 MET), over 15 minutes of continuous High Definition Television (HDTV) video was received on the ground with no errors. The crew played back views of the ISS during rendezvous, then switched to a live view, performed an audio check, gave a live view of a black background for pixel test, and downlinked camera-generated color bars. On FD 8, at ~327/00:38 GMT (07/02:34 MET), the crew called down requesting to downlink Shuttle HDTV. The ground configuration issues from the previous day had been resolved. The crew cued up the tape before plugging the firewire cable into the camcorder, began playback, and buffer errors started immediately. After cycling power on the DTV MUX, no errors were received for the remaining approximately 3 min prior to Loss of Signal (LOS). On FD 10, at approximately 328/23:58 GMT (08/23:02 MET), the crew requested to downlink Shuttle HDTV. When the link came up, the HDTV was in SDTV mode, and the MUX power was turned off. Upon turning on in HDTV mode, buffer errors again occurred. Errors continued through another MUX power cycle, and after the crew switched to live camera view. On a subsequent pass, at 329/01:31 GMT (09/00:35 MET), with a live camera view set up from the previous pass, steady video from the flight deck camera streamed with DTV MUX buffer error occurring approximately every 30 sec.</p> <p>Post-Flight Status: During a test in the OV-105 vehicle with the MPC and the Shuttle DTV MUX, the HDTV downlink glitch problem that was seen on STS-126 was recreated. The MUX channel 2 has malfunctioned and is causing periodic buffer overflows. This failure is unique to MUX S/N 1008 and has been accepted to fly as-is.</p>
STS-126-V-14	LDRI Loss of Data	<p>During the Late Inspection port wing survey, when the Laser Dynamic Range Imager (LDRI) was in Mode 6, the LDRI video "went blank and flashed" intermittently. This occurred twice during the Port Survey. During the first LDRI blanking, scan 1 on all of port wing panels 8 and 1/2 of panel 9 was missed. The TPS Imagery Coordinator (TIC) analyzed the data and determined there was sufficient scan overlap from another sequence, and an additional scan of these panels was not needed. For the second occurrence, the SRMS was moving slowly enough that TIC received all the data required. It was later determined that during the Flight Night (FN) 9 mode cycle to obtain temperature data, a video dropout was noted similar to what was observed later during late inspection.</p> <p>Post Flight Status: Anomaly was recreated in a long duration vacuum test when is kept in Mode 2 for ~5 days then mode changed to an active mode (3-6). Anomaly is repeatable and consistent, but root cause has not been determined.</p>

APPENDIX B STS-126 IN-FLIGHT ANOMALIES

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IFA Number	Title	Comments
STS-126-V-15	CDR Keyboard 3 Key Duplicate Input	<p>During the GPC expansion prior to undocking, the Orbit 3 DPS team noticed an instance of a double keystroke of the CDR keyboard 3 key. In conversations with other DPS controllers, it was revealed that others had noticed multiple occurrences of the same thing. An ODRC data over the course of FD 14 and 15 revealed several instances. The crew was asked if they noticed anything wrong with the key or abnormal tactile feedback. Their response was that they noticed "double hits" from the key.</p> <p>Post-flight Status: Troubleshooting confirmed double keystroke occurred once out of 48 trys (approximately 2% error rate). Keyboard unit (KBU) removed and replaced. Failure analysis at vendor is in work.</p>
STS-126-V-16	Payload Signal Processor (PSP) 1 Bypass	<p>At 332/17:39:12 GMT, the 'S62 BCE BYP PSP1' message was annunciated onboard indicating that PSP 1 lost I/O with the SM GPC. The PSP I/O reset command was uplinked in an effort to re-establish this interface, but it was not successful, and the 'S62 BCE BYP PSP1' message was re-annunciated. PSP 1 was then power cycled from the ground, and again the PSP I/O reset was uplinked. This time the PSP maintained I/O with the SM. The DPS personnel observed the numerous I/O errors during the PSP bypass/recovery events. The PSP bypass bit was set in the SM until PSP was recovered with the power cycle. Approximately 10 hours later, PSP 1 bypassed again. This occurred 2 min into the crew sleep period, thus the decision was made to keep it bypassed during crew sleep. PSP 1 was powered off from the ground. At 333/11:55 GMT (13/10:59 MET), the PSP was activated by ground command with no issues. An analysis was performed to determine if there was any commonality between the Ku-Band anomalies (MDM PF 1 Card 8 Channel 2 and FF 3) and no commonalities were found.</p> <p>Post-Flight Status: The problem recurred during vehicle power ops during vehicle preparations at EAFB. Troubleshooting exonerated the vehicle wiring. Troubleshooting indicated that the PSP and MDM PF1 were communicating (cannot recreate the anomaly on the ground). Additional troubleshooting (inspection and push/pull test on all the pins on connector J1 of PSP1 that interface with MDM PF1) was performed with nominal results. Hi-pot testing is complete. The PSP was replaced and a UA processed.</p>

APPENDIX B STS-126 IN-FLIGHT ANOMALIES

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IFA Number	Title	Comments
STS-126-V-17	APU 1 Fuel Tank Outlet Pressure Transducer Not Tracking With Temperature	<p>Beginning at approximately 322/14:36 GMT (02/13:40 MET), the Auxiliary Power Unit (APU) 1 fuel tank outlet pressure reading appeared to have stopped tracking with two other tank temperature sensors after 3 days MET. At 328/05:18 GMT (08/04:22 MET), a data bit rise (2 psi) was seen for this reading even though the tank temperature was decreasing. The redundant fuel tank pressure (GN₂ side of tank) reading showed nominal tracking with the tank temperature.</p> <p>Post-Flight Status: Troubleshooting isolated the problem to a biased APU no. 1 fuel outlet pressure transducer. Troubleshooting of the vehicle side of sensor signal path was performed with no anomalies noted. The sensor was replaced.</p>
STS-126-V-18	CDR Intermittent Loss of Audio	<p>Starting during the Heading Alignment Circle (HAC) maneuver and continuing post-landing, the Commander (CDR) noticed that he could not consistently hear himself in his headset when speaking. The other crewmembers reported hearing him fine. However, the audio recording did not record the Commanders voice (other crewmembers could be heard responding to the CDR, but the CDR was not heard). The issue was intermittent. CDR estimated it did not work about 80% of the time.</p> <p>Post-flight Status: The Headset Interface Unit (HIU) was removed and routed to the FCS Laboratory for checkout. The HIU checkout was completed and did not recreate the anomaly. On-vehicle troubleshooting was performed and the anomaly did not repeat. A UA with most probable cause being the CDR microphone position or voice level was insufficient to activate the ICOM VOX circuit was approved.</p>

