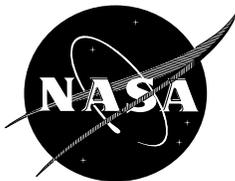


STS-119 SPACE SHUTTLE MISSION REPORT

November 2009



**National Aeronautics and
Space Administration**

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

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STS-119
SPACE SHUTTLE MISSION REPORT

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STS-119 SPACE SHUTTLE MISSION REPORT

INTRODUCTION

The Space Transportation System (STS) -119 Space Shuttle Mission Report presents a discussion of the Orbiter activities during 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 mission of the Space Shuttle Program. The purposes of this mission were to deliver and install the final U.S. Truss Segment (S6), rotate the Expedition 18 Flight Engineer with the Expedition 18/19 Flight Engineer, perform three Extravehicular Activities (EVA's), transfer mandatory quantities of water and transfer and stow critical cargo items to the International Space Station (ISS).

STS-119 was the 12th mission since the return to flight following the STS-107 mission, and the 28th mission to the ISS. STS-119 was also the 36th flight of the OV-103 Orbiter vehicle.

The primary objectives of the STS-119 mission were as follows:

1. Deliver and install the final U. S. Truss Segment (Starboard 6);
2. Exchange the Expedition 18 Flight Engineer with the Expedition 18/19 Flight Engineer;
3. Perform three Extravehicular Activities;
4. Transfer mandatory quantities of water;
5. Transfer and stow critical cargo items; and
6. Deliver a replacement Urine Processor Assembly-Distillation Assembly.

The flight vehicle consisted of the OV-103 Orbiter; the ET, a Super Lightweight Tank (SLWT) designated ET-127; three Block II SSMEs that were designated as serial numbers (S/Ns) 2048, 2051, and 2058 in positions 1, 2 and 3, respectively; and two SRBs that were designated BI-135. The two RSRMs were designated flight set RSRM-103. The individual RSRMs were S/N 360W103A (left) and S/N 360W103B (right). Launch pad 39A and Mobile Launch Platform (MLP) -3 were used as the platform for launch of the STS-119 mission.

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

The eight crewmembers (seven up, seven down) that were on the STS-119 flight were Lee J. Archambault, Colonel U.S. Air Force, Commander; Dominic A. Antonelli, Commander, U.S. Navy, Pilot; Joseph M. Acaba, Civilian, Mission Specialist 1; Steven R. Swanson, Civilian, Mission Specialist 2; Richard R. Arnold II, Civilian, Mission Specialist 3; John L. Phillips, PhD, Captain, U.S. Navy Reserve (Retired), Mission Specialist 4; Koichi Wakata, PhD, Civilian, Japan Aerospace Exploration Agency (JAXA), Mission Specialist 5 (up to ISS); and Sandra H. Magnus, PhD, Civilian, Mission Specialist 5 (down from ISS).

STS-119 was the third Shuttle flight for the Mission Specialist 4, Mission Specialist 5 (up to ISS), and the second Shuttle flight for the Commander, Mission Specialist 2, and Mission Specialist 5 (down from ISS). STS-119 was the first Shuttle flight for the Pilot, Mission Specialist 1 and Mission Specialist 3.

MISSION SUMMARY

Pre-Launch

The STS-119 launch was originally planned for February 12, 2009, but was postponed at the February 3 Agency Flight Readiness Review (FRR) to allow additional time and analysis to further develop flight rationale in response to the Flow Control Valve (FCV) anomaly which occurred on STS-126.

The first launch attempt on March 11, 2009, was scrubbed during External Tank (ET) tanking. When transitioning from fast-fill to topping, Liquid Hydrogen (LH₂) leakage in the area of the Ground Umbilical Carrier Plate (GUCP) exceeded specification during vent-valve cycling. An attempt was made to cycle the LH₂ vent valve as has been done in the past, but high LH₂ concentrations continued to be observed when the valve was opened. Launch was scrubbed, the ET was drained, and the launch was rescheduled for four days later.

Due to the launch slip of four days, the mission timeline was reduced due to a planned Soyuz launch on March 26th. To accommodate this constraint, undocking was required no later than March 25th. This resulted in the deferral of the 4th EVA from the planned timeline to the post-STS-119 International Space Station (ISS) stage operations.

During preparations for the second launch attempt, at 074/14:34:34 Greenwich Mean Time (GMT), when the vent valve was opened during the LH₂ topping phase of tanking, three of the four LH₂ plate gap differential pressure (ΔP) measurements temporarily violated the Launch Commit Criteria (LCC) 0.026-psid limit. The ground supply pressure was manually increased from approximately 135 psia to approximately 188 psia at the plate gap, and the plate gap ΔP increased to acceptable levels. A waiver was written to accept the momentary violation below the lower LCC limit.

At approximately 074/18:02 GMT, an abort light indicator command was issued from the Flight Dynamics Officer (FDO) workstation to the Orbiter. No impact occurred from this command as the Orbiter was still on the pad and the crew had not yet ingressed. The role of the command is for ground controllers to illuminate the onboard abort indicator light.

During the second tanking attempt, launch controllers spotted a bat after it had clawed onto the foam of the ET as Discovery stood at Launch Pad 39A. Real-time assessment indicated the bat posed no debris transport threat to the Orbiter. The temperature never dropped below 60 °F at that part of the tank, and Infrared cameras showed that the bat was still attached after lift-off.

Ascent and Flight Day 1

The STS-119 mission was launched at 074/23:43:44:019 GMT on March 15, 2009, on the twenty-eighth Space Shuttle Program (SSP) mission to the ISS.

During main engine start and through ascent, the main engine 3 gimbal accelerometer was erratic, but did not affect ascent or the mission. Post-flight troubleshooting identified the problem as a loose connector on the Orbiter side (IFA STS-119-V-14).

Evaluation of the ground imagery showed that the Reaction Control System (RCS) thruster F4D Tyvek rain cover released as expected at 5.28 sec Mission Elapsed Time (MET) (approximately 63 mph); however, a piece remained attached to the thruster lip. This piece is believed to have separated at approximately 17.3 sec MET (approximately 259 mph) (IFA STS-119-V-08). Imagery showed that the piece that released late did not impact the Orbiter.

All Solid Rocket Booster (SRB) systems performed as expected during the launch countdown and ascent. The SRB was visible through separation. Both SRBs were successfully separated from the ET and reports from the recovery ships in the area indicated that the deceleration subsystem performed as designed.

During ascent, the Modular Auxiliary Data System (MADS) Pulse Code Modulation (PCM) Base Heat Shield External Pressure Sensor measurement stepped to Off Scale Low (OSL) during ascent and remained OSL through entry to wheel stop (IFA STS-119-V-05). Post-flight troubleshooting isolated the cause to a connector which demated due to the launch environment.

A nominal Orbital Maneuvering System (OMS) assist maneuver was performed following SRB separation. Ignition occurred at 074/23:45:59.5 GMT (00/00:02:15.6 MET), and the maneuver was 88.20 sec in duration.

Main Engine Cutoff (MECO) occurred at 074/23:52:09 GMT (00/00:08:25 MET). The ET separated from the Orbiter at 074/23:52:39 GMT (00/00:08:55 MET). During ET Separation, the Digital External Tank Thermal Protection System (DETTPS) camera flash was not observed in the live video. Based on the video downlinked, imagery analysis confirmed the observation. The crew was then unable to retrieve the images from the DETTPS camera as planned. A second attempt to download the imagery later in the flight was not successful (IFA STS-119-V-04).

A nominal OMS-2 maneuver was performed at 075/00:22:14 GMT (00/00:38:30 MET). The maneuver was 63.2 sec in duration with a Differential Velocity (ΔV) of 96.1 ft/sec. The achieved orbit was 85.1 by 125.8 nmi.

The payload bay doors were opened at 075/01:19:44 GMT (00/01:36:00 MET).

The Ku-Band antenna was deployed at 075/01:33 GMT (00/01:50 MET). The system was powered at 075/01:38 GMT (00/01:54 MET), and the RADAR self-test was initiated at 075/01:44:01 GMT (00/02:00:16 MET). The Ku-Band system failed the self-test with the expected hot-receiver signature. The crew placed the system in the Communications (COMM) mode and the system operated normally.

At 075/01:57 GMT (00/02:14 MET), the fuel cell 3 Oxygen (O₂) flowmeter failed static to off-scale low (IFA STS-119-V-01). A slight decrease in Mid Power Controller 3 current was observed coincident with the fuel cell 3 O₂ flow meter anomaly. This anomaly did not impact the mission.

During the post-insertion Shuttle Remote Manipulator System (SRMS) shoulder brace release, the release time was 2 sec, shorter than the expected 6-8 sec. This was determined to be due to the plunger not being properly seated in the collet pre-flight. The SRMS was subsequently checked out successfully, and ground analysis confirmed no load impacts for the flight.

An OMS-3 Nominal Correction (NC)1 maneuver was performed nominally at 075/03:18:23.4 GMT (00/03:34:40 MET) with the cutoff at 075/03:19:30.0 GMT (00/03:35:46 MET) and both OMS engines operated nominally. The maneuver was 64.9 sec in duration with a ΔV of 100.7 ft/sec. The resulting orbit was 125.8 by 141.9 nmi.

During Photo/TV equipment setup, the crew reported that the Flight Deck camcorder would not operate. The crew exchanged the Audio Visual Interface Unit (AVIU) from the Middeck Payload General Support Computer (PGSC) (Desktop Downlink) with the Flight Deck and the Camcorder operated properly, thus confirming a failed AVIU (IFA STS-119-V-02).

Flight Day 2

The main activities on Flight Day (FD) 2 were the survey of the vehicle exterior and leading edge surfaces, rendezvous tool checkout, and docking system ring extension.

The crew reported that while trying to exercise using the Ergometer, the pedal movement was restricted (IFA STS-119-V-03). A troubleshooting procedure was developed and uplinked for use during FD 3 activities.

The time of ignition for the OMS-4 NC2 maneuver was 075/16:41:41.2 GMT (01/16:57:56:2 MET). The right Orbital Maneuvering Engine (OME) performed for this single-engine maneuver. The maneuver was 11.2 sec in duration with a ΔV of 8.3 ft/sec

The Orbiter Boom Sensor System (OBSS) surveys of the starboard Reinforced Carbon-Carbon (RCC), nose cap RCC, and the port RCC were completed nominally. Two additional inspection areas were inserted into the generic procedure starting with this mission: the Intensified Television Camera (ITVC) inspection of the starboard and port

T-O umbilical areas. The survey began at 075/17:57:25 GMT (00/18:13:41 MET) and was successfully completed at 076/00:31:00 GMT (02/00:47:16 MET).

The first on-orbit fuel cell purge was a manual purge beginning at 075/18:42 GMT (00/18:59 MET).

The Orbiter Docking System (ODS) ring extension was completed at 076/01:38:54 GMT (001/01:55:10 MET). The ring extension was performed within nominal dual-motor drive time to the initial position of 77.2 deg. No anomalies were noted during the ring extension.

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

The time of ignition for the NC3 maneuver was 076/03:15:48 GMT (01/03:32:04 MET) with the cutoff at 076/03:16:00 GMT (001/03:32:16 MET). The RCS maneuver was performed as a 2-engine +X firing. The duration of the maneuver was 12 sec with a ΔV of 2.7 ft/sec. The resulting orbit was 125.8 by 147.5 nmi. Engine performance was nominal.

Flight Day 3

The primary activities for FD 3 were rendezvous, docking, hatch opening, and ingress to the ISS.

The OMS-5 Nominal Height (NH) was performed using both OMS engines. The time of ignition was 076/16:13:13.3 GMT (01/16:29:29 MET) with the cutoff at 67.9 sec later. The maneuver had a ΔV of 105.5 ft/sec, and the resulting orbit was 134.6 by 196.6 nmi. Engine performance was nominal.

The OMS-6 NC4 was also a dual engine firing. The time of ignition was 076/17:03:28.8 GMT (01/17:19:45 MET) with the cutoff at 48.5 sec later. The maneuver had a ΔV of 76.1 ft/sec, and the resulting orbit was 178.1 by 196.8 nmi. Engine performance was nominal.

The Nominal Corrective Combination (NCC) maneuver was not required.

The OMS-7 Terminal Initiation (TI) maneuver was a left-engine firing. Ignition was at 076/18:35:39.1 GMT (01/18:51:55 MET) with the cutoff 11.4 sec later. The ΔV delivered was 8.7 ft/sec and the Orbiter was placed in a 183.1 by 196.8 nmi orbit. Engine performance was nominal.

The Midcourse Correction (MC)1 maneuver and the out-of-plane null maneuver were not required. The MC2 maneuver was a 10.3-sec +X RCS firing using two primary thrusters. Ignition occurred at 076/19:32:34.7 GMT (01/19:48:51 MET). The ΔV delivered was 2.4 ft/sec and the Orbiter was placed in a 183.6 by 196.7 nmi orbit.

The MC3 maneuver was a 0.76 sec +X RCS firing using two primary thrusters. Ignition occurred at 076/19:49:35.2 GMT (01/20:05:51 MET). The ΔV delivered was 0.17 ft/sec and the Orbiter was placed in a 183.7 by 196.8 nmi orbit. The MC4 maneuver was a 5.1-sec Z-axis RCS firing using 10 primary thrusters. Ignition occurred at 076/19:59:34.7 GMT (01/20:15:51 MET). The ΔV delivered was 1.2 ft/sec and the Orbiter was placed in a 184.3 by 196.8 nmi orbit.

The R-bar Pitch Maneuver (RPM) started at approximately 076/20:19:32 GMT (01/20:35:48 MET) and ended at 076/20:27:29 GMT (01/20:43:44 MET). The peak off-axis rates during the 0.70 deg/sec pitch maneuver reached -0.062 deg/sec in roll and 0.064 deg/sec in yaw.

An auto-angular-alignment maneuver was performed in accordance with the established procedures. This is only the 2nd time that an auto-alignment maneuver has been performed during rendezvous and docking operations.

The ODS was activated at 076/20:45:39 GMT (01/21:01:55 MET). The Shuttle captured the International Space Station (ISS) at 76/21:19:50 GMT (01/21:36:06 MET). The system was allowed to dampen out for approximately 8 min 43 sec. Ring retraction using dual motors was started at 76/21:28:38 GMT (01/21:44:54 MET), and it proceeded nominally for approximately 3 min 18 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 076/21:36:44 GMT (01/21:53:00 MET). At that time, docking operations were complete.

The Nitrogen (N₂) transfer to the ISS was initiated at 077/00:34 GMT (2/00:50 MET) and 26 lb of nitrogen subsequently transferred over to the ISS.

The RCC Damage Assessment Team (DAT) completed the review of the RCC imagery obtained from the FD 2 SRMS/OBSS survey. In addition, all FD 3 RPM imagery was downlinked and the Thermal Protection System (TPS) DAT commenced review of the data.

Flight Day 4

Activities on FD 4 included robotic Starboard 6 Truss unberthing, hand-off, and maneuver to the end of the ISS. All activities were completed successfully.

The crew reported that the overhead light in the Waste Management Compartment had failed off. The crew used a drag-on light for the remainder of the mission.