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ORBITER ANOMALIES

IFA Number	Title	Comments
STS-126-V-19	Ku Band 216 Kbps Fwd Link Frame Sync Telemetry Dropouts	<p>At times during the mission, the Ku-Band 216 kbps Forward Link Frame Sync parameter went low even though the DATA PRESENT signal stayed high and the signal strength was maintained. A high signal indicates good Frame Synchronization. The 216 kbps Forward Link Frame Synchronized parameter is created in the Ku-Band Signal Processor Assembly (SPA), routed to the Electronic Assembly 1 (EA-1), and included in a status word sent from EA-1 through PF-1 to the System Management (SM) General Purpose Computer (GPC). The 216 kbps Forward Link Frame Sync dropouts occurred in GPC ACQ and GPC DESIG modes. Start and stop of extended 216 kbps Forward Link Frame Synchronized dropouts appeared to occur close to FF3/EA-1 I/O Error events. Ground controllers verified that while the frame synchronized indication was low, the OCA hardware maintained GREEN lights, indicating a good configuration for uplinking messages, and successful OCA uplinks were made. In addition, during a PAO event with the NSP configured to receive the Forward Link from Ku-Band, the Ku-Band 216 kbps Forward Link Frame Synchronized dropped out, but did not affect the PAO event.</p> <p>Post-Flight Status: Troubleshooting consisted of 4 sessions that totaled approximately 20 hours of communications testing. During all Forward Link testing in the OPF, the Ku-band system processed the Forward Link correctly and there were no dropouts of the Forward Link Frame Sync Indicator. Wire wiggle tests on cable were performed with no anomalies. Connectors were de-mated and inspected with no anomalies. The PRT decided to process a UA with the most probable cause was an intermittent failure within the EA-1 to SPA Serial Interface of microprocessor circuitry. The PRT also decided to replace EA-1.</p>

APPENDIX B STS-126 IN-FLIGHT ANOMALIES

ORBITER ANOMALIES

IFA Number	Title	Comments
STS-126-V-20	Ku-Band Erroneous Radar Data	<p>During the post undocking timeframe, the Ku-band was taken to RADAR mode. The RADAR was in a proper configuration for this procedure in GPC. However, when powered up in the RADAR mode, the data for range and range rate was erratic and unusable. At 333/15:26 GMT, the crew took the pointing mode from GPC to GPC DESIGNATE to check for range and range rate data improvement. The RADAR did not lock on to the ISS. At 333/15:28 GMT, the crew took the pointing mode back to GPC. The same results as the previous GPC mode were seen with very erratic range and range rate data. During this entire period the SM GPC data did not show the RADAR had detected the ISS, but it did show that RADAR was tracking the ISS. The GNC GPC data showed both DETECT and TRACK. At 333/15:37 GMT, the crew took the Ku-band back to COMM mode in standby. At 333/16:03 GMT the ground controller powered on the Ku-band. The Ku-band operated well in the COMM mode with good closed loop tracking in GPC. Prior to this point in the mission, the Ku-Band had been utilized in GPC DESIGNATE mode.</p> <p>Post-Flight Status: Radar mode data appeared nominal; radar range, range rate, and angle rate data steady. Additional troubleshooting of EA-2 to look at PF-1 data and range/rate data was performed, but the anomaly did not repeat. EA-2 will not be replaced. IPR will be upgraded to COM PR for deferral.</p>

APPENDIX B STS-126 IN-FLIGHT ANOMALIES

SOLID ROCKET BOOSTER ANOMALIES

IFA Number	Title	Comments
STS-126-B-001	Hold Down Post 3 Blast Container Debris Containment Failure	<p>The Imagery Review showed the Plunger and Compression Spring on Hold Down Post (HDP) 3 went through the Right Hand (RH) Aft Skirt Bore Post during lift-off. It was confirmed during the open assessment of the blast container that the plunger was not there. During the Mobile Launch Platform (MLP) -3 inspection remnants of the compression spring were found, although the plunger has not been found. The initial inspection of the stud showed melted material on the forward end. The forward end of the stud was also visibly warped. Shoe shim and attaching hardware was observed to be over 95% eroded from the shoe.</p> <p>Post-flight Activities: The investigation was continuing as this was written. A redesign has been initiated to add stop blocks to prevent the plunger from passing through the spherical washer hole and exiting the blast container should the plunger shoulders completely fail. Ten velocity tests and four hot-fire tests have been completed to verify stop block functionality. All certification tests were successfully completed. No damage to the plunger assembly was observed and all tests successfully prevented the plunger from passing through the hole in the spherical washer. The stop-block modification is being implemented for the next mission.</p>

APPENDIX B
STS-126 IN-FLIGHT ANOMALIES

REUSABLE SOLID ROCKET MOTOR ANOMALIES

No Reusable Solid Rocket Motor anomalies were identified from the STS-126 Mission.

**APPENDIX B
STS-126 IN-FLIGHT ANOMALIES**

SPACE SHUTTLE MAIN ENGINE ANOMALIES

No Space Shuttle Main Engine anomalies were identified from the STS-126 Mission.

APPENDIX B
STS-126 IN-FLIGHT ANOMALIES

EXTERNAL TANK ANOMALIES

No External Tank Anomalies were identified from the STS-126 Mission.

APPENDIX B STS-126 IN-FLIGHT ANOMALIES

SYSTEM ENGINEERING AND INTEGRATION ANOMALIES

IFA Number	Title	Comments
STS-126-I-001	SM GPC Failure to Send GCIL Commands	<p>An inadvertent data shift affecting the Payload Signal Processor (PSP) port-moding and Ku-Band automatic handover commanding only (pre-OI-33 capabilities) was introduced by an unrelated software change in OI-33 (OI-33 Software Change Request (SCR) 93122 "PSP Reject Indicator Fix to DR 122444). This change inserted a data item into a common data structure (com pool) shared by the affected commanding data. The inserted data caused a shift in subsequent data that rendered three downstream commands inaccessible by the Input/Output (I/O) processor (IOP). The following corrective actions have been taken:</p> <ol style="list-style-type: none"> 1. Post mass-memory release patches to correct data misalignment for remaining OI-33 systems (STS-119 and STS-127), 2. Plan to fix as source modification for OI-34 systems and 3. Audit of proper alignment of all output data locations in OI-32, OI-33 and OI-34 completed. <p>The controls documented in IFSW-01 remain valid as written, and the preventative actions performed as a result of this IIFA serve to enhance these controls and reduce the likelihood of the occurrence of future IFAs.</p>
STS-126-I-002	Debris Released Near the LH ₂ T-0 Plate	<p>At 26.696 sec MET, debris was observed to liberate between the LH₂ T-0 umbilical and port OMS pod. Review of the 16mm film from camera E022 on the Main Launch Platform (MLP) and inside the LH₂ Tail Service Mast (TSM) has identified an ice buildup that formed on the Orbiter, internal to the LH₂ umbilical peripheral seal and was not visible until T-0 at umbilical retraction. The ice buildup has been identified as the object observed liberating. A fault tree assessment failed to identify a root cause; however, the leading theory is the cold cavity temperature in combination with low differential pressure (ΔP) to ambient, along with possible water intrusion from rain or condensation, resulted in the ice formation. Mitigations such as increased inspections of the inner/outer umbilical plate seals, pre- and post-umbilical mate inspections to verify zero gaps, increased awareness during final pre-launch walkdown inspections, modifications to implement the rain diverters to prevent water intrusion, and additional on-orbit inspections, will help to further mitigate and classify this as an acceptable risk for flight.</p>

APPENDIX B STS-126 IN-FLIGHT ANOMALIES

SYSTEM ENGINEERING AND INTEGRATION ANOMALIES

IFA Number	Title	Comments
STS-126-I-003	Aft Skirt HDP no.3 Debris Containment System Anomaly	At 0.683 sec MET, the plunger and spring from Hold-Down Post (HDP) no. 3's Debris Containment System (DCS) was observed in imagery remaining on the ground. During nominal operations, the plunger remains with the Solid Rocket Booster (SRB) Aft Skirt to prevent frangible nut and pyrotechnic debris from exiting the aft-skirt borehole. During STS-126 liftoff, debris was observed exiting the HDP no.3 borehole as the Space Shuttle moved away from the launch pad. The spring prevented the HDP blast cover from closing nominally, and there was erosion to the MLP HDP no. 3 Shoe as a result of plume impingement. The RSRB Anomaly Resolution Team, which included SE&I and Ground Operations, isolated the STS-126 anomaly to a plunger-shoulder failure (excessive damage). To preclude the observed failure, the corrective action for this design deficiency was to add a redundant mechanism that stops the plunger from exiting the bore hole if the shoulders fail. The design modification to the DCS will not change the NSTS 60559 allowable debris if the shoulders fail. The design modification has been evaluated by analysis and testing, and it does not pose an adverse effect on the RSRB HDP system.
STS-126-I-004	MPS GH ₂ Pressure Flow Control Valve Opened With No Command	During STS-126, shortly after the thrust bucket, Main Propulsion System (MPS) Space Shuttle Main Engine (SSME) no. 2 Gaseous Hydrogen (GH ₂) outlet pressure dropped approximately 200 psi from a normal 260 psi without a corresponding flow control valve (FCV) open command. The drop is indicative of a partial valve transition from low flow to high flow. This drop did not impact the mission because SSME 1 and 3 FCVs compensated to maintain the overall required tank-ullage pressure. Post-flight inspection showed approximately 1/4 of the SSME no. 2 FCV poppet head was missing, which allowed approximately 80% of high flow past the valve. The broken valve moved to the low flow position and remained there. A broken poppet can lead to two main categories of risks - risks due to the higher-than-expected pressurization flow past the broken poppet and risks due to the liberated poppet head debris. The poppets that are installed on the next flight vehicle have been inspected and no cracks have been discovered based on the best possible inspection capabilities. The interim closure of this IIFA is based on accepting an increase in risk.

APPENDIX B STS-126 IN-FLIGHT ANOMALIES

SYSTEM ENGINEERING AND INTEGRATION ANOMALIES

IFA Number	Title	Comments
STS-126-I-005	Debris from Multiple HDPs at NSI Firing	During imagery review of the STS-126 launch, an increase in smoke and debris was observed ejecting from the area of the DCS of HDP: 1, 2, 5, 6 and 7 during NASA Standard Initiator (NSI) firing. The signature observed during STS-126 is beyond the experience base of the imagery analysis community (JSC, KSC and MSFC Imagery Analysis Teams (IATs)) based on the quantity (5 of 8 HDPs) and size (approximately 0.2 in. smallest dimension and approximately 1.5 in. longest dimension) of the debris observed. STS-126 had a unique configuration with the firing lines tape wrapped, which was installed on the firing lines in the area over the shoe and extended to within inches of the NSI connector which is internal to the DCS. The debris is most likely attributed to possible firing line tape, drifting material from Hydrogen Burn Off Igniters (HBOIs) remnant, and/or foreign debris surrounding the HDP. STS-119 photographs were reviewed and the tape installation is in the proper configuration. With the debris being light and floating in the wind currents, there is not a detrimental mass that is not already accounted for in NSTS 60559.
STS-126-I-006	Unexpected Debris/Expected Debris Exceeding Mass Allowable Prior to Pad Clearance (Lift-off Debris)	Closure Rationale was presented to the Systems Integration Control Board (SICB) on January 20, 2009. The rationale for closure of STS-126-I-006 was accepted by the board. The recommendation was accepted and the IIFA was closed. Risk Assessment indicates that given the proposed mitigations, observed debris poses no appreciable increase in risk. Lift-off debris risk is currently characterized as infrequent, catastrophic due to significant limitations in controls and significant uncertainties in analysis. Expected lift-off debris risk is classified as infrequent catastrophic in IDBR-01 cause AD. Unexpected lift-off debris from KSC Facilities/GSE is transferred from IDBR-01 cause AJ to LL-0077, which is classified as infrequent catastrophic. Debris release mitigations are identified for potential sources by adding inspections for system-level components. Ongoing mitigations include Foreign Object Damage (FOD) awareness, attrition-based removal of hardware, routine inspections and monitoring for facility corrosion. No updates to NSTS 60559 are recommended as part of this IIFA closure.