During Wing Leading Edge Sensor (WLES) Micrometeoroid/Orbital Debris (MM/OD) monitoring with the RCC Group 2 sensors, Serial Number (S/N) 1024 sensor on the port wing unexpectedly dropped out of the on-orbit mode after 5-6 hr of monitoring (IFA STS-119-V-09). A health check of the sensor showed that the sensor was in the "idle" mode. The sensor was subsequently regained and stayed operational for the remainder of the flight.

The RCC DAT completed the imagery analysis and identified no requirements for a focused inspection.

The TPS DAT presented preliminary results of the imagery obtained from the FD 3 RPM maneuver. One damage site on the left inboard elevon was still under review, and no focused inspection requirements had been identified.

The ISS Program submitted a request to the Space Shuttle Program that if the FD 6 focused inspection was not required, to move up the crew off-duty time (originally scheduled after undock) so that it would be taken during the docked timeframe. This change would eliminate the dedicated crew off-duty day after undocking, and allow ISS returning payload cold stowage to survive to End of Mission (EOM)+2 days, if required.

The Ergometer team completed development of an In-Flight Maintenance (IFM) procedure to attempt to resolve the Ergometer jam. The procedure was uplinked to the crew in the Execute Package.

Flight Day 5

Activities for FD 5 included the first EVA, Starboard 6 Truss installation, and the Ergometer IFM.

The first EVA duration was 6 hr 7 min and all planned tasks plus one get-ahead task were completed satisfactorily. The major focus of the EVA was the installation of the S6 Truss.

Execution of the Ergometer IFM regained full functionality of the unit. The crew found a bend in the calibration strap. The bend in the strap was placed in the proper configuration, which fixed the unit.

The TPS DAT presented analysis results to the FD 5 Mission Management Team (MMT). The team identified nine items that exceeded pre-defined screening criteria and required additional analysis. All but one of the items, a gap-filler protuberance on the left inboard elevon, was cleared. The team continued assessment to clear the gap filler, but indicated that no focused inspection would be required (IFA STS-119-V-06).

The FD 5 MMT discussed several options for accommodating the ISS request to shorten the post-undocking mission duration to allow returning-payload cold stowage to survive through EOM+2 days. The MMT reduced the options to two.

During the Flight Night (FN) 5 crew sleep period, no telemetry was received from the Shuttle-to-Station Power Transfer System (SSPTS) Orbiter Power Converter Unit (OPCU) 2A when power was reapplied to the unit following the first EVA. The following morning after crew awake, the unit was reset and full functionality was regained. The cause was attributed to a false trip of the fault-isolator circuit, which was seen during the development phase of the SSPTS.

Flight Day 6

Crew activities for FD 6 included the deployment of the two Solar Array Wings (SAW's) and preparations for the second EVA. Since no Focused Inspection was required, the SAW deploy moved up in the timeline from FD 8 to FD 6.

At 079/14:10:08 GMT (04/14:26:24 MET), the Orbiter took over attitude control in support of the ISS Solar Array Deployment. At 079/14:13:24 GMT (04/14:29:40 MET), the inertial maneuver from the Bias -XLV -ZVV Starboard Solar Array Rotary Joint (SSARJ) Torque Equilibrium Attitude (TEA) to the 1B SAW Deployment attitude began. The maneuver was completed at 079/14:29:57 GMT (04/14:46:13 MET). The Digital Auto Pilot (DAP) was moded to free drift at 079/15:04:41 GMT (04/15:20:57 MET) for the first half of the 1B Solar Array Wing (SAW) deployment. After the 1B SAW was deployed to 49%, the Orbiter resumed attitude control at 079/15:12:38 GMT (04/15:28:54 MET) for thermal conditioning of the solar array. Upon completion of the thermal conditioning, the DAP was moded back to free drift at 079/15:45:34 GMT (04/16:01:50 MET) to continue the 1B SAW deployment. Upon full deployment of the 1B array, the Orbiter resumed attitude hold at the SAW Deployment attitude at 079/15:53:05 GMT (04/16:09:21 MET).

At 079/16:35:07 GMT (04/16:51:23 MET), the Orbiter DAP was moded to free drift for deployment of the 3B SAW. The entire 3B solar array deployment was performed with the Orbiter DAP in free drift. When the 3B array was deployed to 49% at 079/16:43:00 GMT (04/16:59:16 MET), the ISS took attitude control for the thermal conditioning of the array. After thermal conditioning was complete, the ISS was moded back to free drift at 079/17:10:48 GMT (04/17:27:04 MET) for resumption of the 3B SAW deployment. Upon full deployment of the 3B array at 079/17:18:00 GMT (04/17:34:16 MET), the ISS resumed attitude control. At 079/17:24:00 GMT (04/17:40:16 MET), the ISS began the maneuver back to the TEA attitude.

A second attempt was made to download External Tank separation images from the DETTPS camera, but the attempt was unsuccessful (IFA STS-119-V-04). No further on-orbit troubleshooting was attempted.

WLES Sensor Unit 1033 did not begin on-orbit monitoring as planned (IFA STS-119-V-07). It was determined that the unit did not have the correct internal time. A command was sent to the unit from the ground to start on-orbit monitoring immediately. The unit continued to be used for the remainder of the on-orbit monitoring period.

Following the Pressure Control System (PCS) Nitrogen (N₂) repressurizations, the N₂ regulator pressure rise-rate gradually slowed down until the pressure stopped rising. Following the N₂ repressurization on FD 6, the N₂ regulator pressure exhibited typical responses except the pressure continued to rise. The rise-rate was at a near linear rate of approximately 2.4 psi/hr for the last 10 hr. Monitoring of this condition continued.

The TPS DAT continued assessment of the left inboard elevon protruding gap filler. The team also summarized an additional damage item under assessment on the upper surface body flap. The damage was part of a missing stub tile, but it was expected to be cleared based on a previous assessment from STS-123. All other TPS/RCC issues had previously been cleared.

The FD 6 MMT discussed the remaining two options for accommodating an ISS payload request to shorten the post-undocking mission duration to allow cold stowage to survive to EOM+2 days, if required. The MMT selected the option of delaying undocking until late on FD 11 and performing the Late Inspection on the morning of FD 12. This option scheduled the Flight Control Systems (FCS) checkout on FD 13, and landing on FD 14.

Flight Day 7

The primary activity for FD 7 was the second EVA.

The Orbiter took control of the mated stack at 080/14:13:47 GMT (05/14:30:03 MET) and a 6 deg maneuver to water-dump attitude began at 080/14:15:46 GMT (05/14:32:02 MET). The Orbiter maintained attitude-hold throughout the water dump procedures. The 6 deg maneuver back to TEA began at 080/16:23:26 GMT (05/16:39:42 MET) and the ISS assumed control of the mated stack at 080/17:01:28 GMT (05/17:17:44 MET). The Orbiter was in attitude control for approximately 2 hr 48 min.

The second EVA began at 080/16:51:00 GMT (05/17:17:16 MET) and had a duration of 6 hr 30 min. The crew completed the P6 battery replacement worksite preparation, the Kibo Global Positioning System (GPS) antenna installation, and the S1/P1 radiator imaging. The P3 Unpressurized Cargo Carrier Attachment System (UCCAS) was not deployed due to an issue with a restraint pin, and as a result, the S3 truss Payload Attachment System (PAS) deployment was deferred. Due to an issue with the P2 connector, the Z1 truss patch panel reconfiguration task was not reconfigured as planned.

During the EVA, the ISS Control Moment Gyroscopes (CMGs) saturated and the Orbiter took over attitude control at 080/18:39:08 GMT (05/18:55:21 MET) and returned control to the ISS at 081/00:03:44 GMT (06/00:20:00 MET). The cause of the CMG saturation was later attributed to the location of the ISS Mobile Transporter having an effect greater than expected by pre-flight analyses. During Orbiter attitude control, Vernier Reaction Control System (VRCS) propellant usage was greater than expected for similar reasons (IFA STS-119-N-01).

The fifth and sixth Contingency Water Containers (CWC's) were filled and transferred to the ISS.

Following the second EVA, at 081/01:32:38 GMT (06/01:48:44 MET), the SSPTS OPCU 2A failed to reactivate in the same manner as occurred two days earlier. The planned procedure was re-performed, and the unit began operating properly.

The TPS DAT presented final results of the assessments of the left inboard elevon gap filler and the upper surface broken stub tile. The team recommended to the MMT that all damage assessments were complete and that all items were cleared for entry.

Flight Day 8

Activities for FD 8 included preparations for the third EVA. Ground personnel replanned the EVA to accommodate the P3 UCCAS which was not deployed during the second EVA.

Due to the extended VRCS attitude-hold following the CMG saturation on FD 7, the ISS accumulated a ΔV , which led to a conjunction concern that was predicted to occur during the third EVA on FD 9. The conjunction, along with the need to support an upcoming Soyuz rendezvous, led to a decision to perform a small deboost maneuver on FD 8. The desired deboost, 1 ft/sec, was small enough that it could be accomplished using the VRCS in the attitude-hold mode. Shuttle control was engaged at 81/20:00:44 GMT (06/20:17:00 MET) to maneuver to the undocking attitude. The attitude-hold activity started at 81/20:41:00 GMT (06/20:57:16 MET). The maneuver back to the Torque Equilibrium Attitude (TEA) started at 81/23:34:00 GMT (06/23:50:16 MET) and was completed at 82/00:03:00 GMT (07/00:19:16 MET). The maneuver provided a retrograde velocity of approximately 1 ft/sec.

The seventh and eighth CWC's were filled and transferred to the ISS.

Flight Day 9

The main activity for FD 9 was the third EVA.

The SSPTS was deactivated at 082/12:05:16 GMT (07/12:21:32 MET) for the EVA and to increase Shuttle water production for transfer to the ISS.

The start time for the third EVA was 082/15:37 GMT (07/15:53 MET) with both suits switching to battery power. The EVA ended at 082/22:04 GMT (07/22:20 MET) with a total EVA time of 6 hr 27 min.

The second attempt of the P3 UCCAS deployment was unsuccessful. As a result, the S3 Payload Attachment System (PAS) deployment was not achieved. The Segment-to-Segment Attachment System (SSAS) Bolt Bus Controller (BBC) connector, the Crew and Equipment Translation Aid (CETA) coupler, and two of the six P-Clamps were installed.

The ninth CWC was filled and transferred to the ISS.

Flight Day 10

All activities for FD 10, which included crew off duty time and transfer, were completed.

A revised SSPTS reactivation procedure was developed to reduce the likelihood of the fault-isolation circuit trip. The procedure was successfully performed at the conclusion of the water-collection activities 083/11:52:48 GMT (08/02:09:04 MET), and no false trips were observed.

The tenth and eleventh CWC's were filled and transferred to the ISS.

Flight Day 11

Activities for FD 11 included hatch closure and undocking from the ISS.

When the -Z Star Tracker was powered-on prior to undocking, a failed-pressure Built-In Test Equipment (BITE) message was annunciated. This Star Tracker had been powered off during the docked timeframe due to blockage by the ISS. Also, this Star Tracker has a history of pressure decay which may have caused this BITE to annunciate. There was no impact to the performance of the Star Tracker as a result of this indication.

The ODS hatch was closed at approximately 84/17:23 GMT (09/17:39 MET).

The ODS performed nominally for undocking. The command to undock was initiated at 84/19:51:25 GMT (09/20:07:41 MET). The Shuttle/ISS separation occurred at 84/19:53:27 GMT (09/20:09:43 MET). The total drive time of 2 min, 2 sec for Hook Groups 1 and 2 was nominal.

The fly-around was initiated with RCS +X pulses of L1A and R1A thrusters at 084/20:21:52 GMT (09/20:38:08 MET). The separation 1 maneuver was initiated with RCS +X pulses for 6.32 sec using thrusters L1A and R1A at 084/21:08:27 GMT (09/21:24:43 MET). The separation 2 maneuver was performed at 084/21:36:27 GMT (09/21:52:43 MET). This was a 12.08 sec RCS +X maneuver using thrusters L3A and R3A.

After undocking and prior to the separation 1 maneuver, the Ku-Band was taken to the RADAR mode at 084/21:05:00 GMT (09/21:21:16 MET) and locked on to the ISS at an approximate range of 630 ft. The Ku-Band was configured back to the Communications (COMM) mode at 084/21:13:13 GMT (09/21:29:29 MET) at a range of approximately 800 ft.

The operation of the Trajectory Control Sensor for undocking and fly-around activities was nominal.

A review of the on-orbit imagery showed that the painted white lines on the OBSS Electrical Flight Grapple Fixture (EFGF) target were peeling in several places. This

grapple fixture was used by the SRMS to grapple the OBSS. This condition did not affect the use of the target as an alignment aid during the grapple of the OBSS.

Flight Day 12

Activities for FD 12 included the standard inspection of the Orbiter's RCC panels for Micrometeoroid/Orbital Debris (MM/OD) damage.

The third on-orbit fuel cell purge was performed, beginning at 085/10:34:55 GMT (10/10:51:11 MET). During the 118-hr purge interval, the approximate performance decay was 0.27 Vdc for fuel cell 1, 0.26 Vdc for fuel cell 2, and 0.20 Vdc for fuel cell 3. Since both of the fuel cell 3 flowmeters were failed, purge valve operation was verified by other parameters, including coolant pressure, Hydrogen (H₂) pump motor status, vent line temperatures, and observing the fuel cell performance increase.

The late inspection started with the starboard survey at 085/14:06 GMT (10/14:22 MET) and ended with the port survey at 85/19:04 GMT (10/19:20 MET). The OBSS was berthed on the starboard Manipulator Positioning Mechanism (MPM) at 085/19:40 GMT (10/19:56 MET). The SRMS was cradled and latched, and power down was completed at 085/20:17 GMT (10/20:33 MET).

The late inspection surveys were completed successfully. The crew performed only one Pan-Tilt Unit (PTU) reset throughout the whole survey. The PTU errors started out within family of past missions and by the end of the inspection had grown to 6.6 deg for pan and 9.8 deg for tilt. The crew was able to match the pictures needed at the beginning of each scan. The missed T-seal and RCC of panel R7 on FD 2 were imaged during late inspection survey.

There were no recurrences of the momentary Laser Dynamic Range Imager (LDRI) video dropouts that were seen on the FD 2 inspection imagery. The ground control had recommended staying in Mode 6 to ensure proper thermal conditioning for laser electronics.

At 085/16:46 GMT (10/17:02 MET), the Auxiliary Power Unit (APU) 2 fuel pump B heater circuit primary thermostat began to dither (IFA STS-119-V-10). The fuel pump B heater circuit thermostat cycle range shifted from a 11.2 °F control band as measured by the bypass line temperature reading to a 3.2 °F band. There was no impact to the mission, and the thermostat returned to the normal cycling range on FD 13.

Flight Day 13

Activities for FD 13 included stowing the cabin for entry and performing the FCS checkout and RCS hot-fire tests.

The review of the late inspection survey imagery was completed by the RCC DAT, and the vehicle was cleared for entry.