APPENDIX B STS-126 IN-FLIGHT ANOMALIES

SYSTEM ENGINEERING AND INTEGRATION ANOMALIES

IFA Number	Title	Comments
STS-126-I-007	Meteorological System Computer (MSC) Was Non-Responsive Due to Backlog of Balloon Data.	<p>The Meteorological System Computer (MSC) was non-responsive and had to be rebooted (recovered by L-1:50). All balloon data must go through the MSC. A backlog caused by balloon data that had to be Quality Controlled (QC) caused the MSC to be non-responsive. The MSC was rebooted while the L-2:20 balloons were in the air, causing the Jimsphere (JS) data to be lost. The Automated Meteorological Profiling System (AMPS) Hi-Resolution (HR) data was retransmitted from the AMPS computer and used for DOLILU assessment. The root cause of the STS-126 MSC failure was a back-log of data due to a large amount of data editing. Balloon priorities have been established and are documented. The objective of these changes is to help alleviate the strain on the MSC's. Cape Winds will plan to send only 3 balloons to the QC terminal at a time, but based on the balloon priorities a situation should not arise where more than two balloons will be edited at once (except at the -3:45 time frame). Cape Winds will update their console operating procedures as required. The PRD will be updated to document balloon requirements.</p>
STS-126-I-008	External Tank Top Coat/TPS Adhered to GOX Vent Hood Sealing Surface	<p>During Gaseous Oxygen (GOX) vent-arm retraction, the GOX vent seal adhered to the Liquid Oxygen (LOX) tank topcoat resulting in the loss of topcoat and a small amount of TPS (location XT 376.5 and Φ:141 +Y side). Topcoat, a latex substance, is applied to the pencil sharpened area of the LOX tank ogive to provide a leak tight seal for the GOX vent. Top coat adhesion and loss during GOX vent-arm retraction has been observed on previous missions. An assessment of the STS-126 vent-seal adhesion event concluded that there was no increased risk from this event. No documented requirements were violated. The mass of the largest piece of TPS found on the seal, 0.000042 lbm, was significantly less than the NSTS 60559 expected mass of 0.004 lbm. No evidence of debris liberation. The TPS foam particles remained adhered to the GOX vent seal. The divot created by TPS loss was enveloped by the hail damage accepted for ET-124.</p>

APPENDIX B STS-126 IN-FLIGHT ANOMALIES

SYSTEM ENGINEERING AND INTEGRATION ANOMALIES

IFA Number	Title	Comments
STS-126-I-009	Helium Pneumatic Pressure Decay	During STS-126, the MPS pneumatic Helium system tank pressure began to decay following the initiation of the SSME purge sequence 4 (T-4 minutes). The decay leveled off prior to lift-off, but then started again at mainstage and continued through Main Engine Cutoff (MECO) until the MPS dump. The tank pressure in the pneumatic and all other MPS tanks remained essentially constant during on-orbit until entry. At that time, all MPS tanks decayed at the nominal decay rate until postlanding, when the MPS system was again closed. An isolation test was performed by venting the MPS Helium tank to ambient and the subsequent leak check determined CV1, CV2 and CV3 passed, isolating the leak to Pneumatic-Fill Check Valve (CV4). Initial CV4 x-rays appear to show a minor seat alignment offset. CV4 was removed on 1/15/09 and CAR126RF05 was taken out. Failure analysis shows the sealing surface of the poppet had a large machining remnant around approximately 180 degrees of the poppet head. The poppet cylinder and internal housing showed significant signs of wear and the Teflon O-ring had large amounts of contaminant on it and numerous dings
STS-126-I-010	Tyvek Cover Entanglement in the ET Umbilical Area	During STS-126 ascent, at approximately 42 sec MET, approximately five pieces of debris were observed to release from the LH ₂ (port) ET/Orbiter umbilical area. The Imagery Analysis Team is convinced this debris is from the F4D Tyvek cover getting caught between the LH ₂ Umbilical door and the ET cross beam. The Tyvek cover of F4D is observed releasing from the forward RCS at 5.992 sec MET. (The remainder of F4D was observed to release at approximately 29sec MET.) The F4D Tyvek cover appeared to travel aft near the Orbiter belly, crossing the vehicle centerline, and was last observed near the inboard edge of the LH ₂ umbilical door near the ET cross beam. From approximately 10 to 11 sec MET, a stationary white object was observed between the forward edge of the LH ₂ umbilical door and the ET cross beam (close to the Orbiter belly). At 42.116 sec MET, the white object is seen at the same location by camera E215. The white object released as five pieces of debris, which then got caught in the recirculation airflows. Additional information is required to quantify the risk associated with Tyvek entanglement

APPENDIX B
STS-126 IN-FLIGHT ANOMALIES

FLIGHT SOFTWARE ANOMALIES

No Flight Software Anomalies were identified from the STS-126 Mission data.

APPENDIX B STS-126 IN-FLIGHT ANOMALIES

FLIGHT OPERATIONS AND INTEGRATION ANOMALIES

IFA Number	Title	Comments
STS-126-N-001	ROEU Motor 2 Drove on 2 of 3 Phases	<p>At approximately 002/15:59 MET, the Remotely Operated Electrical Umbilical (ROEU) Orbiter Docking Drive Mechanism (ODM) drove in the Demate direction. During this time, Motor 2 appeared to only drive on 2 of 3 AC phases. The AC 2 only had a current draw of approximately 0.08 Amperes (A) while the other two phases had a current draw of approximately 0.4 A. The resolution of the AC A transducer is 0.08 A. During ROEU ODM Mate operations (011/22:02 MET), AC 2 B had the same signature that was seen on AC 2 C during Demate operations. During the Relax operations (011/22:05 MET), AC 2 C only bit-toggled while the other two phases had nominal current draw. The ROEU was in a good Latched and Relaxed configuration.</p> <p>Post-Flight Status: On-vehicle resistance readings were performed to determine whether the problem is in the ROEU motor or further back into the Orbiter. A short was found in motor 2. This unit has been removed and will be repaired at the NSLD and then routed to the contractor for checkout.</p>

APPENDIX B STS-126 IN-FLIGHT ANOMALIES

MISSION OPERATIONS DIRECTORATE ANOMALIES

IFA Number	Title	Comments
STS-126-D-001	Updating Minimum EPS Consumables	<p>A change to the minimum lift-off quantities, which are used to calculate pad hold capability, was made by EGIL at approximately I-31 hr. The change in quantities was informally communicated to and acknowledged by the correct personnel at JSC and KSC, but there was confusion and delays in the process of formally transmitting and posting the update.</p> <p>Resolution: The process agreed to between JSC and KSC is JSC EGIL will write a JSC-MAS Chit that will document that a change has been requested and state the preliminary new minimum lift-off quantities and request the MER Manager to inform KSC of the change. The USA EPS Consumables Analysts will update the E-Consumables web page within 24 hr of the Chit initiation. This process is documented in a Memorandum (MOU) between JSC and KSC.</p>
STS126-D-002	Loss of Crewlock Bag During EVA 1	<p>During the first EVA at approximately 323/20:39 GMT, a crewlock bag became untethered and was lost. The crewlock bag contained 3 retractable equipment tethers, 1 retractable equipment tether with PIP pin, 2 adjustable equipment tethers, 2 wire ties, 1 SARJ grease gun with straight nozzle, 1 SARJ grease gun with J-hook nozzle, 1 EVA wipe caddy, 2 lubricated EVA wipes, 4 dry EVA wipes, 1 SARJ scraper debris container, 1 SARJ scraper, 1 EVA large trash bag.</p> <p>Resolution: MOD and the Astronaut Office will review tool configuration procedure conventions and establish standards for documenting tool configurations to insure critical tether connections are clearly captured. For future flights, schedule all activities that require access to EVA tools prior to EVA Tool Configuration for a given EVA, when possible. When not possible, such as the EVA camera with flash which has to have batteries loaded the morning of the EVA, will train configuration of affected tool(s) after the prime tool configuration activity is complete. Constraints will be documented in the Generic Ground Rules and Constraints Document, Part II. The assisting intravehicular (IV) crew member should be timed with the Extravehicular (EV) crew for an independent review (audit) of the EVA Tool Configuration. Increase EVA tool configuration to 1.5 hr (currently 1.0 hr) and include task IV crewmember for last 0.5 hr of tool configuration. IV crew members will be trained to perform independent audit of bag during Neutral Buoyancy Laboratory (NBL) training. MOD EVA flight controllers are working with Crew Time Working Group and the Generic Joint Operations Panel to implement the above timeline changes for STS-119 and subsequent. For EVA tasks requiring new or modified tools, MOD will work with the hardware suppliers to prioritize development of training tools with emphasis on volumetric trainers to allow crews and training teams to determine effective means of configuring and handling tools. This has been passed on to the next MOD EVA flight controller teams.</p>

APPENDIX B

STS-126 IN-FLIGHT ANOMALIES

IFA Number	Title	Comments
STS-126-D-003	Over-Torque of Trundle Bearing Assembly Mount	<p>During the second EVA, the mount bolt on Trundle Bearing Assembly (TBA) s/n 1001 was torqued to approximately 12.0 ft-lb. The Pistol Grip Tool (PGT) used to torque the mount bolt was inadvertently set to B2 (16.0 ft-lb) instead of A2 (3.8 ft-lb) as specified by the EVA checklist. The EV crewmember recognized the PGT was applying too much torque and stopped driving the mount bolt before the PGT reached the target torque of 16.0 ft-lb. The applied torque of 12.0 ft-lb significantly exceeded the mount bolt predicted failure torque of 5.1 ft-lb and the trundle bearing mount package was removed and the TBA was returned to the ground.</p> <p>Resolution: Provide EV crews with training that includes operating a high-fidelity Pistol Grip Tool (PGT) with gloved hands. Train EV crews to read settings from switches/collars on the PGT when reading settings back to the IV crewmember assisting them, prior to performing PGT operations.</p>
STS-126-D-004	MADS System Documentation Error	<p>While configuring the MADS switches to warm up the system before entry, it was discovered that the system was warming up with only the MADS STRAIN GAUGE switch in the ON position. Our current documentation (System Brief and SSSH drawing) incorrectly indicates that a second switch (MASTER MADS - ON) was required to perform the warm up function.</p> <p>Resolution: All errors in MOD INCO console documentation for MADS functions have been identified and corrected.</p>
STS-126-D-005	Middeck Return Item Weights Missing	<p>Weights for a number of middeck return items were missing from the Transfer List at Shuttle-ISS docking. Some of the weights were not received from ISS sources until Flight Day 7. The FDO console requires the weight of items being transferred to the Shuttle middeck, daily, for Orbiter c.g. calculations in case an emergency landing is required.</p> <p>Resolution: For corrective action, NASA/MOD is updating Flight Control Operations Handbook [FCOH] Paragraph 8.12.4, ISS/SHUTTLE CENTER OF GRAVITY CALCULATIONS, with the clarifying words for the drawing and weight suppliers in the ISS Program Office.</p>
STS-126-D-006	MPLM Telemetry Parameters Missing	<p>Approximately 140 Multi-Purpose Logistics Module (MPLM) downlink telemetry parameters (CDH, EPS and ECLSS) were discovered to be missing from the downlink list shortly before STS-126. Most of this telemetry was contained in the Caution and Warning (C&W) and was deselected per the ICATT process. Remaining parameters were deselected via the nominal process and of no impact to the FCT during STS-126.</p> <p>Resolution: This issue is specific to telemetry received from the MPLM; and therefore, does not impact flights prior to STS-128. The investigation is ongoing between NASA/OD and the MPLM team to determine the impacts of the telemetry deselection and the proper resolution. The appropriate corrective actions will be implemented prior to the next MPLM mission (STS-128).</p>

APPENDIX C

DOCUMENT SOURCES

MER DAILY REPORTS

The following STS-126 MER Daily Reports by Michael D. Wright, Lead MER Manager:

- First Daily Report (Ascent Plus 2-Hour Report), dated November 14, 2008
- Second Daily Report, dated November 15, 2008
- Third Daily Report, dated November 16, 2008
- Fourth Daily Report, dated November 17, 2008
- Fifth Daily Report, dated November 18, 2008
- Sixth Daily Report, dated November 19, 2008
- Seventh Daily Report, dated November 20, 2008
- Eighth Daily Report, dated November 21, 2008
- Ninth Daily Report, dated November 22, 2008
- Tenth Daily Report, dated November 23, 2008
- Eleventh Daily Report, dated November 24, 2008
- Twelfth Daily Report, dated November 25, 2008
- Thirteenth Daily Report, dated November 26, 2008
- Fourteenth Daily Report, dated November 27, 2008
- Fifteenth Daily Report, dated November 28, 2008
- Sixteenth Daily Report, November 29, 2008
- Seventeenth Daily Report, dated November 30, 2008
- Landing Plus 2 Hour Report, dated November 30, 2008
- Mission Summary Report, dated December 3, 2008