The FCS checkout was performed satisfactorily. APU 1 was started at 86/13:56:56 GMT (11/14:13:12 MET) and ran for 5 min and 50 sec consuming 15 lbs of fuel. During FCS checkout, the APU 2 fuel pump B heater circuit primary thermostat returned to the normal cycling range.

Also during FCS checkout, the Radar Altimeter 2 displayed an out-of-tolerance altitude value on an onboard display. The crew reported that the altitude data was good for the first 5 sec of the self-test, and then the display held the out-of-tolerance value for the remainder of the self-test. On the ground, the altitude data remained good for the duration of the self-test period. The most likely cause of the onboard display indication was that a timing error occurred during the self-test period as a similar condition was observed early in the Shuttle program. This was not considered an issue, and the Radar Altimeter 2 was cleared for use during approach and landing.

The RCS hot-fire was initiated at 86/15:00:26 GMT (11/15:16:42 MET) and completed at 86/15:12:41 GMT (11/15:28:57 MET). All 38 RCS thrusters were fired at least twice for at least 0.240 sec per pulse. No anomalies occurred.

An OMS maneuver was performed in support of the Shuttle Ionospheric Modification with Pulsed Local Exhaust (SIMPLEX) payload of opportunity. The OMS-8 maneuver was performed at 86/20:15:43 GMT (11/20:31:59 MET). The dual-engine, straight-feed maneuver was 11.8 sec in length. The ΔV delivered was 21.5 ft/sec and the achieved orbit was 183.0 by 189.1 nmi.

The Ku-Band system was stowed without issue at 86/22:59:21 GMT (11/23:15:37 MET) and powered off at 86/22:59:31 GMT (11/23:15:47 MET).

Flight Day 14 - Entry and Landing

The main activities were closing of the Payload Bay Doors (PLBDs), the deorbit maneuver, entry, and landing.

Both PLBDs were closed nominally by 087/14:03:51 GMT (012/14:20:07 MET) in preparation for landing.

The first landing opportunity of the planned landing day was waved off because of unacceptable weather at Kennedy Space Center (KSC).

The deorbit maneuver for the second landing opportunity at KSC, a dual-engine straight-feed firing, was performed on orbit 202 at 087/18:08:14 GMT (12/18:16:30 MET). The maneuver was 179.5 sec in duration with a ΔV of 338.6 ft/sec. The orbit after the deorbit maneuver was 21.8 by 188.3.

Entry interface occurred at 087/18:41:56.404 GMT (12/18:41:56 MET).

During the post-entry interface time period, the APU 2 Exhaust Gas Temperature (EGT) temperature sensor became erratic (IFA STS-119-V-11). This condition did not impact entry or landing.

In the final stage of entry, after onboard Navigation (NAV) software had processed Tactical Air Navigation (TACAN) system range and bearing data for approximately four min, all three TACAN's temporarily and intermittently lost lock in Bearing for approximately 29 sec. There were no impacts to entry approach since the NAV state was using only Global Positioning System (GPS) data at the time. Post-flight, this phenomenon was determined to be an explained condition associated with a null in the antenna pattern that results in a dropout.

During the higher APU loading periods of entry between Terminal Area Energy Management (TAEM) and wheel stop, the APU 3 Z-Axis Accelerometer readings were intermittently Off-Scale-High (OSH), greater-than 100 G Peak-to-Peak) (IFA STS-119-V-12). There was no impact to APU performance.

During the final approach, the Heads-Up Display (HUD) Mini-Camcorder video was not observed by the ground team (IFA STS-119-V-16). Post-flight, the MILA ground station confirmed that there was no modulation in the downlink, indicating no presence of a video signal. The entire entry mini-camcorder video recorded onboard (approximately 2 hr) was reviewed, confirming nominal performance by the camera and video recorder.

The main landing gear touchdown occurred KSC runway 15 at 087/19:13:26 GMT (12/19:29:42 MET) on March 28, 2009. The drag chute was deployed at 087/19:13:29.3 GMT (12/19:29:45.3 MET). The nose gear touchdown occurred at 087/19:13:34 GMT (12/19:29:50 MET). Drag chute jettison occurred at 087/19:13:58.7 GMT (12/19:30:14.7 MET). Wheels stop occurred at 087/19:14:44 GMT (12/19:31:00 MET). The rollout was normal in all respects.

It was first reported from video imagery and later verified during post-flight inspection that there was a hole in the canopy area of the drag chute. The inspection revealed that four ribbons were torn at locations 22 through 25 in gore 7. A more detailed review of slow-motion video imagery supported the initial evaluation that the most probable cause of the torn ribbons was due to higher-than-normal turbulence experienced during deployment. This is type of damage is not unexpected and repair of the ribbons is covered by procedures used at the refurbishment facility.

Post-landing, the forward RCS fuel Helium A-leg valve did not cycle closed when commanded at 087/19:40:21 GMT. Approximately 2 min after the command, the valve closed. The valve normally closes in 1 sec when commanded. Approximately 14 min after the scheduled test, the valve was recycled and performed nominally.

The flight duration was 12 days 19 hr 31 min 00 sec. The last APU was shutdown 12 min and 04 sec after landing.

Post-Flight

During post-flight hydraulic inspections of the Orbiter ET door interfaces, one of the three LH₂ Forward Outboard ET actuators was not in the fully retracted locked position (IFA STS-119-V-13). The ET retract actuators are inspected every flow to verify the actuators retracted into the locks following commands issued from the Master Event Controllers (MEC) after ET separation. There was no impact to ET door closing during the flight as the other two LH₂ actuators retracted and locked nominally.

During the post-flight crew debriefing, the crew reported that the Re-Hydration (RHS) Shuttle Orbiter Repackaged Galley (SORG) consistently leaked during dispenses (IFA STS-119-V-15). The on-orbit leakage required the usage of towels daily to absorb the water leakage around the cup enclosure.

PAYLOADS AND EXPERIMENTS

The primary purpose of the mission was to deliver and deploy the Starboard (S) 6 Integrated Truss Segment (ITS) to the International Space Station (ISS); exchange an ISS crewmember; transfer critical supplies and cargo to the ISS; and perform ISS get-ahead tasks in preparation for the 2J/A mission.

LAUNCH PACKAGE OVERVIEW

The ISS 15A launch package consisted of delivering, installing and deploying the Starboard 6 ITS located in the Orbiter cargo bay. The ISS Program utilization payloads flown in the Middeck included the General Laboratory Active Cryogenic ISS Experiment Refrigerator (GLACIER), the Protein Crystallization Diagnostics Facility Processing Unit (PCDF-PU), 12 National Laboratory Pathfinder (NLP) Vaccine Group Activation Packs (GAPs), Commercial Generic Bioprocessing Apparatus (CGBA) Science Insert (CSI), Dome Gene, Optimization of Root Zone Substrates (Lada-MIS ORZS), and a double cold bag to return thermally conditioned science samples.

Short Duration Bioastronautics Investigations (SDBIs) performed during the mission included SDBI 1634 (Sleep Short), SDBI 1904 (Assessment of Human Factors), SDBI 1900 (Integrated Immune), and ISS Long Duration Integrated Immune. Development Test Objectives (DTOs) on this flight included DTO 695, Thrust Oscillation Seat; DTO 805, Crosswind Landing Performance; DTO 854, Boundary Layer Transition Flight Experiment; and DTO 900, Shuttle RSRB Chamber Pressure, Strain Gauge and Acceleration Rates Data Collection. In addition, Maui Analysis of Upper-Atmospheric Injections (MAUI), Shuttle Engine Ion Turbulence Experiment (SEITE), and Shuttle Ionospheric Modification with Pulsed Local Exhaust (SIMPLEX) were flown as payloads of opportunity with no in-flight hardware required.

CREW ACTIVITY SUMMARY

The Orbiter successfully docked to Pressurized Mating Adapter (PMA)-2 on ISS at 4:20 p.m. Central Daylight Time (CDT) on March 17, 2009. On FD 4, the Space Station Remote Manipulator System (SSRMS) grappled the S6 Truss and unberthed it from the Shuttle Payload Bay and handed the truss off to the Shuttle Remote Manipulator System (SRMS). The SSRMS was then maneuvered into position for translation via the Mobile Transporter (MT) to Worksite 1. After translation, the SRMS handed the S6 Truss back to the SSRMS for placement in preparation for installation and activation the following day.

On FD 5, the S6 truss was maneuvered to the pre-installation position and S6 was installed to the S5 truss during the first Extravehicular Activity (EVA), which was successfully completed in 6 hr and 7 min. With no Focused Inspection (FI) required, the mission timeline was updated to move Solar Array Wing (SAW) deployment from FD 8

to FD 6. The last two Primary Power System (PPS) channels 1B and 3B Solar Array Wings were successfully deployed.

On FD 7, the second EVA was completed in 6 hr 30 min. During the second EVA, the ISS Control Moment Gyroscopes (CMG)'s saturated, which resulted in the loss of ISS altitude control. The Shuttle crew manually regained attitude control with the Shuttle Vernier Reaction Control System (VRCS), which resulted in a mated stack "reboost" of approximately 0.15 Meters/Second (M/S) Differential Velocity (ΔV). On FD 8, the third EVA timeline was replanned to add the deployment of the stuck P3 Nadir Unpressurized Cargo Carrier Attach System (UCCAS) and the S3 Zenith Payload Attach System (PAS) deployment following the Crew Equipment Translation Aid (CETA) cart relocation.

On FD 9, the third and final EVA was completed in 6 hr 27 min. FD 10 was mostly an off-duty day for the crew. On FD 11, the crew participated in their final farewells and then closed the hatches. Discovery successfully undocked from Pressurized Mating Adapter-2 (PMA-2) at 2:54 p.m. CDT on March 25, 2009. The Orbiter completed a flyaround of the ISS, obtaining the first ever imagery of the ISS with the full complement of solar arrays.

TRANSFER WEIGHT SUMMARY

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

TOTAL WEIGHT TRANSFERRED DURING THE MISSION

Parameter	To ISS, lb _m	From ISS, lb _m
Cargo Bay	30.937	0
Middeck	2,025	1,963
Totals		

1. **Water** – A total of 12 Contingency Water Containers (CWCs) were filled with 1129.8 lb_m of water and one Payload Water Reservoir (PWR) was filled with 19.5 lb_m of iodinated water.
2. **Oxygen** – No oxygen was transferred during the STS-119 mission.
3. **Nitrogen** – A total of 26 lb_m of nitrogen was transferred to the ISS Air Lock tanks.
4. **Lithium Hydroxide** – A total of five LiOH canisters were transferred to the ISS, and one canister was transferred to the Space Shuttle.
5. **Food** – The amount of food transferred to the ISS is included in the Middeck transfer totals.

SIGNIFICANT FIRSTS

The significant first for the STS-119 mission was the Boundary Layer Transition (BLT) Development Test Objective (DTO) that was performed to attempt to gather data during

entry regarding the aerothermal effects caused by the boundary layer transitioning from laminar flow to turbulent flow at a high Mach number.

SIGNIFICANT ISS ANOMALIES

During the scheduled ISS Treadmill with Vibration Isolation and Stabilization (TVIS) quarterly maintenance, it was discovered that the forward gyro wire rope was broken. Photographs were taken for assessment by ground teams. The wire rope was replaced and the TVIS operation was regained.

A hardware issue during the second EVA prevented the deployment of the P3 nadir Unpressurized Cargo Carrier Attachment System (UCCAS). Real time troubleshooting was unsuccessful and the associated timeline impact caused several tasks to be dropped from the second EVA. The UCCAS troubleshooting during the third EVA was also unsuccessful.

MAJOR ISS MISSION PRIORITIES AND END-OF-MISSION STATUS

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

ISS MISSION PRIORITIES COMPLETION STATUS

No.	Task	Flight Day Task Completed
Category 1 Tasks		
1	Rotate Expedition 18/19 FE-2 (ULF2) with Expedition 18 FE-2 (15A), transfer mandatory crew rotation cargo per Flight 15A Transfer Priority List (TPL) and perform mandatory tasks consisting of Individual Equipment Liner Kit (IELK) install and Sokol suit check.	FD 3
2	Configure ISS for Starboard (S) 6 Installation. <ul style="list-style-type: none"> a. Configure ISS power distribution and loads to support operations with no tracking of starboard Solar Alpha Rotary Joint (SARJ). b. Position and lock S3/SARJ at required S6 installation orientations. c. S4-1A/3A BGAs are to be positioned for operational constraints (including robotic clearances). 	IVA FD 5 FD 5 FD 5 FD 5
3	Perform Robotic operations in support of S6 unberthing and installation. <ul style="list-style-type: none"> a. Unberth S6 from the Shuttle Payload Bay using SSRMS b. Hand S6 off from SSRMS to SRMS c. MT translation to outboard worksite with SSRMS d. Hand S6 off from SRMS back to SSRMS for overnight park and installation 	Imagery FD 4 FD 4 FD 4 FD 4 FD 4

ISS MISSION PRIORITIES COMPLETION STATUS (Continued)

No.	Task	Flight Day Task Completed
4	Starboard 6 installation and deployment tasks <ul style="list-style-type: none"> a. S6 to S5 with Rocketdyne Truss Attachment System (RTAS) 4 of 4 bolts or corresponding contingency bolts to the minimum configuration to support subsequent visiting vehicle docking and undocking loads. b. Connect S5/S6 lower (nadir) and upper (Zenith) utility tray power umbilicals. c. Starboard 6 PVR un-cinch and un-winch. d. Prep S6 Solar Array Wings. e. SSU and Electronics/Environmental Control Unit (ECU) blankets. f. Activate S6 to minimal survival configuration. 	FD 5/FD 6 IVA/EVA Imagery FD 5 EVA/FD 5 FD 5 EVA FD 5 EVA FD 5 Ground FD 6
Category 2		
5.	Transfer mandatory quantities of water from the Orbiter to the ISS per Flight 15A Transfer Priority List (TPL)	IVA FD 5-FD11
6.	Transfer and stow critical cargo items to ISS per Flight 15A TPL	IVA FD4-FD10
7	Deploy S6 Photovoltaic Radiator (PVR). <ul style="list-style-type: none"> a. Configure ISS power distribution and loads to support locked S3/SARJ operations. b. Position and lock S3/SARJ at the PVR deployment position. c. Configure and deploy S6 PVR. d. Activate S6 thermal control system. 	IVA FD 5 FD 5 Ground FD 5 EVA FD 5 FD 6
8	Configure ISS, S3/S4 and deploy S6 (Channel 1B and 3B) Solar Array Wings (SAWs). <ul style="list-style-type: none"> a. Configure ISS power distribution and loads to support locked S3/SARJ operations. b. Position and lock S3/SARJ, and S6 Beta Gimbals for S6 SAW deployment. c. Position S4 Beta Gimbals for optimal S6/SAW viewing and command to position hold. d. Maneuver to required attitude and perform thermal conditioning of S6 SAWs. e. Deploy S6 1B and 3B SAWs. 	IVA/EVA FD 6 FD 6 FD 6 FD 6 FD 6 FD 6
9	Configure ISS for post S6 installation. <ul style="list-style-type: none"> a. Resume S4 Beta Gimbal Tracking. b. Begin S6 Beta Gimbal Tracking. c. Resume Starboard SARJ tracking within constraints of SARJ recovery strategy. d. Resume nominal power distribution and loads & configure to accept S6 power. 	IVA FD 6 FD 6 FD 6 FD 6 FD 6
10	Verify S6 1B & 3B SAW positioning capability to support docking and undocking operations for visiting vehicles.	IVA FD 6
11	Perform minimum crew handover of 12 hours per rotating crewmember which includes crew safety handover.	IVA FD 10
11.1	Remove Urine Processor Assembly-Distillation Assembly S/N 001	IVA FD 6
11.2	Perform PWD remediation and collect samples.	IVA FD 4

ISS MISSION PRIORITIES COMPLETION STATUS (Continued)

No.	Task	Flight Day Task Completed
11.3	Install Urine Processor Assembly-Distillation Assembly S/N 002 a. Remove and replace Recycle Filter Tank Assembly b. Perform initial functional checkout of Urine Processor Assembly-Distillation Assembly defined as a five minute dry spin-up including IWIS and HD audio/video data.	IVA FD 6 FD 7
11.4	Perform a minimum of one Urine Processor Assembly processing cycle including IWIS and HD audio/video data.	IVA FD 8
11.5	Collect WRS RIP and PWD Auxiliary port samples.	IVA FD 11
12	Relocate 1 CETA Cart to Starboard for Stbd-MT-Port Configuration	EVA FD 9 Robotics
13	P6 Battery preparation for Flight 2J/A.	EVA FD 7
Category 3		
13.1	Prepare and install JAXA Proximity Global Positioning System (GPS) antenna B on JLP (for HDTV.	IVA/EVA FD 7
14	Deleted	
15	Deploy S3 Upper Outboard PAS. (For Flight ULF3)	Deferred/ EVA
16	Deploy P3 Nadir Unpressurized Cargo Carrier Attachment System (UCCAS) site. (For Flight ULF3)	Incomplete EVA FD 7 and FD 9
16.1	Perform remaining high priority maintenance activities of the ROS systems after Progress 32P arrival.	FD 5 - FD 9
17	Perform ISS daily ISS payload status checks as required.	IVA FD 3 – FD 9
18	Perform ISS payload research operations tasks, Sortie experiments, and Short Duration Bioastronautics Investigations (SDBI). a. GLACIER MDK status checks b. ISS Integrated Immune c. Sleep Long d. JAXA Dome Gene Fixation e. ESA Low Back Pain – Muscle f. ESA Motion Perception g. Sleep Short (SDBI 1634) h. Integrated Immune (SDBI 1900) i. PCDF-PU MDK status checks	IVA FD 3 – FD 9
19	Transfer required N ₂ from the Orbiter to the ISS A/L HPGT. Required transfer quantities shall be consistent with the plan to have ISS A/L tanks full at Shuttle retirement.	IVA FD 8
20	Perform additional crew handover of 4 hours for rotating crewmember.	IVA Robotics Imagery

ISS MISSION PRIORITIES COMPLETION STATUS (Continued)

No.	Task	Flight Day Task Completed
21	<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> <ul style="list-style-type: none"> a. Release S6 Integrated Equipment Assembly (IEA) MicroMeteoroid Orbital Debris (MMOD) Cover. b. Remove and replace S0-1A-D RPCM. c. Deleted. d. Lubricate SSRMS LEE B Snares e. Z1 Patch Panel Reconfiguration f. Perform imagery survey of Port and Starboard HRS radiators using IR Camera and Digital Still Camera. g. Deploy S3 Lower Outboard PAS (For Flight ULF5) h. Deploy S3 Upper Inboard PAS (For Flight ULF5) i. Disconnect S1/S3 SSAS Umbilicals and Install Caps j. SPDM OCTM2 Wrap blanket rolled up to cover aluminum ground tabs (1.5 flaps remaining) k. SPDM EP1 Thermal Cover Removal l. Retrieval & relocation of Tool Stanchion (TS) to APFR no. 2 m. Reinstallation of APFR #4 to Airlock starboard tool box. n. SPDM Arm 2, SJEU flap 2.6, tack down remaining (2 of 4) o. SPDM Arm 2, wrist flap 2.6, tack down remaining flap (1 of 4) p. Install WVS External Transceiver Assembly (WETA) no. 3 at CP1 (S3 location) q. Remove S1 FHRC launch restraint bolts. r. Remove P1 FHRC launch restraint bolts. s. Connect P1-P3 NH3 contingency jumper. t. Connect S1-S3 NH3 contingency jumper. 	<p>EVA FD 5</p> <p>Deferred Deleted FD 9 (Not Complete) FD 7</p> <p>Imagery FD 7</p> <p>Deferred Deferred FD 9</p> <p>Robotics Deferred Robotics Deferred Deferred Deferred Deferred Deferred Deferred</p> <p>Partial FE 9</p> <p>Deferred Deferred Deferred</p>
Category 4		
22	<p>Perform program-approved EVA get-ahead tasks. The following EVA get-ahead tasks do not fit in the existing EVA timelines; however, the EVA team will be trained and ready to perform should the opportunity arise. EVA/Mission Operations Directorate (MOD) has the flexibility to select the tasks to be completed based on efficiencies gained in performing the already scheduled required tasks.</p> <ul style="list-style-type: none"> a. Remove the Grounding Tabs on the JEMRMS End Effectors (EE). b. Install shortened active CETA cart coupler c. APFR no. 5 Retrieval and relocation of TS to CETA Cart d. APFR no. 5 Reinstallation to external WIF e. Install insulating sleeves on Node 1 Forward SSPTS floating connectors. f. Install insulating sleeve on Channel 1/4 CR 8018 cable on S0. g. Deploy S3 Lower Inboard PAS (For Flight ULF5) h. Retrieve tool caddy from A/L ETSD 	<p>Deferred FD 9</p> <p>Deferred Deferred Deferred</p> <p>Deferred Deferred FD 9</p>

ISS MISSION PRIORITIES COMPLETION STATUS (Continued)

No.	Task	Flight Day Task Completed
23	<p>Perform Program-approved IVA get-ahead tasks. The following IVA get-ahead tasks do not fit in the existing IVA timelines; however, the IVA team will be trained and ready to perform should the opportunity arise.</p> <ul style="list-style-type: none"> a. Remove & Replace failed PROX GPS Data Cable in JPM and perform PROX/GPS initial checkout for B-String b. Tape ungrounded power connector in LAB1 Port-Deck 3 Standoff c. Repair TVIS Forward gyro wire rope 	IVA /Ground Deferred Deferred FD 5
24	Perform imagery survey of the ISS exterior during Orbiter flyaround after undock (obtain symmetrical view of all SAWs in either auto track or directed position).	IVA/Imagery FD 11
25	Reboost ISS with the Orbiter if mission resources allow and are consistent with ISS trajectory analysis and planning.	IVA/Imagery FD 9
26	Transfer O ₂ from the Orbiter to the ISS A/L HPGT. Required transfer quantities shall be consistent with the plan to have ISS A/L tanks full at Shuttle retirement.	IVA Deferred
27	Perform SDTO 13005-U, ISS Structural Life Validation and Extension, during S6 installation.	Ground FD 5 Data loss
28	Perform SDTO 13005-U, ISS Structural Life Validation and Extension, during Shuttle mated Reboost. (IWIS required). Rover (6th) accelerometer in Orbiter airlock only if crew time available).	IVA/Ground Imagery FD 9
29	Perform SDTO 13005-U, ISS Structural Life Validation and Extension, during 15A Orbiter Undocking (IWIS highly desired, but not required) (only if crew time available).	IVA/Ground FD 11
30	Perform SDTO 25007-U Spatial Differences in CO ₂ Concentrations on ISS (Part 2).	IVA Complete
31	Perform payloads of opportunity, Maui Analysis of Upper Atmosphere Injections (MAUI), Shuttle Exhaust Ion Turbulence Experiments (SEITE), and Shuttle Ionospheric Modification with Pulsed Localized Exhaust (SIMPLEX).	IVA/Ground FD 12

VEHICLE PERFORMANCE

LAUNCH DELAY

The STS-119 launch planned for February 12, 2009, was postponed to further develop flight rationale for the Flow Control Valve (FCV) hardware. The first launch attempt on March 11, 2009 was scrubbed because of Liquid Hydrogen (LH₂) leakage that exceeded the specification at the Ground Umbilical Carrier Plate (GUCP) during vent valve cycling. The GUCP is attached to the External Tank (ET) at its intertank.

The GUCP disconnect and seals were removed and replaced with a decision to launch on March 15, 2009, and reducing the mission content by 1 day and 1 EVA. This change was made because of the impending Soyuz launch.

SOLID ROCKET BOOSTERS

All Solid Rocket Booster (SRB) systems performed as expected during the launch-countdown and ascent of the STS-119 mission. No Launch Commit Criteria (LCC) or Operations and Maintenance Requirements and Specifications Document (OMRSD) violations occurred. One in-flight anomaly was identified during the review and analysis of the data.

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

During SRB recovery, at least one of the first stage 10-sec Delay Cutters did not function within the $\pm 10\%$ of the expected 8.87 sec minimum average delay time. The two 10-sec Delay-Cutters were installed on Left-Hand Main Parachute no. 3. Using onboard video and accelerometer data, the function time (cutting the reefing line) was determined to be within a range of 8.68 to 8.89 sec (IFA STS-119-B-001).

REUSABLE SOLID ROCKET MOTORS

The STS-119 Reusable Solid Rocket Motor (RSRM) set performed within established and predicted limits (nominal). No LCC or OMRSD violations occurred during the pre-launch and launch countdown. No in-flight anomalies were identified during the mission.

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 flexible bearing temperatures within the required LCC ranges.

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

EXTERNAL TANK

The initial launch attempt scheduled for March 11, 2009, was scrubbed with less than 20 min remaining in the ET tanking process to troubleshoot a leak in a gaseous hydrogen vent line (IFA STS-119-T-001). The official scrub time was 1:37 p.m. CDT. The tanking was halted after a leak was detected somewhere near the GUCP.

For the second launch attempt, all External Tank (ET) systems performed as expected during countdown and ascent. The ET pre-launch countdown was nominal. No LCC or OMRSD violations occurred during the pre-launch and launch countdown. No in-flight anomalies were identified during the mission.

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

ET separation was nominal. Since Main Engine Cut Off (MECO) occurred as expected, and the ET impact was at latitude 35.725 deg South and Longitude 157.564 deg West, which was within the predicted footprint.

SPACE SHUTTLE MAIN ENGINES

All Space Shuttle Main Engine (SSME) systems performed as expected during the launch countdown and ascent, and performance was typical of previous flights. The SSME pre-launch countdown was nominal, and no potential SSME in-flight anomalies were identified from the review and analysis of the data.

Engine "Ready" was achieved at the proper time, and no LCC or OMRSD violations were identified. The thrust build-up was nominal. The flight data indicates nominal SSME performance during startup, mainstage, throttling, and shutdown.

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

The commanded Maximum Dynamic Pressure (Max Q) throttle-down was a one step throttle to 72%, as predicted. The preliminary average SSME specific impulse tag value was 452.01 sec at 104.5% power level.

Propellant dump operations data were normal and the Main Engine Cutoff (MECO) time was Engine Start + 511 sec.

The review of the 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 dumping on all engines. All accelerometer measurements were healthy.

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 nominally during launch countdown and ascent, and one in-flight anomaly was identified from the review and analysis of the data. There was one Launch Commit Criteria (LCC) violation, which is discussed in a following paragraph.

During loading for the second launch attempt, 2 of the 4 plate-gap Differential Pressure (ΔP) measurements exceeded the minimum requirement of 0.026 psid. This LCC requires the verification that there is a positive pressure within the umbilical-cavity well. The ground-supply Helium pressure was increased, and all ΔP measurements remained above the minimum requirement for the remainder of prelaunch operations. There was no indication that the positive pressure was ever lost at the plate gap. A waiver was written to accept the momentary violation below the lower LCC limit.

The LH₂ pre-pressurization cycle count was 9 cycles, 14 cycles violates the LCC criteria. Engine inlet net positive suction pressure requirements were met throughout the flight. Pressurization performance was nominal indicating proper operation of the Flow Control Valve (FCV) hardware.

During main engine start and through ascent, the main engine 3 gimbal accelerometer was erratic, but did not affect ascent or the mission. Post-flight troubleshooting identified the problem as a loose connector on the Orbiter side (IFA STS-119-V-14)

Hazardous Gas Concentrations

The aft hazardous gas concentrations during loading were nominal. The overall Gaseous Hydrogen (GH₂) system in-flight performance was nominal. All three FCVs performed nominally with 26 cycles on FCV no. 1, 8 cycles on FCV no. 2 and 27 cycles on FCV no. 3.

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 E-3 mid-fuselage Helium supply temperature violated the minimum limit of minus 80 °F. The actual temperature was approximately 80.4 °F and the violation lasted for approximately 4 min. The temperature measurement is on the Helium tank and eventually gets mixed with substantially warmer aft Helium supply tanks (-37°F). This violation does not pose any concern for MPS hardware and no additional ground work is warranted.

Additionally, the Helium bottle temperatures exceeded the less-than 40 deg difference between measurements during the blow-down phase of entry. The purpose of the

requirement is to verify transducer accuracy and the measurements were within the 40 °F difference during ascent and while on-orbit.

The following table summarizes the results.

HAZARDOUS GAS CONCENTRATIONS AT LAUNCH

Parameter	Peak, ppm	Steady State, ppm
Helium	9400	6500
Hydrogen	85	10
Oxygen	16	3
LD54/55	0	0

Gas Sample Analysis

The measured sample bottle pressures indicate the redesigned Orbiter aft fuselage gas sampler system. The redesigned gas sampler system performed nominally. All six measured pressures were within the range of acceptable pressures established by the Propulsion Systems Integration Group (PSIG).

A summary of bottle pressure and gas concentration for STS-119 is given in the following table.

SUMMARY OF BOTTLE PRESSURES AND GAS CONCENTRATION

Bottle No.	Position	Pressure, psia	Helium, %	Measured Oxygen, %	Hydrogen, %
1	RH 1	3.92	0.66	2.04	0.05
2	LH 1	1.55	0.41	1.92	0.05
3	RH 2	1.50	0.83	1.31	0.10
4	LH 2	0.80	0.68	2.62	0.07
5	LH 3	0.17	1.89	1.36	0.24
6	RH 3	0.07	5.97	0.64	0.76

The Ascent Hazard Analysis indicates the maximum hydrogen firing leak rates in the following table.

HYDROGEN FIRING LEAK RATE SUMMARY

Bottle no.	Position	Hydrogen Firing Leak Rate, scim
1	RH 1	2710
2	LH 1	1320
3	RH 2	1160
4	LH 2	2550
5	LH 3	1070
6	RH 3	1470

The measured sample bottle pressures indicate the redesigned Orbiter aft-fuselage gas-sampler system successfully collected all six samples. STS-119 was the 12th flight using the new gas chromatograph/mass spectrometer at the Kennedy Space Center (KSC) Materials Science Laboratory.