ET/SRB/RSRM/SSME REPORTS

- STS-126 Anomalies, David W. Morr, USA-Huntsville, January 22, 2009
- STS-126 Final Event Times, David W. Morr, USA-Huntsville, January 22, 2009
- STS-126 HOSC Console Flash Report, David W. Morr, USA-Huntsville, November 14, 2008
- STS-126 RSRM Flash Report, Robert Zahl, ATK--Huntsville, November 14, 2008
- STS-126 Post-Launch SRB Debris Open Assessment, Thomas F. Ford, NASA-KSC, November 20, 2008

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- STS-126 Landing and Deceleration Report, C. C. Heinol, Boeing-Houston, December 19, 2008
- STS-126 Landing and Deceleration Mission Summary, Thomas L. Hoffman, Boeing-Houston, December 18, 2008
- STS-126 Communications and Tracking Report, C. J. Stafford, Boeing-Houston, January 21, 2009
- STS-126 Ascent Hazard Analysis Report, Lillian P. Gibson, Boeing-Houston, January 26 2009
- STS-126 Descent Postflight Summary, Rosalyn R. Mark, USA-Houston, November 14, 2008
- STS-126 Displays and Controls and Lighting Report, D. Steinle, Boeing-KSC, December 17, 2008
- STS-126 Shuttle Remote Manipulator System, Nik Doshewnek, MDA-Houston, December 19, 2008
- STS-126 HYD/WSB System, Douglas T. Morsches, Boeing-Houston, December 18, 2008
- STS-126 PRSD System Mission Report, Johnny D. Wong, Boeing-Houston, December 19, 2008
- STS-126 Main Propulsion System Report, Trina A. Martingano, Boeing-Houston, December 16, 2008
- STS-126 Mechanical Systems Data Review, Jeff Goodmark, Boeing-Houston, December 19, 2008
- STS-126 Auxiliary Power Unit System, Christopher N. Adi, Boeing-Houston, December 19, 2008

STS-126 MADS Recorder and MMU Report, Quoc P. Ngo, Boeing-Houston, December 17, 2008
 STS-126 OI/MADS Sensors, Signal Conditioners and Fuel Cell Monitoring System, Dwight A. Favors, Boeing-Houston, December 1, 2008
 STS-126 OI/MADS MUX and Timing Report, Bruce S. Woods, Boeing-Houston, December 5, 2008
 STS-126 Data Processing System Integrated Report, James T. Westergard, Boeing-Houston, December 18, 2008
 STS-126 EPDC Mission Report, William D. Peterson, Boeing-Houston, December 9, 2008
 STS-126 ATCS Post-Flight Mission Report, Carmelo Asuncion, Boeing-Houston, December 10, 2008
 STS-126 Life Support Subsystem Report (ARPCS and Airlock Systems); Jamie M. Haynes, Boeing-Houston, December 11, 2008
 STS-126 Orbiter Docking System Summary, Robert E. Davis, NASA-JSC, December 19, 2008
 STS-126 OMS Report, Donald E. Varanauski, Boeing-Houston, December 18, 2008
 STS-126 RCS Mission Report, Donald E. Varanauski, Boeing-Houston, December 18, 2008
 STS-126 Preliminary Aeroheating Report, Dennis C. Chao, Boeing-Houston, December 5, 2008
 STS-126 Final Aeroheating Report, Erin M. Ainsworth, Boeing-Houston, December 2, 2008
 STS-126 Fuel Cells Mission Report, Johnny D. Wong, Boeing-Houston, December 19, 2008.
 STS-126 Global Positioning System Report, Ray Nuss, NASA-JSC, December 12, 2008
 STS-126 Thermal Control System Summary, Than X Nguyen, Boeing-Houston, December 17, 2008
 STS-126 Purge, Vent and Drain Report, C. C. Heinol, Boeing-Houston, January 6, 2009
 STS-126 Flight Controls and ADTA Mission Report, Donald E. Marquith, Boeing-Houston, December 17, 2008
 STS-126 Final Mission Events List, Vernon C. Hill, ESCG-Houston, December 2008
 STS-126 WLE IDS Post Flight Report, Jennifer C. Hodge, Boeing-Houston, February 17, 2009
 STS-126 SE&I In-Flight Anomalies, J. J. Hill, NASA-JSC, March 16, 2009
 STS-126 Flight Operations and Integration Anomalies, Ray Serna, NASA-JSC, January 15, 2009
 STS-126 Tyvek Discussion, E. J. Fitzgerald, Boeing-Houston, April 1, 2009
 STS-126 Windows Report, Jamshid Banakar, Boeing-Houston, February 23, 2009

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 STS-126 Final Landing Debris Report, Thomas F. Ford, NASA-KSC, December 9, 2008
 STS-126 Final Debris Maps, Thomas F. Ford, NASA-KSC, December 9, 2008
 STS-126 SRB Open Assessment, Thomas F. Ford, NASA-KSC, November 20, 2008
 STS-126 Orbiter Debris Assessment, Thomas F. Ford, NASA-KSC, December 3, 2008
 STS-126 Extravehicular Activity Report for EVA 1, Shannon L. Cagle-Strimple, Hamilton Standard, November 18, 2008
 STS-126 Extravehicular Activity Report for EVA 2, Shannon L. Cagle, Hamilton Standard, November 20, 2008
 STS-126 Extravehicular Activity Report for EVA 4, Jeff Outlaw, Hamilton Standard, November 25, 2008
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 STS-126 L-1 Day Briefing, Thomas F. Marren, NASA-KSC, November 13, 2008
 STS-126 By The Numbers, David S. Moyer, NASA-JSC, December 5, 2008
 STS-126 Imagery Reports, Imagery Integration Group, NASA-JSC, November 15-20, 2008
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APPENDIX D