The hydrogen concentrations were well below the flammability limit in each bottle. The highest estimated leak rate was 2710 scim from the right hand no. 1 bottle. The oxygen concentrations were well below the flammability limit. The highest concentration was 2.62 % in the left hand no. 2 bottle.

The highest Helium concentration was 5.97% in the right hand no. 3 bottle. 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.

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, %
1109 FLT-2	RH1	202.7	0.09	9.10	0.66	<0.01	<0.01	<0.01	1.91	2.04	0.05	0.05
1103 FLT-3	LH1	80.3	0.07	7.17	0.41	0.19	0.01	0.01	1.51	1.92	0.15	0.05
1113 FLT-2	RH2	77.6	0.05	4.82	0.83	<0.01	<0.01	<0.01	1.01	1.31	0.11	0.10
1104 FLT-3	LH2	41.2	0.09	9.85	0.68	<0.01	<0.01	0.01	2.07	2.62	0.07	0.07
1106 FLT-2	LH3	8.89	0.04	3.96	1.89	0.05	<0.01	0.02	0.83	1.36	0.27	0.24
1123 FLT-1	RH3	3.52	0.03	3.43	5.97	0.07	0.02	0.01	0.72	0.64	0.79	0.76

Purge, Vent, and Drain System

The Purge, Vent and Drain (PV&D) system performed nominally throughout the mission. The purge readings and hazardous gas detection system readings were nominal. No in-flight anomalies were identified during the analysis of the flight data.

During tanking, the LH₂ ET/Orbiter disconnect-cavity high-range pressure transducers no. 1 and no. 2 went below the Launch Commit Criteria (LCC) limit of 0.026 psid immediately after the last LH₂ tank-vent cycle during topping operations. Prior to the violation, the cavity pressure was approximately half of the nominal value based on analysis of the data from previous flights. The auxiliary supply line was activated and the pressures in the cavity rebounded to approximately 0.031 psid after raising the supply pressure from 132 to 140 psig. The team decided to increase the supply

pressure at the Main Launch Platform (MLP) to avoid any issues during the rest of the countdown.

The supply pressure was adjusted to 184 psi with a corresponding cavity pressure increase to approximately 0.065 psid. The cavity pressure remained constant and no further adjustments were needed. An LCC waiver was approved which allowed 2 of 2 low-range (high-fidelity) measurements to be used in place of 3 of 4 readings, essentially ignoring the high-range (lower-fidelity) measurements. Both of the low-range pressure transducers remained above the lower limit of 0.026 psid. The cavity pressure did not change from the adjusted numbers until the launch of the vehicle.

The post-landing purge was not initiated within 45 min of touchdown (occurred at 57 min). This condition was documented in a Data Trend Notice (DTN). The purge was initiated within 30 min (was 24 min) of the completion of the upper aft safety assessments.

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 in the review and analysis of the flight data, and it is discussed in a later paragraph in this 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, lb	1305	811	1523.	962	1523	962
Calculated, %	82.76	79.87	100.79	100.69	100.56	100.69
Advertised, %	1344.2	817.9	1527.1	961.4	1524.1	961.4
PASS WHI ^a	4.3441	4.2872	4.3471	4.2530	4.3478	4.2133
BFS WHI ^b	4.3513	4.2935	4.3616	4.2643	4.3623	4.2517

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 nominally with the exception of F4D which ripped on ascent, leaving a remnant attached to the thruster. Tyvek cover release speeds and vehicle alpha/beta angles at cover release are given in the following table.

Ground imagery showed that when thruster F4D's Tyvek rain cover released at 5.28 sec MET (63 mph), a 21 in. by 7.4 in. piece remained attached to the thruster lip (IFA STS-

119-V-08). This piece is believed to have separated by 17.3 sec MET (250 mph). Imagery shows that the piece did not impact the Orbiter. No vehicle/mission impacts ensued.

TYVEK COVER RELEASE TIMES, VELOCITIES AND ALPHA/BETA ANGLES

Cover	MET (sec)	Velocity (mph)	Alpha (deg)	Beta (deg)
F1D	4.1	50	-13	11
F2D	5.0	62	-11	10
F3D	5.2	65	-11	10
F4D ^a	5.3	65	-11	10
F1L	7.1	79	-13	9
F3L	7.1	92	-13	8
F1U	8.4	110	-10	7
F2R	8.7	115	-9	6
F1F	8.7	115	-9	6
F2F	9.2	122	-8	5
F3U ^b	9.6	128	-6	4
F2U ²	9.6	128	-6	4
F4R	10.0	134	-4	3
F3F	11.6	159	0	-2
REMNANT RELEASE DATA				
F4D	17.3	252	11	0

^a Partial release of F4D cover.

^b Release times are approximated as the lighting was inadequate to determine precise time of release (night launch).

The review of the imagery from the STS-119 flight failure determined that the F4D Tyvek cover tear with its subsequent late release of the cover remnants were similar with the post-STS-118 analysis, test, and flight rationale. However, while the F4D remnant released earlier than the data samples tested as part of the STS-118 analysis, the remnant was larger than samples tested during the analyses and the remnant released at a velocity greater than the 170 mph certification requirement for this location. The Program will continue to pursue fly-as-is rationale with the current Tyvek design, and in parallel, develop and certify a modified cover to be installed in F3D and F4D only.

The RCS window-protect firing of F1U, F2U and F3U was initiated at 074/23:45:48 GMT (00/00:02:04 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 windows during SRB separation.

The ET Separation maneuver was performed at 074/23:52:29 GMT (00/00:08:45 MET) and was a 8.0-second, 10-thruster translation. The ET Photographic +X firing was performed. The ET Photographic pitch maneuver was not performed.

The RCS maneuvers performed during the mission are shown in the following table.

RCS MANEUVERS AND FIRING DATA

Maneuver/Firing	Engine/System	Time of Ignition, GMT	ΔV , ft/sec	Duration, sec
RCS Window Protect	RCS	074/23:45:48	N/A	2.08
ET Separation	RCS	074/23:52:29	N/A	8.0
ET Photo +X	RCS	074/23:52:40	N/A	10.6
ET Photo Pitch	RCS	Not required		
NC3	RCS	076/03:15:48	2.7	12.0
NCC	RCS	Not required		
MC1	RCS	Not required		
MC2	RCS	076/19:32:34.7	2.4	10.3
MC3	RCS	076/19:49:35.2	0.170	0.760
MC4	RCS	076/19:59:34.7	1.2	5.1
Separation 1	RCS	084/21:08:27	N/A	6.32
Separation 2	RCS	084/21:36:27	N/A	12.08
RCS Hotfire	RCS	086/15:00:26		
Forward Reaction Control System Dump	RCS	087/18:24:03.2		25.9

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	3.6	48.6	2.5	33.8
Forward Fuel	0	0	-0.4	-3.4
Left Oxidizer	51.2	691	50.2	677.7
Left Fuel	49.8	423	50.0	425.0
Right Oxidizer	47.2	637	46.4	626.4
Right Fuel	45.8	389	45.5	386.8

Note:

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

The RCS propellant usage is shown in the following table.

RCS PROPELLANT CONSUMPTION

Parameter	Oxidizer, lb	Fuel, lb	Mixture ratio, Oxidizer/Fuel
Forward RCS	1083.4	682.3	1.59
Left RCS	682.9	430.9	1.58
Right RCS	731.2	469.1	1.56

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
	076/21:19:48	FREE DRIFT	Docking / ISS Capture
Orbiter	076/21:42:11	LVLH	
ISS	076/21:46:48	FREE DRIFT	
Orbiter	076/21:47:01	AUTO	
ISS	076/22:25:34	FREE DRIFT	
Orbiter	076/22:29:03	AUTO	
ISS	076/22:50:27	FREE DRIFT	
Orbiter	079/14:10:08	AUTO	
ISS	079/15:04:41	FREE DRIFT	
Orbiter	079/15:12:38	AUTO	
ISS	079/15:45:34	FREE DRIFT	
Orbiter	079/15:53:05	AUTO	
ISS	079/16:35:07	FREE DRIFT	
Orbiter	080/14:13:47	DAP AUTO –	Water Dump
ISS	080/17:01:28	FREE DRIFT	
Orbiter	080/18:39:04	LVLH	
ISS	080/18:40:33	FREE DRIFT	
Orbiter	080/18:40:44	AUTO	
ISS	081/00:03:47	FREE DRIFT	
Orbiter	081/19:55:58	LVLH	
ISS	081/19:56:32	FREE DRIFT	
Orbiter	081/19:56:42	AUTO	Maneuver to Undock attitude and back to TEA
Station	082/00:33:41	FREE DRIFT	
Orbiter	084/17:31:00	AUTO	
Station	084/18:28:53	FREE DRIFT	
Orbiter	084/18:31:42	AUTO	Maneuver to Undock attitude
Station	084/19:34:19	FREE DRIFT	for Logic configuration
Orbiter	084/19:36:12	AUTO	
Station	084/19:50:51	FREE DRIFT -	for Driver configuration
Orbiter	084/19:52:00	ALT/No Low Z	
-----	084/19:53:36	Undock	

During attitude hold for a water dump, the ISS accumulated ΔV in a posigrade sense which led to a debris conjunction concern. The debris conjunction concern drove a decision to perform a small deboost firing. The desired deboost was small enough (1 ft/sec), and as such it could be accomplished using the Vernier RCS attitude hold mode. The maneuver to the undock attitude required 41 min 44 sec. The Vernier RCS held attitude until the ISS could maneuver back to Torque Equilibrium Attitude (TEA).

The debris avoidance attitude-hold maneuver was successful in delivering approximately 1 ft/sec ΔV to the ISS in the retrograde direction.

Orbital Maneuvering System

The Orbital Maneuvering System (OMS) performed nominally and no in-flight anomalies were identified during the review and analysis of the data. The following table provides the OMS configuration data.

OMS CONFIGURATION

Vehicle/ Equipment	Flight	Orbital Maneuvering Engine (OME)	Ancillary data
Left Pod (LP) 01	39 th	L-OME S/N 115	6 th rebuilt flight - 21 st flight
Right Pod (RP) 03	37 th	R-OME S/N 106	10 th rebuilt flight - 34 th flight

The following table lists the OMS maneuvers performed during the STS-119 mission.

OMS MANEUVERS

Maneuver designation	Configuration	Time of ignition, GMT	Firing time, sec	ΔV, ft/sec
Assist	Dual Engine	074/23:45:59	88.3	N/A
OMS-2	Dual Engine	075/00:22:14.2	63.2	96.1
OMS-3 (NC1)	Dual Engine	075/03:18:23.4	64.9	100.7
OMS-4 (NC2)	Right Engine	075/16:41:41.2	11.2	8.3
OMS-5 (NH)	Dual Engine	076/16:13:13.3	67.9	105.5
OMS-6 (NC4)	Dual Engine	076/17:03:28.8	48.5	76.1
OMS7 (TI)	Left Engine	076/18:35:39.1	11.4	8.7
OMS-8 (SIMPLEX)	Dual Engine	086/20:15:43.4	11.8	21.5
(Deorbit)	Dual Engine	087/18:08:14.2	179.5	338.6

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

INTERCONNECT USAGE, %/POUNDS

Parameter	Total, %	Total, lb
Left OMS	1.791	231.95
Right OMS	1.899	245.93

The propellant usage during the STS-119 mission is shown in the following table.

PROPELLANT USAGE DATA

Parameters	Left OMS pod		Right OMS pod	
	Oxidizer	Fuel	Oxidizer	Fuel
Loaded, lbm	7051	4254	7050	4254
Residual, lbm (aft gage)	464	241	435	247
Residual, lbm (burn time integration)	338	185	442	197
Residual, lbm (SODB flow rate)	496	262	447	274

Auxiliary Power Unit System

The Auxiliary Power Unit (APU) system performance was nominal throughout the STS-119 mission. Three APU-related in-flight anomalies were identified from this mission, none of which impacted the mission. 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 (310)	00:21:05	00:05:50	01:02:56	01:29:51
2 (403)	00:21:28	00:00:00	01:28:54	01:50:22
3 (207)	00:21:53	00:00:00	01:03:23	01:25:16

APU FUEL CONSUMPTION

APU (S/N)	Ascent, lb	FCS Checkout, lb	Entry, lb	Total, lb
1 (310)	49	15	112	176
2 (403)	53	0	154	207
3 (207)	54	0	133	187

At 085/16:46 GMT (10/17:02 MET) the APU 2 fuel pump B heater-circuit primary thermostat began to dither. The fuel pump B heater circuit thermostat cycle range shifted from a 11.2 °F control band as measured by the bypass-line temperature reading to a 3.2 °F band (IFA STS-119-V-10). This condition did not impact the vehicle or mission, and no crew response or procedural change was required. This condition lasted for approximately one day before the control band returned to its original control band of 11.2 °F at 086/14:04 GMT (11/14:20 MET) after Flight Control System (FCS) checkout was performed with APU 1. As preventative maintenance that is the result of the high-vibration environment, the fuel-pump-circuit primary thermostats are removed and replaced whenever the control-band decreases below 7 °F.

During entry, the APU 2 Turbine Exhaust Gas Temperature (EGT) No. 1 exhibited erratic behavior before returning to normal after the APU was shutdown and during heat soak-back period (IFA STS-119-V-11). The EGT sensors are in a high-vibration high-temperature environment and have a history of failing by exhibiting an erratic signature.

During the entry between Terminal Area Energy Management (TAEM) and wheel stop, which is a higher APU loading period, the APU 3 Z-Axis Accelerometer readings were elevated with 96 total readings of Off Scale High (OSH), which indicates greater-than 100 G's Peak-to-Peak (IFA-STS-119-V-12). Evaluation of the data could not conclusively determine if this condition resulted from real vibration readings or a sensor anomaly. Historical data also showed that this particular APU has a history of higher vibration levels, though not at the level seen during entry of this flight. All of the OSH excursions were between 0.1 – 0.2 sec in duration. These excursions do not violate the Shuttle Operational Data Book (SODB) Volume 1 limit, (APU should not be operated for extended periods of time above 100 g's peak-to-peak in either axis).

Hydraulics/Water Spray Boiler System

The Hydraulic/Water Spray Boiler (HYD/WSB) system performance was nominal during the flight, and one IFA was identified.

All three WSB system cores were loaded with approximately 5.0 lb of the additive mixture [53% water; 47% Propylene Glycol Monomethyl Ether (PGME)]. Initial PGME/Water Tank loading for WSBs 1, 2 and 3 were approximately 133.8 lb. Nominal WSB performance was observed on all three systems during pre-launch and vehicle ascent. The WSB System 2 and 3 Vent Heater operated at 100% duty cycle due to ET cryogenic propellants loading effects.

The WSB lubrication oil temperatures during Ascent for spray cooling were as follows:

ASCENT WATER SPRAY BOILER TEMPERATURES AND PGME/WATER USAGE

WSB	Spray Start Temperature, °F	Steady State Temperature, °F	PGME/H₂O Usage, lb
System 1	249	249	3.4
System 2	257	255	3.1
System 3	255	253	3.6

Circulation pump 1 operated for 1 min 53 sec to perform Elevon Park following ascent. No circulation pump runs were required on-orbit for thermal conditioning or bootstrap re-pressurization.

WSB lubrication oil temperatures and quantity usage for entry are tabulated as follows.

ENTRY WATER SPRAY BOILER TEMPERATURES AND PGME/WATER USAGE

WSB	Spray Start Temperature, °F	Steady State Temperature, °F	PGME/H₂O Usage, lb
System 1	247	247	22.4
System 2	259	253	36.1
System 3	257	253	22.2

During the post-flight inspection, the Liquid Hydrogen (LH₂) ET/Orbiter umbilical forward inboard-retract-actuator was not in the fully retracted and locked position and this condition occurred after ET separation (IFA STS-119-V-13). This problem is undetectable during flight and the anomaly did not have an effect on the mission.

Power Reactant Storage and Distribution System

The OV-103 Power Reactant Storage and Distribution (PRSD) system performance was nominal during the STS-119 mission, and no in-flight anomalies were identified during the review and analysis of the data. The loading of the five PRSD tanks was completed on March 10, 2009 in preparation for the first launch attempt. The prelaunch reactant boiloff rate averaged 0.061 lb_m/hr-tank for hydrogen and 0.20 lb_m/hr-tank for oxygen.

The PRSD system supplied the fuel cells with 2211 lb_m of oxygen and 278 lb_m of hydrogen for the production of the electrical energy. Hydrogen (H₂) tanks 4 and 5 and Oxygen (O₂) tank 5 were depleted to residual quantities.

The tank quantities at the end of loading, the 352 lbm of O₂ off-loaded, launch, and landing are listed in the following table.

PRSD TANK QUANTITIES

Oxygen	Tank 1, %	Tank 2, %	Tank 3, %	Tank 4, %	Tank 5, %	Total Mass, lb_m
Loaded	101.8	102.2	100.9	101.4	101.8	3968
Off-loaded	92.6	92.6	92.6	92.6	92.6	3616
Launch	89.1	88.7	89.1	89.1	89.1	3476
Landing	33.5	41.8	47.5	12.9	6.3	1109
Hydrogen	Tank 1, %	Tank 2, %	Tank 3, %	Tank 4, %	Tank 5, %	Total Mass, lb_m
Loaded	101.8	102.3	102.8	102.3	103.2	471.4
Launch	92.6	91.7	93.1	93.5	93.9	427.6
Landing	44.0	56.4	55.5	4.2	2.0	149.1

The total oxygen supplied to Shuttle Environmental Control and Life Support System (ECLSS) was 156 lb_m. No oxygen was transferred to the ISS during this flight.

A 111-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 10.6 kW. At the mission extension day power level of 12.47 kW, a 95-hr mission extension was available.

Fuel Cell System

Fuel Cells

The overall performance of the OV-103 Fuel Cell system was nominal for STS-119. One in-flight anomaly was identified early in the mission and it did not impact the mission. The anomaly is discussed in a later paragraph.

The fuel cells were started for the first launch attempt on March 11, 2009. However, this launch attempt was scrubbed because of a leak in the ET hydrogen vent system and the fuel cells were shut down. The second start of the fuel cells was initiated on March 15, 2009.

The fuel cell Orbiter electrical power level averaged 10.6 kW and the total Orbiter load averaged 341 Amperes (A). When combined with the Station-to-Shuttle Power Transfer System (SSPTS), the Orbiter average electrical power level was 13.44 kW for the mission duration. During the 307.52-hr mission, the fuel cells produced 3272 kWh of electrical energy and 2490 lb_m of potable water. The fuel cells consumed 2211 lb_m of oxygen and 278 lb_m of hydrogen. Four fuel cell purges were performed, occurring at approximately 19, 133, 251, and 298 hr MET.

The actual fuel cell voltages (200 A load) at the end of the mission were 0.10 Vdc above the level predicted for fuel cell 1, 0.15 Vdc above the predicted level for fuel cell 2, and 0.10 Vdc above the predicted level for fuel cell 3. The voltage margins above the minimum performance curves at 200 A at the end of the mission were 1.22 Vdc above the minimum level for fuel cell 1, 1.06 Vdc above the minimum level for fuel cell 2, and 0.84 Vdc above the minimum level for fuel cell 3.

The Fuel Cell Monitoring System (FCMS) was used to monitor individual cell voltages within each fuel cell during prelaunch, on-orbit, and postlanding operations. Full-rate on-orbit data was recorded for 12 min, and no outliers were identified; however, "pin sharing" was observed on fuel cell 3, cells 95/96.

At 075/01:57:15 GMT (00/02:13:31 MET), the instrumentation for the fuel cell 3 Oxygen (O₂) flowmeter abruptly failed to an Off-Scale-Low (OSL) reading (IFA STS-119-V-01). The Mid Power Control Assembly (MPCA) no. 3 supplies power to the fuel cell 3 O₂ flowmeter and the circuit is protected by a 1-A fuse. The MPCA no. 3 load went down one bit (0.40 A) when the measurement went OSL. Ground troubleshooting was performed and fuel cell 3 was removed due to nearing Time-Between-Overhaul (TBO) and sent to the manufacturer for additional testing.

Station-to-Shuttle Power Transfer System (SSPTS) Operation

This was the third flight of SSPTS on OV-103. The system is activated when the Orbiter is docked to the ISS. The SSPTS transfers and converts power from the 120 Vdc ISS

electrical system to supplement fuel cell power to the Orbiter's 28-Vdc buses. The SSPTS supplied 861.5 kWh of power to the Orbiter while docked to ISS.

When set at maximum output, SSPTS regulates Orbiter bus voltage at approximately 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 reaching the 183.5 °F turn-on point during SSPTS operations.

Electrical Power Distribution and Control System

The Electrical Power Distribution and Control (EPDC) system performed nominally during all mission phases of STS-119. The data review and analysis of all available EPDC parameters identified no abnormal conditions.

The Station to Shuttle Power Transfer System (SSPTS) was used during the docked operations except during the EVA's. All SSPTS telemetry measurements were monitored in real-time and no issues were identified from the data.

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 (FPCA's) voltages and currents
6. Mid Power Control Assemblies (MPCA's) voltages and currents
7. Aft Power Control Assemblies (APCA's) 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 operations 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
15. Assembly Power Converter Unit (APCU) voltages and currents
16. Orbital Power Converter Unit (OPCU) voltages and currents
17. APCU and OPCU temperatures
18. MDCA motor switch statuses
19. APCU status bits and trips
20. OPCU trips

On two occasions, the ISS power transfer switch was closed to reactivate the SSPTS OPCU channel 2A. The OPCU Channel 2A telemetry remained off-scale low indicating no input power. This signature is indicative of a Power Transfer Unit (PTU) fault isolator

tripping. The channel 2A converter power was regained using the standard power cycle.

Following a power down for an Orbiter water dump, a second occurrence of the fault isolator tripping was observed. The OPCU 2A was again regained following the performance of the standard procedure.

During qualification testing it was determined that the OPCU fault isolators may experience nuisance trips at power up. Due to the low frequency of occurrence and the ability to regain via a power cycle, the program chose to accept the design as is. The Flight Controllers developed improved procedures that reduce the likelihood of fault isolator nuisance trips occurring. This procedure was performed, and the fault isolator nuisance trip did not recur. This is an explained condition.

Orbiter Docking System

The Orbiter Docking System (ODS) performed satisfactorily, and no in-flight anomalies 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 9 min 53 sec, and the avionics hardware was powered for 6 min. The system was ready for rendezvous and docking with the ISS.

The application of power for the docking activities was initiated at 076/20:45:38 GMT (01/21:01:54 MET), and the ODS was powered for 57 min 20 sec. The initial contact and capture of the ISS occurred at 076/21:19:50 (01/21:01:54 MET). The initial damping of 5 min 27 sec and performance of the “Disable and Release Dampers” procedure of 3 min 5 sec was necessary to ensure that any stuck dampers were disengaged. The start of the final drive was 076/21:28:37 GMT (01/21:44:53 MET) and lasted for 3 min 18 sec. The capture latches began release at 076/21:36:33 GMT (01/21:52:49 MET) and operated for 2 sec and at that time the docking was completed, and the ODS power was removed from the system.

In preparation for undocking, the ODS was activated at 084/19:25:11 GMT (09/19:41:27 MET). The undocking and separation from the ISS was completed satisfactorily at 084/19:53:26 GMT (09/20:09:42 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. No in-flight anomalies were identified from the review and analysis of the flight data.

Pressure Control System (PCS) 1 was configured and used for the entire mission through undocking. Following undocking, the PCS 1 was placed in the Auto mode and the checkout was successfully completed. The PCS 2 Gaseous Nitrogen (GN₂) 200-psi regulator operated nominally; however, the system was leaking approximately 0.04 psi/min, which was within the specification limit. The down-stream pressure peaked at approximately 268-psi with the down-stream Nitrogen/Oxygen (N₂/O₂) controller valve closed. The specification allowable leakage rate is 0.21 psi/min, therefore, no violation was noted. The PCS 2 N₂/H₂O tank regulator inlet valve was opened to bleed down the pressure in the line when the temperature was at the higher level.

An Orbiter-to-ISS N₂ transfer was performed and the final offload to the ISS was approximately 26 lb. No O₂ was transferred to the ISS during this mission. The Vestibule was leak-checked for docking and undocking operations. There were three Orbiter/ISS stack repressurizations performed prior to undocking using the Orbiter PCS. The re-pressurizations were performed by opening the payload N₂ valves with restrictors in the line that limited the flow to 7 lb/hr for better cabin-air mixing. One O₂ re-pressurization was performed prior to docking with the ISS.

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, structural and vestibule heaters cycled on all systems.

Supply and Waste Water System

The performance of the Supply Water and Waste Management Systems (SWWMS) was nominal throughout the mission and all of the scheduled in-flight checkout requirements were satisfied. No in-flight anomalies were identified from the review and analysis of the flight data. Supply water was managed through the use of the Flash Evaporator System (FES) and water transfer to the ISS.

One Portable Water Reservoir (PWR) dump was performed through the supply line. The line-heater maintained the supply water dump line temperature between 65 °F and 94 °F. One waste-water dump was performed as a simultaneous nozzle-dump at a nominal average rate of 1.88 %/min (3.11 lb/min). In addition, one Orbiter condensate bag was dumped through the waste line. The waste water dump line temperature was maintained between 60 °F and 90 °F throughout the mission.

A total of 12 Contingency Water Containers (CWC's) were filled with supply water and transferred to the ISS, for a total of 1129.8 lbm. In addition, 1 PWR of iodinated water containing 19.5 lbm was filled and transferred to the ISS.

The A and B supply water tank quantity sensors exhibited a quantity dropout many times throughout the mission. Such dropouts have been experienced during previous

flights and the problem was caused by either contamination on the collector bar and/or surface defect on the collector bar of the potentiometer, which causes an intermittent break in continuity. These dropouts are understood problems and do not impact the mission.

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

Smoke Detection and Fire Suppression System

Smoke Detection and Fire Suppression (SDFS) operated nominally with no issues. The smoke detector checkout was completed, and all smoke detection A and B sensor circuits passed the checkout requirements. Use of the Fire Suppression system was not required.

Active Thermal Control System

The Active Thermal Control System (ATCS) supported Orbiter and ISS operations nominally throughout the mission. No in-flight anomalies were identified during the review and analysis of the flight data.

The nominal configuration for operating the Flash Evaporator System (FES) was in Primary B during the first 18 hr of ISS docked operations. Thereafter, the FES was deactivated to support water accumulation for use in filling CWC's during the remainder of the docked phase.

At 077/15:17 GMT (02/15:33 MET), the Water Coolant Loop (WCL) 2 bypass valve was configured from the auto mode to the manual mode to satisfy an ISS pre-flight request to increase humidity in the Orbiter and ISS. In the manual bypass valve mode, the crew set the Interchanger Heat Exchanger (ICHX) flow rate to about 1,300 lb/hr to increase the inlet temperature of the water into the cabin heat exchanger, thereby reducing condensate collection at the cabin exchanger. Then at 084/17:23 GMT (09/17:39 MET), the WCL 2 bypass valve was returned back to the auto mode as part of end-of-docking-phase operations.

The Carbon Dioxide (CO₂) levels were maintained below 5 mm Hg as part of nominal Lithium Hydroxide (LiOH) canister changeout schedule. The crew reported daily that air quality during pre-docked, docked, and post-dock days was good and they made no reports on CO₂ symptoms. Three expired Russian LiOH canisters were used on the ISS side for some of the docked days and that activity still resulted in manageable CO₂ levels for the ISS. The Personal Computer-Based Thermal Analyzer Program (PCTAP) math modeling of the Russian LiOH canister performance matched well against flight data.

The Ammonia Boiler System (ABS) B primary controller was activated post-landing at 087/19:20 GMT (12/19:36 MET) and continued for approximately 41 min. The ABS system A primary controller was activated when ABS B was deactivated. ABS

operation on system A continued for approximately 6 min. The start of ground cooling activation inadvertently occurred at approximately 3 min before system A was deactivated. The Ground Support Equipment (GSE) worked in concert with the ABS A controller for the overlapping period and kept the Orbiter Freon system temperature at the GSE pre-set temperature of 39 °F. When the ABS A system was shut down, the GSE then took full Orbiter temperature control and maintained the system at the adjusted temperature of 48 °F.

Flight Software

The Primary Avionics Software System (PASS) and Backup Flight System (BFS) Flight Software (FSW) performed satisfactorily, and no in-flight anomalies were identified from the review and analysis of the data.

During crew ingress, the GPC 5 mode switch on Panel 06 was inadvertently taken to the "HALT" position while in the Operations (OPS) mode, resulting in the halting of the BFS General Purpose Computer (GPC) and the loss of the downlist. The BFS was recovered and returned to nominal operation 10 min later when the GPC 5 mode switch was restored to the Stand-By position. The effect of the switch sequence in OPS 0 is that the BFS performed a system reset, which resulted in the resetting of the GPC, the Input/Output (I/O) Error Logs, GPC internal time and re-annunciation of any alarm conditions that exist. Following the system reset, BFS annunciated seven additional Fault Summary messages, all of which were expected. Post-launch, a short test of the switch operation was performed in the Shuttle Avionics Integration Laboratory (SAIL) and the test determined that the lock/detent is present only in the RUN position. This condition exposes the BFS to the possibility that the switch could be bumped to HALT from the Stand-By position. No adverse affects on the BFS resulted from the condition.

Data Processing System Hardware

The data review and analysis of the Integrated Data Processing System (DPS) parameters show that the DPS performed nominally, and no in-flight anomalies were identified for the analysis.

Multifunction Electronic Display System

The Multifunction Electronic Display System (MEDS) hardware and software performance was nominal throughout the mission, and no in-flight anomalies were identified from the review and analysis of the data. A change was made to the MEDS software for this mission in the manner that the software cyclically read data and displays.

During On-Orbit operations, there were three instances of a violation of the SODB concerning the Integrated Display Processor (IDP) power cycles. No negative performance resulted from these short IDP power cycles, but repeated violations have

the potential to reduce the IDP's Mass Storage Unit (MSU) life due to cumulative wear and damage to MSU heads and/or media.

Displays and Controls System

The Display and Controls (D&C) system performed nominally throughout the mission, and no in-flight anomalies were identified.