ACRONYMS, ABBREVIATIONS, AND UNITS OF MEASURE

Acronym/ Abbreviation	Explanation
A	Ampere
AA	Accelerometer Assembly
ABS	Ammonia Boiler System
ACQ	Acquisition
A/D	Analog/Digital
ADTA	Air Data Transducer Assembly
AEC	Aft End Cone
AGT	Adaptive Guidance Throttling
AHMS	Advanced Health Monitoring System
ALC	Automatic Lighting Control
APCU	Auxiliary Power Converter Unit
APU	Auxiliary Power Unit
ARED	Advanced Resistive Exercise Device
ARPCS	Atmospheric Revitalization Pressure Control System
ASTT	Aerodynamic Sensor Transport Mode
ATCS	Active Thermal Control System
ATP	Acceptance Test Procedure
BET	Best Estimate Trajectory
BFS	Backup Flight System
BLT	Boundary Layer Transition
BSM	Booster Separation Motor
CCTV	Closed Circuit Television
CDR	Commander
CEI	Contract End Item
CEVIS	Cycle Ergometer with Vibration Isolation System
CETA	Crew Equipment Translation Assembly
CIR	Combustion Integrated Rack
CNSC	Communication Navigation Sensor Engineer
CO ₂	Carbon Dioxide
C/O	Checkout
COMM	Communications
CQ	Crew Quarters
C&W	Caution and Warning
CTB	Cargo Transfer Bag
CTVC	Color Television Camera
CWC	Contingency Water Container
DAT	Debris Assessment Team
DA	Distillate Assembly
D & C	Display and Control

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ACRONYMS, ABBREVIATIONS, AND UNITS OF MEASURE

Acronym/ Abbreviation	Explanation
DCS	Debris Containment System
DDU	Data Display Unit
DESIG	Designate
DET	Data Elapsed Time
DMHS	Dome Mounted Heat Shield
DOLILU	Day of Launch I-Load Update
DPS	Data Processing System
DRWP	Doppler Radar Wind Profiler
DSO	Development Secondary Objective
DTO	Development Test Objective
DTV	Digital Television
ΔP	Differential Pressure
ΔV	Differential Velocity
EA	Electronics Assembly
EAFB	Edwards Air Force Base
ECLSS	Environmental Control and Life Support System
ECO	Engine Cut-off
EDAS	Enhanced Data Acquisition System
EDV	Russian Water Container
EE	End Effector
EFBM	Exposed Facility Berthing Mechanism
EI	Entry Interface
E/O	External Tank/Orbiter
EOM	End-of-Mission
EPDC	Electrical Power Distribution and Control
ER	Express Rack
ET	External Tank
ETVCG	External Television Camera Group
EV	Extravehicular (Crewmember)
EVA	Extravehicular Activity
EXPRESS	Expedite the Process of Experiments-to-Space Station
FC	Fuel Cell
FCE	Flight Crew Equipment
FCMS	Fuel Cell Monitoring System
FCS	Flight Control System
FCV	Flow Control Valve
FD	Flight Day
FE	Flight Engineer
FES	Flash Evaporator System

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ACRONYMS, ABBREVIATIONS, AND UNITS OF MEASURE

Acronym/ Abbreviation	Explanation
FET	Flight Evaluation Team
FF	Flight Forward
FHRC	Flex Hose Rotary Coupler
FI	Focused Inspection
FID	Failure Identifier
FIT	Final Inspection Team
FNCS	Frangible Nut Crossover System
FOM	Figure of Merit
FOV	Field of View
FRCS	Forward Reaction Control System
FRSI	Flexible Reusable Surface Insulation
FS	Factor of Safety
FSE	Flight Support Equipment
FSS	Fixed Service Structure
FSW	Flight Software
G/g	Gravity
GCA	Ground Carrier Assembly
GCIL	Ground Interface Command Logic
GEI	Ground Environmental Instrumentation
GFE	Government Furnished Equipment
GH ₂	Gaseous Hydrogen
GMT	Greenwich mean time
GN&C	Guidance, Navigation and Control
GN ₂	Gaseous Nitrogen
GO ₂	Gaseous Oxygen
GPC	General Purpose Computer
GPS	Global Positioning System
Grms	Gravity root mean square
GUCP	Ground Umbilical Carrier Plate
H ₂	Hydrogen
H ₂ O	Water
HDP	Holddown Post
HDTV	High Definition Television
HPFTP	High Pressure Fuel Turbopump
HPGT	High-Pressure Gas Tank
HPOTP	High Pressure Oxidizer Turbopump
HR	High Resolution
HYD	Hydraulic
IBA	Inspection Boom Assembly

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ACRONYMS, ABBREVIATIONS, AND UNITS OF MEASURE

Acronym/ Abbreviation	Explanation
ID	Identification
I/O	Input/Output
IELK	Individual Equipment Liner Kit
IFA	In-Flight Anomaly
IFM	In-Flight Maintenance
IMU	Inertial Measurement Unit
I/O	Input/Output
IPR	Interim Problem Report
IPT	Intelligent Pressure Transducer
ISS	International Space Station
ITVC	Intensified Television Camera
IVA	Intravehicular Activities
IWIS	ISS Wireless Instrumentation System
JEM	Japanese Experiment Module
keas	knots estimated air speed
KSC	Kennedy Space Center
L	Launch
LCC	Launch Commit Criteria
LDRI	Laser Dynamic Range Imager
LEE	Latching End Effector
LESS	Leading Edge Structure System
LH	Left Hand
LHA	Lamp Housing Assembly
LH ₂	Liquid Hydrogen
LiOH	Lithium Hydroxide
LMC	Lightweight MPES Carrier
LO ₂ /LOX	Liquid Oxygen
LP	Left Pod/Launch Package
MADS	Modular Auxiliary Data System
MAGR	Miniature Airborne GPS Receiver
Max Q	Maximum Dynamic Pressure
Mb	Megabyte
MCC	Mission Control Center
MC	Midcourse Correction
MCRG	Manual Crack Repair Gun
MDCA	Main Distribution Control Assembly
MECO	Main Engine Cutoff
MEDS	Multifunction Electronics Display System
MET	Mission Elapsed Time