At 077/15:24 GMT (02/15:41 MET), the crew reported that the Waste Management Compartment (WMC) flood light went from bright to dim. The light is a 16.5 W fluorescent flood light through a 3A circuit breaker. Data did not show any signs of a short. The crew cycled the switch multiple times but the light stayed dim. At 077/17:10 GMT (2/17:26 MET), the crew reported that the WMC flood light had completely failed. The switch was turned to the OFF position for the remainder of the mission.

Flight Control System

The Flight Controls System (FCS) performed nominally throughout the mission. No in-flight anomalies were identified from the review and analysis of the data.

The FCS hardware/effector systems performed nominally. At all times, the SRB Thrust Vector Controller (TVC), Main Propulsion System (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 each other normally, and no Spin Motor Rotation Detector (SMRD) dropouts were noted. The outputs of the four Accelerometer Assemblies (AAs) also tracked each other normally. The Reaction Jet Driver (RJD) operation was also normal with no thruster failures or other anomalies noted. The 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. Rudder/Speed Brake Power Drive Unit (RSB PDU) motor backdrive did not occur during hydraulic system shutdown.

During entry, the pre-Time of Ignition (TIG) Orbital OMS gimbal profile was as expected with the OMS actuator active and standby channels reaching nominal drive rates. All actuator positions closely tracked General Purpose Computer (GPC) commands. Entry hydraulic system temperatures were nominal with aerosurface actuator temperatures being within the normal limits. The MPS TVC actuator positions and GPC commands followed each other closely.

Air Data Transducer Assembly

The Air Data Transducer Assemblies (ADTAs) performed nominally and no in-flight anomalies were identified from the review and analysis of the flight data.

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

During the FCS checkout, the ADTAs power-on and self-tests were performed with no anomalies. All 16 transducer outputs showed nominal responses.

During entry, all 16 transducers tracked during the pre-probe deployment phase of entry. Air data probes were deployed at approximately Mach 4.7, and deployment timing was within specification at less than 15 sec. ADTA data were incorporated into Guidance, Navigation, and Control (GN&C) at about Mach 2.5. No ADTA dilemmas or Redundancy Management (RM) failures occurred during deployment through wheels-stop.

Inertial Measurement Unit and Star Tracker System

The Inertial Measurement Unit (IMU) system performed nominally throughout the mission. One adjustment was made to the onboard IMU's accelerometer compensation values. In addition, two adjustments were made to the IMU drift compensation values.

The Star Tracker (ST) performance was nominal throughout the STS-119 mission. However, one problem was noted on the -Z ST and it is discussed in the following paragraph.

The -Z ST annunciated a pressure-fail Built-In Test Equipment (BITE) 084/18:10 GMT on the Image Dissector Tube (IDT) and the BITE remained on for the remainder of the mission. The annunciation was accompanied by a tracker-good fail BITE. This is an understood problem with the ST's.

Global Positioning System Navigation

Overall, the one-string Global Positioning System (GPS) performed nominally and no in-flight anomalies were identified from the analysis of the data.

Power was applied to the GPS at 074/18:34:36 GMT, approximately 5 hr 9 min prior to launch and the GPS remained on for the mission duration. During entry, the GPS high Figure of Merit (FOM) period usually encountered in the Plasma region cleared well before the GPS was incorporated into the navigation system. The FOM varied between 1 and 3 after GPS incorporation. 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.

The GPS state vector was incorporated into both the Primary Avionics Software System (PASS) and Backup Flight System (BFS) in Major Mode (MM) 304 after the performance confirmation was completed with the high-speed C-band tracking. This occurred at approximately 147,000 ft altitude, and simultaneously with the instruction to incorporate Tactical Air Command and Navigation System (TACAN's). The effect was that the PASS and BFS navigation-state-vector residuals were reduced significantly, as expected. The PASS navigation state vector residuals remained consistently low from GPS incorporation down to the Microwave Landing System (MLS) incorporation (approximately 16,000 ft) where the PASS automatically stops taking GPS updates per design. Likewise, the BFS navigation state vector residuals remained consistently low from GPS incorporation all the way through rollout as designed.

Communications and Tracking System and Navigation Aids

The Communications and Tracking systems performed nominally. Likewise, the Navigation Aids (NAV AIDS) performed nominally. No In-flight anomalies were identified from the review and analysis of the data.

During the NAVAIDS Self-Test in the OPS 8 operational mode, the Radar Altimeter 2 displayed an out-of-tolerance altitude value of 1961 ft with an up-arrow (out-of-limits high) on the onboard monitor. The crew reported that for approximately the first 5 sec, the altitude data was indicating 980 ft and the value should be 900 to 1100 ft.). The value then changed to 1961 ft until the crew executed a command to terminate the test about 40 sec later. The downlisted data remained good (980 ft) for the duration of the test.

This is a known signature with the Radar Altimeter in that an occasional one bit shift of the output word occurs due to a timing issue between the hardware and the Multiplexer/Demultiplexer (MDM). The one bit shift results in an altitude reading, which is double the actual value. This occurs for one sample only. The General Purpose Computer (GPC) was reading the altimeter data at 6.25 Hz. The crew display is updated at one sample per second and the downlist also operates at one sample per second but the two are not on the same cycle. The onboard software reads the radar altimeter data 19 sec after the test is initiated and if an out-of-tolerance condition exists then the data is latched. As it turned out, the data read after 19 sec coincided with an instance of the bit shift in the output word. Since the downlist is on a different cycle this was not seen on the ground. A nearly identical situation was documented in Kennedy Space Center (KSC) Interim Problem Report (IPR) in 1989. Radar Altimeter 2 performance during approach and landing was nominal.

Operational Instrumentation/Modular Auxiliary Data System

The Operational Instrumentation (OI), including the Pulse Code Modulation Master Unit (PCMMU), Payload Data Interleaver (PDI), Master Timing Unit (MTU), performed

nominally. One in-flight anomaly was identified during the mission or after review of the mission data.

The Modular Auxiliary Data System (MADS) PCM ascent data was recorded on the Solid State Recorder and downlinked to the ground for in-flight analysis. Post-flight, the MADS PCM data recorded on the Solid State Recorder was reviewed and no problems related to the MADS PCM unit were identified.

During ascent, the MADS PCM Base Heat Shield External Pressure Sensor measurement stepped to Off-Scale-Low (OSL) and remained OSL during entry to wheel stop (IFA STS-119-V-05). The cause was attributed to a connector which demated due to the launch environment.

The APU 2 Turbine Exhaust Gas Temperature (EGT) No. 1 transducer became erratic during entry at 081/18:51:38 GMT (12/19:07:54 MET) and remained erratic throughout the rest of entry (IFA STS-119-V-11). Approximately 43 min after landing, the EGT measurement suddenly recovered and trended according to the expected temperature profile. Because of the long history of EGT sensor failures and their lack of problem impact/significance, the Space Shuttle Program documents these for trending purposes only.

During the higher APU loading periods of entry between Terminal Area Energy Management (TAEM) and wheel stop the APU 3 Z-axis accelerometer readings were elevated with a total of 96 peak readings (greater than 100 G peak to peak) of off-scale high (OSH) (IFA STS-119-V-12). All of the OSH excursions were between 0.1 and 0.2 sec in duration.

During main engine start and through ascent, the main engine 3 gimbal accelerometer was erratic as reported by the Marshall Space Flight Center (MSFC). Post-flight testing identified the problem as being in the Orbiter side and troubleshooting identified the problem as a loose connector (IFA STS-119-V-14).

Mechanical and Hatches System

All mechanical and hatch systems performed nominally, and no in-flight anomalies were identified from the review and analysis of the data.

The mechanical systems were active during ascent. Post-insertion, the ET door closing and star tracker door opening were satisfactory. In preparation for entry, the star tracker closure and vent door repositioning were satisfactory. During entry, the vent doors repositioning for Entry Interface (EI) and post-EI was normal. The Air Data probe deployment was normal.

Post-landing, the ET door opening and vent door repositioning on the runway was nominal.

Landing and Deceleration System

The Landing and Deceleration System performance during STS-119 was nominal. The nose landing gear tires used on this mission had flown on a previous flight. The nose gear tires were in good condition considering second landing usage and performance was nominal. The main landing gear tires also appeared nominal. The inspection showed the normal appearance of tread cord materials on areas of the tire's surface, and this condition is a known and expected characteristic of the new tire design.

The parachute performance was nominal. It was first reported from video imagery and later verified during the post-flight inspection that there was a hole in the canopy area of the chute. The inspection revealed that four ribbons were torn at locations 22 through 25 in gore 7. A more detailed review of slow motion video imagery supported the conclusion that the most probable cause of the torn ribbons was due to higher-than-normal turbulence was experienced during the deployment. This is type of damage is not unexpected and repair of the ribbons will be made at the refurbishment facility.

The following table presents the landing parameters for the STS-119 mission.

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	2792.2	087/19:13:25.022	203.3	188.2	-2.14	N/A
Drag Chute Deployment	4020.0	087/19:13:29.265	187.5	173.3	-	-
Nose Landing Gear Touchdown	5366.7	087/19:13:34.062	167.6	152.1	-	-5.81
Drag Chute Disreef	5830.4	087/19:13:35.011	146.4	140.6	-	-
Drag Chute Jettison	9321.5	087/19:13:58.649	73.2	59.6	-	-
Brakes On	11407.9	087/19:14:23.863	OSL ^b	39.9	-	-
Wheels Stop	12129.8	087/19:14:43.100	0.0	0.0	-	-
Parameter			Data			
Brake Initiation Speed, keas			OSL ^b			
Brake On Time, sec			19.24			
Rollout Distance, ft			9337.6			
Rollout Time, sec			78.08			
Runway Location, Surface and Degrees			KSC/15 Concrete			
Orbiter Weight at Landing, lb			201906.5			
Parameter	Maximum Brake Pressure, psia		Total Brake Energy, Mft/lb			
Left inboard	647.7		3.77			
Left outboard	686.5		3.82			
Right inboard	582.6		3.35			
Right outboard	450.1		1.63			

^aKnots equivalent air speed ^bOff-scale-low

Aerothermodynamics, Integrated Heating and Interfaces

Inspection of the overall Orbiter Thermal Protection System (TPS) indicated normal heating. The lower structural temperature data indicated normal entry heating. The recorded structure temperatures are within the flight experience of OV-103. However, the sensor at location S4 ($T_{\max} = 77.9$ °F) experienced the most temperature rise for the OV-103 vehicle. The Modular Auxiliary Data System (MADS) data showed that the Boundary Layer Transition (BLT) was asymmetric. The BLT on the right side of the vehicle occurred around Mach 10.5 and the BLT on the left side of the vehicle, except for an area downstream of the BLT Flight Experiment (FE), the transition occurred around Mach 7.8. For location inside the turbulent wedge of the BLT FE protuberance site, the inception of transition occurred around Mach 15.8 and the effective transition occurred near Mach 13.1. No significant slumping or erosion of the BLT protuberance was noted and all of the TPS behind the protuberance looked nominal.

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)	135.1	124
Lower fuselage forward left-hand (B2)	179.8	168.7
Lower fuselage forward mid left-hand (B3)	156.1	162.8
Lower fuselage mid center (B4)	156.1	162.8
Lower fuselage mid aft center (B5)	179.8	178.9
Lower fuselage aft center (B6)	177.2	153.3
Left-wing center (LW)	122	131.3
Right wing center (RW)	119.4	138.9
Port side FRCS forward (P1)	166.6	140.2
Port side fuselage forward center (P2)	111.6	98
Port side fuselage forward mid center (P3)	101.2	90.1
Port side fuselage mid aft center (P4)	83	79.6
Port side fuselage aft center (P5)	93.4	64.4
Starboard side FRCS Forward (S1)	166.6	137.7
Starboard side fuselage forward center (S2)	116.8	133.7
Starboard side fuselage forward mid center (S3)	96	87.5
Starboard side fuselage mid-aft center (S4)	77.9	92.2 ^b
Starboard side fuselage aft center (S5)	75.3 ^a	69.3 ^a
Left-hand OMS pod side forward (LP)	83	61.7
Right-hand OMS pod side forward (RP)	70.1 ^a	43.7 ^a
Lower body flap center	103.8 ^a	77.4 ^a
Right-hand PLBD forward	75.3 ^a	122.5 ^a
Left-hand PLBD forward	75.3 ^a	109.9 ^a
Right-hand PLBD aft	83	122.7

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

Thermal Sensor Location	Maximum Temperature, °F	Maximum Temperature Rise, °F
Left-hand PLBD aft	80.5 ^a	110.0 ^a
Right wing upper center	93.4 ^a	117.9 ^a
Left wing upper center	98.6 ^a	107.9 ^a
Forward RCS center	98.6 ^a	77.3 ^a
Forward Fuselage Upper Center	75.3	92.2

Notes

- ^a Maximum temperature occurred 30 min after wheel stop.
- ^b Maximum temperature ever experienced on the OV-105 vehicle.

Thermal Control System

The passive Thermal Control System (TCS) performed nominally during the STS-119 mission, and all temperatures were maintained within acceptable limits. One in-flight anomaly was identified from the review and analysis of the data.

The B system thermostat on the APU 2 Fuel Bypass Line of OV-103 was dithering (IFA STS-119-V-10). The thermostat will be replaced prior to the next flight of this vehicle.

All heater systems performed normally. The new APU 1 and 2 GN₂ heaters were effective in warming the Quick Disconnects (QD's) based on the Tempasure label indicators that were installed on the QD caps. The labels indicated that the APU 1 and 2 QD's remained above 32 °F while the unheated APU 3 QD minimum was between +23 °F and -4 °F.

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	76
Upper Surface/Window	1	23
Right OMS pod	2	10
Left OMS pod	0	10
Totals	11	119

A post landing walk-down of the runway was performed. The flight hardware found included a rudder speed-brake clip and a temperature-sensor strip.

All components of the drag chute were recovered. The drag chute hardware and components appeared to have functioned nominally. Both reefing-line-cutter pyrotechnic devices were expended.

Tire material loss on the main landing gear and nose landing gear tires was nominal.

The nose landing gear door and the Main Landing Gear (MLG) doors did not have any corner tile chips.

The Orbiter nose cap appeared to be in nominal condition, as well as Left-Hand (LH) and Right-Hand (RH) Reinforced Carbon-Carbon (RCC) panels.

The SSME Dome Mounted Heat Shield (DMHS) blankets all appeared to be in excellent condition, with a very low amount of fraying. A stub tile below SSME 2 was broken off.

The retaining device on the External Tank/Orbiter (EO) -3 salad bowl was not fully closed. The EO-3 also had 2 clips bent around the perimeter. The LH₂ umbilical had some white Room Temperature Vulcanizing (RTV) material on the inboard aft perimeter.

Window no. 2 had some hazing in the upper outboard corner. Window no. 3 appeared to have two small dings or smudges. Window no. 4 appeared to have 2 small dings or smudges. Window no. 5 has some hazing on the upper side.

Tile and Blanket Flight Assessment

The overall performance of the TPS was satisfactory.