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ACRONYMS, ABBREVIATIONS, AND UNITS OF MEASURE

Acronym/ Abbreviation	Explanation
METOX	Metal Oxide
MHz	Mega Hertz
MLG	Main Landing Gear
MLI	Multilayer Insulation
MLP	Mobile Launch Platform
MLS	Microwave Landing System
MM	Momentum Manager/Major Mode
MM/OD	MicroMeteoroid/Orbital Debris
MMT	Mission Management Team
MMU	Master Measurement Unit
MNB	Main Bus
MPCA	Mid Power Control Assembly
mph	mile per hour
MPLM	Multi Purpose Logistics Module
MPM	Manipulator Positioning Mechanism
MPS	Main Propulsion System
MPTA	Main Propulsion Test Article
MS	Mission Specialist/Margin of Safety
MTL	Moderate Temperature Loop
MUX	Multiplexer
N ₂	Nitrogen
NASA	National Aeronautics and Space Administration
NAVAID	Navigation Aids
NC	Nominal Correction
NCC	Nominal Correction Combination
NH	Nominal Height
NLG	Nose Landing Gear
NOAX	Non-Oxide Adhesive Adapter
NSTS	National Space Transportation System
NTA	Nitrogen Tank Assembly
O ₂	Oxygen
OAA	Orbiter Access Arm
OBSS	Orbiter Boom Sensor System
OCA	Orbiter Communications Adapter
ODS	Orbiter Docking System
OFI	Operational Flight Instrumentation
OMRSD	Operational Maintenance and Requirements Specification Document
OMS	Orbital Maneuvering System

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ACRONYMS, ABBREVIATIONS, AND UNITS OF MEASURE

Acronym/ Abbreviation	Explanation
OPCU	Orbiter Power Converter Unit
OPO	Orbiter Project Office
OPT	Operational Pressure Transducer
ORGA	Orbiter Rate Gyro Assembly
ORU	Orbital Replacement Unit
P	Port
PAO	Public Affairs Office
PASS	Primary Avionics Software System
PCM	Pulse Code Modulation
PCS	Pressure Control System
PDU	Power Drive Unit
PET	Phase Elapsed Time
PGME	Propylene Glycol Monomethyl Ether
PLB	Payload Bay
PLBD	Payload Bay Door
PLT	Pilot
PMBT	Propellant Mean Bulk Temperature
ppCO ₂	Partial Pressure Carbon Dioxide
PRSD	Power Reactant Storage and Distribution System
PRT	Problem Resolution Team
PSP	Payload Signal Processor
PSSC	Pico-Satellite Solar Cell
PTU	Power Transfer Unit/Pan-Tilt Unit
PV&D	Purge, Vent and Drain
PWB	Portable Water Bag
PWR	Payload Water Reservoir
QD	Quick Disconnect
R & R	Remove and Replace
RCC	Reinforced Carbon-Carbon
RCS	Reaction Control System
OI	Operational Instrumentation
OIU	Orbiter Interface Unit
OME	Orbital Maneuvering Engine
OMRS	Operational Maintenance and Requirements Specification
RH	Right Hand
RHC	Rotational Hand Controller
RJD	Reaction Jet Driver
RM	Redundancy Management
ROEU	Remotely Operated Electrical Umbilical

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ACRONYMS, ABBREVIATIONS, AND UNITS OF MEASURE

Acronym/ Abbreviation	Explanation
RPC	Remote Power Controller
RPCM	Remote Power Controller Modules
RPM	R-Bar Pitch Maneuver
RS	Russian Segment
RSB	Rudder Speed Brake
RSP	Resupply Stowage Platform
RSR	Resupply Stowage Rack
RSRM	Reusable Solid Rocket Motor
RSS	Range Safety System
RTV	Room Temperature Vulcanizing (material)
S&A	Safe and Arm
SARJ	Solar Alpha Rotary Joint
SDFS	Smoke Detection and Fire Suppression
SLA	Super Lightweight Ablator
SLWT	Super Lightweight Tank
SM	System Management
SMRD	Spin Motor Rotation Detector
S/N	Serial Number
SODB	Shuttle Operational Data Book
SPA	Signal Processor Assembly
SPC	Stored Program Command
SRB	Solid Rocket Booster
SRGA	Station Rate Gyro Assembly
SRI	Stanford Research Institute
SRMS	Shuttle Remote Manipulator System
SRSS	Shuttle Range Safety System
SSAS	Segment-to-Segment Attachment System
SSLM	Solid State Light Module
SSME	Space Shuttle Main Engine
SSP	Space Shuttle Program
SSPL	Space Shuttle Picosat Launcher
SSPTS	Station-to-Shuttle Power Transfer System
SSRMS	Space Station Remote Manipulator System
ST	Star Tracker
STS	Space Transportation System
TBA	Trundle Bearing Assembly
TCS	Thermal Control System/Trajectory Control Sensor
TDRS	Tracking and Data Relay Satellite
TAEM	Terminal Area Energy Management

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ACRONYMS, ABBREVIATIONS, AND UNITS OF MEASURE

Acronym/ Abbreviation	Explanation
TEA	Torque Equilibrium Attitude
THC	Translation Hand Controller
TI	Terminal Phase Initiation/Transfer Initiation
TIG	Time of Ignition
TMBU	Table Maintenance Block Update
TPL	Transfer Priority List
TPS	Thermal Protection System
TSM	Tail Service Mast
TUS	Trailing Umbilical System
TVC	Thrust Vector Controller
T-Zero	Time of Lift-off/Launch
ULF	Utilization Logistics Flight
UPA	Urine Processing Assembly
UTC	Universal Time Code
V	Volt
VCR	Video Cassette Recorder
VDT	Vehicle Data Table
VIDD	Vertical Interval Date Decoder
vs.	Versus
WCL	Water Coolant Loop
WHC	Waste Hygiene Compartment
WIS/WIS-GFE	Wireless Instrumentation System – Government Furnished Equipment
WLE	Wing Leading Edge
WLEIDS	Wing Leading Edge Impact Detection System
WLES	Wing Leading Edge Subsystem
WPA	Water Processing Assembly
WRS	Water Recovery System
WSB	Water Spray Boiler
WVE	Wrist Vision Equipment
ZSR	Zero-g Stowage Rack

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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
g/G	gravity
Grms	gravity root mean square
Hr	hour
In.	inch
Kbps	kilobit per second
Keas	knots estimated air speed
Kgs	knots ground speed
kW	Kilowatt
kWh	Kilowatt hour
lb	pound
lbf	pound force
lb/hr	pound per hour
lb _m /lbm	pound mass
lb/min	pound per minute
Mlbf	Million pound force
min	minute
mmHg	millimeters Mercury
mph	miles per hour
nmi	nautical mile
%	percent
ppCO ₂	partial pressure carbon dioxide
ppm	parts per million
psi	pound per square inch
psia	pound per square inch absolute
psi/min	pound per square inch per minute
scim	standard cubic inch per minute
sec	second
Vdc	Volt direct current