A total of 10 Thermal Protection System (TPS) items were identified that exceeded pre-defined screening criteria and were entered into the TIIMS Database. Seven items were cleared using standard procedures/tools, and two items required additional analysis; neither of which caused any impact to the mission (IFA STS-119-V-06).

The Tile and Blanket Damage Assessment Team (DAT) assessment of imagery from the FD 2 inspections and FD 3 RPM determined that no Focused Inspection (FI) was required for TPS tile or blankets.

RCC Flight Assessment

The RCC performed satisfactorily with no in-flight anomalies identified in the review and analysis of the data.

Windows

The windows performed satisfactorily. Two windows (W6 and W7) were not acceptable for reflight because of hypervelocity impacts. The remaining seven windows (W1 through W5 and W8 and W11) were cleared and acceptable for the next flight.

Waste Collection System

The Waste Collection System operated nominally; however, the crew reported that the overhead light in the Waste Management Compartment had failed off. The crew used a drag-on light for the remainder of the mission.

EXTRAVEHICULAR ACTIVITY

During the STS-119/15A mission, three Extravehicular Activities (EVAs) were performed to install the S6 Truss Element and perform several other tasks to support future missions. A fourth EVA was originally planned but was deferred to stage operations following the launch slip to reduce mission timeline due a Soyuz launch. The total duration of the three EVAs was 19 hr 04 min.

FIRST EXTRAVEHICULAR ACTIVITY

The first EVA was performed on Flight Day (FD) 5 (March 19, 2009) by the Extravehicular (EV)1 crewmember (Steve Swanson) and the EV2 crewmember (Richard Arnold), and the total time of EVA 1 was 6 hr and 7 min. The EVA started at 12:16 p.m. Central Daylight Time (CDT). The major focus of the EVA was the installation of the S6 Truss. The following tasks were completed to meet the launch-to-activation criteria:

1. Attachment of the Starboard (STBD) 6 to the S5 Truss;
2. Release of the Capture Latch Pre-Load;
3. Mate the two Power umbilicals and the two Data umbilicals between the S6 and S5 truss;
4. Release the torque of the four S6 Micrometeoroid/Orbital Debris (MM/OD) shield bolts;
5. Rotation of the S6 Keel Pin;
6. Release of the Zenith and Nadir Solar Array Blanket Box (SABB) launch restraints;
7. Actuation of the photovoltaic radiator cinches and winches;
8. Release of the SABB wing Beta Gimbal Assembly (BGA) restraints;
9. Deployment of the Mast Canisters and the Nadir and Zenith Solar Array Wings;
10. Release of the Nadir and Zenith Solar Array Mast Tip Fastener tips;
11. Jettison of the Nadir and Zenith Solar Array Mast Canister Electronics Control Unit (ECU) Multi-layer Insulation (MLI), and
12. Jettison of the Sequential Shunt Unit (SSU) Multi-Layer Insulation (MLI).

SECOND EXTRAVEHICULAR ACTIVITY

The second EVA was completed on FD 7 (March 21, 2009) by the EV1 crewmember and the EV3 crewmember (Joseph Acaba). The duration of the second EVA was 6 hr and 30 min. The EVA started at 11:44 a.m. CDT. The following tasks were completed:

1. Break the torque on six batteries to begin the Port (P) 6 battery preparation task;
2. Install the two gap spanners on P6;
3. Install the Articulating Portable Foot Restraint (APFR) in Worksite Interface Fixture (WIF) no.10;

4. Install a Global Positioning System (GPS) antenna on the Japanese Experiment Logistics Module-Pressurized Section (JLP) while the EV3 crewmember took digital and Infrared (IR) imagery of the P1 and S1 radiators.

Both crew members were unable to fully deploy the P3 Unpressurized Cargo Carriers Attachment System (UCCAS) because the detent parking interface was sticking. The crew members tied down the UCCAS to leave it in a safe configuration and moved on to complete other tasks.

The EV1 crewmember attempted to reconfigure the avionics connectors on the Z1 patch panel. Crewmember EV1 was unable to actuate the bail lever and due to time limitations was unable to execute the contingency plan to actuate the bail lever and reconfigure the avionic connectors. However, attempts were also made on previous missions to actuate the Z1 avionic connector bail-lever, but were unsuccessful.

Because of the extra time used to troubleshoot the UCCAS deployment, the planned S3 Outboard/Zenith Payload Attachment System (PAS) deployment and the Z1 Patch Panel reconfiguration tasks were not completed.

THIRD EXTRAVEHICULAR ACTIVITY

The third EVA was performed on FD 9 (March 23, 2009) by the EV2 and EV3 crewmembers. The task list for the EVA was re-planned to allow a second attempt to deploy the P3 UCCAS. The EVA started at 10:37 a.m. CDT. The duration of the third EVA was 6 hr and 27 min. The following tasks were completed:

1. The EV2 and EV3 crewmembers relocated the Crew and Equipment Translation Aid (CETA) Cart from the Port to the Starboard position to prepare for the next mission.
2. Following the CETA cart relocation, a CETA Cart Coupler was installed as a get-ahead task.
3. The EV2 crewmember performed a lubrication task on the Space Station Remote Manipulator System (SSRMS) Latching End Effector (LEE) side B snares.
4. The EV3 crewmember performed the S1/S3 Segment-to-Segment Attach System (SSAS) patch panel reconfiguration and then performed a get-ahead task to release the S1 Flexible Hose Rotary Coupler (FHRC) Outboard Zenith Tray P-Clamps 5 and 6.

Both crew members then attempted to deploy the P3 UCCAS without success because the detent pins would not release. Another task not completed due to re-planning of the third EVA included the S3 Outboard/Zenith PAS deployment and the Z1 Patch Panel reconfiguration.

REMOTE MANIPULATOR SYSTEM AND ORBITER BOOM SENSOR SYSTEM

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

On Flight Day (FD) 1, the SRMS On-Orbit Initialization began at 075/02:41 GMT (00/02:41 MET). The port and starboard Manipulator Positioning Mechanisms (MPMs) were deployed and the SRMS shoulder brace was released. The SRMS checkout began at 075/03:42 GMT (00/03:42 MET) and was completed successfully 47 min later.

On Flight Day 2, the SRMS was maneuvered to the Orbiter Boom Sensor System (OBSS) Pre-Grapple position at 075/17:02 GMT (00/17:18 MET). The SRMS started the OBSS unberthing to the hover position began at 075/17:19 GMT (00/17:35 MET). The Thermal Protection System (TPS) surveys began at 075/17:57 GMT (00/18:13 MET) and were completed at 076/00:05 GMT (01/00:05 MET). In addition to the inspection of the Starboard and Port Wing Reinforced Carbon-Carbon (RCC), inspections were also performed of the Starboard and Port T-0 Umbilical areas of the Orbiter. When the inspections were completed, the OBSS was re-berthed and the SRMS was maneuvered to the Pre-Cradle position.

On FD 3, the Orbiter (Discovery) docked with the International Space Station (ISS) with the SRMS in the Pre-Cradle position.

On FD 4, the SRMS was maneuvered to the S6 Unberth Viewing position at 077/14:56 GMT (02/15:12 MET) and provided viewing support while the Space Station Remote Manipulator System (SSRMS) grappled and unberthed the S6 Truss. The SSRMS then handed the S6 to the SRMS at 077/17:39 GMT (02/17:55 MET). After the handoff, the SSRMS relocated to Mobile Base System (MBS) Power and Data Grapple Fixture (PDGF) 1 and the Mobile Transporter (MT) was translated from Worksite 6 to Worksite 1. The SRMS then maneuvered the S6 Truss to a position where it was handed back to the SSRMS at 077/22:24 GMT (02/22:55 MET). The SSRMS was maneuvered to an overnight park position and the SRMS was maneuvered to the S6-Install viewing position.

On FD 5, the SSRMS maneuvered the S6 Truss to the Installation position at which point the Extravehicular Activity (EVA) crew performed the final steps to permanently attach the S6 to the ISS. After the S6 Truss installation, the SRMS was maneuvered to the Solar Array Wing (SAW) 1B Deployment viewing-position at 079/00:01 GMT (04/00:17 MET).

On FD 6, after the SAW 1B array was deployed, and the SRMS was maneuvered to the SAW 3B Deployment viewing-position at 079/16:01 GMT (079/16:01 MET). At the end of the day, the SRMS was maneuvered to the Pre-Cradle position.

On FD 9, at 082/14:17 GMT (07/14:33 MET), the SRMS was maneuvered to the Crew and Equipment Translation Aid (CETA) Cart Relocation viewing position in preparation for the third EVA. The SRMS was maneuvered back to the Pre-Cradle position after the completion of the EVA.

Discovery undocked on FD 11 and no SRMS operations were performed that day.

On FD 12, the SRMS was used to perform the Late Inspection of the Orbiter TPS. The SRMS was maneuvered to the OBSS Pre-Grapple position at 085/13:10 GMT (10/13:26 MET). The SRMS started the OBSS unberth to hover position 24 min later. The TPS surveys began at 085/14:02 GMT (10/14:18 MET) and were completed at 085/19:00 GMT (10/19:16 MET). The SRMS berthed the OBSS 13 min later and the RMS was cradled and latched at 085/20:09 GMT (10/20:25 MET), and the MPMs were stowed 7 min later.

WING LEADING EDGE IMPACT DETECTION SYSTEM

ASCENT MONITORING

Ascent summary data downloads began at 5:26 hr MET. All ascent summary files were downlinked and received by 10:51 hr MET. However, at 6:00 hr MET, all ascent download commands on the Wing Leading Edge Impact Detection System (WLEIDS) primary laptop timed out due to the onboard laptop receiver unit not having line-of-site with the cabin relay-unit. Operations were switched to the backup laptop and ascent data downloads and downlinks resumed. A total of 22 half-sec windows of ascent raw data were requested and received. A total of three impact indications above 1.0 Grms; each with a damage likelihood category of I were found and reported for this flight. Automatic scanning of the post-flight data yielded no additional indications above 1.0 Grms.

All units triggered and began data recording on Main Engine Ignition within 0.25 sec of each other with the exception of unit 1029, which triggered 0.595 sec earlier than the rest of the units. A time shift was manually added to this unit so that it was consistent with the others. Mission Elapsed Time was set to 9.20 sec behind Data Elapsed Time (MET = DET - 9.20 sec) for both port and starboard wing units.

Automated scanning of post-flight data acquired from MET 10-500 seconds revealed a total of 73 ascent debris impact indications on the wing leading edge (37 on the port and 36 on the starboard wing) ranging from 0.1 to 3.1 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
102.6	111.8	Stbd	6	1047-J3	3.1	12.6	+	+	+	+	P	P
109.9	119.1	Port	6:7	1034-J3	2.5	8.8	+	+	+	+	P	P
111.8	121.0	Port	5	1123-J3	1.2	3.7	+	+	+	+	P	P

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

^bP = Probable

ORBIT MONITORING

On-Orbit monitoring began at approximately launch plus 18 hr. Due to the sensor-unit battery-life limitations, continuous on-orbit monitoring of each Reinforced Carbon-Carbon (RCC) panel was not possible. The WLE IDS monitored each wing with two groups of sensors consisting of 10 and 11 units. On-orbit monitoring was performed when the risk of critical damage to the RCC from Micrometeoroid/Orbital Debris (MM/OD) was expected to be highest. The periods of increased risk to the RCC were during early- and late-mission surveys and during the International Space Station (ISS)

attitudes during the Solar Array Wing deployment as well as docking and undocking with the ISS. The MM/OD monitoring time for both port and starboard wings was 42.25 hr per wing. After approximately the first 5 hr of monitoring the port wing with on-orbit group 2, sensor unit 1024 went out of the on-orbit mode unexpectedly (IFA STS-119-V-09). The unit was successfully commanded back into on-orbit mode after approximately 4 hr of lost operations. During this time only a single sensor was monitoring RCC panels 14, 16, and 17. No diagonal sensor was available for panel 13. Therefore, the multi-sensor criteria could not be used to evaluate triggers had any occurred on any of these 4 panels. Sensor unit 1033 was not able to keep a consistent time during colder periods of the mission (IFA STS-119-V-07). The problem was identified during the second monitoring period of the port wing with on-orbit group 2 sensor units. This caused a loss of 1hr and 42 min of operations. During this time, no diagonal sensors were monitoring RCC panel 3. However, the multi-sensor criteria could still be evaluated using two horizontal sensors for panel 3.

SUMMARY OF MM/OD IMPACTS

Times ^a	Location			Magni- tude	Criteria				Impact ^b		
	GMT	Wing	RCC		Unit- Channel	Max. G	Transient	Local	Spectral	Shock	In- Flt
076/17:20:12	Stbd	11/12 L	1044-J3	0.52	+	+	-	-	-	N	N

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

N= No

CONCLUSIONS

The WLE IDS system performed well during the ascent impact monitoring. An initial ascent report was published at Launch +14 hr. During the mission, three ascent impact indications above the 1.0 Grms reporting threshold with a damage likelihood of category I were reported. Post-flight review of the data found no additional ascent indications over 1 Grms.

No MM/OD impact indications were detected during on-orbit monitoring using the latest MM/OD Impact Criteria in place during STS-119.

Based on the ascent findings from all systems, including WLE IDS, the Orbiter Project Office (OPO) recommended that an inspection of the WLE RCC should not be performed

The late-mission Orbiter Boom Sensor System (OBSS) survey visually inspected the WLE after Orbiter undocking and prior to entry. 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 satisfactory. Seven in-flight anomalies were identified during the mission, and these are discussed in the following paragraphs. None of these anomalies impacted the successful completion of the mission.

During Photo/TV setup, the crew reported that the Flight Deck camcorder would not operate. The crew exchanged the Audio Visual Interface Unit (AVIU) from the Middeck Payload General Support Computer (PGSC) (Desktop Downlink) with the Flight Deck and the Camcorder operated properly, confirming a failed AVIU (IFA STS-119-V-02).

The crew reported that while trying to exercise using the Ergometer, the pedal movement was restricted (IFA STS-119-V-03). A troubleshooting procedure was developed and uplinked for use during FD 3 activities. Later in the flight, execution of the Ergometer IFM regained full functionality of the unit. The crew found a bend in the calibration strap and adjusted it.

During ET Separation, the Digital External Tank Thermal Protection System (DETTPS) camera flash was not observed in the live video. Based on the video downlinked, imagery analysis confirmed the observation. The crew was then unable to retrieve the images from the DETTPS camera as planned. A second attempt to download the imagery later in the flight was not successful (IFA STS-119-V-04).

WLES Sensor Unit 1033 did not begin on-orbit monitoring as planned (IFA STS-119-V-07). It was determined that the unit did not have the correct internal time. A command was sent to the unit from the ground to start on-orbit monitoring immediately. The unit continued to be used for the remainder of the on-orbit monitoring period.

During WLES MM/OD monitoring with the RCC Group 2 sensors, Serial Number (S/N) 1024 sensor on the port wing unexpectedly dropped out of the on-orbit mode after 5-6 hr of monitoring (IFA STS-119-V-09). A health check of the sensor showed that the sensor was in the "idle" mode. The sensor was subsequently regained and stayed operational for the remainder of the flight.

During the final approach, the Heads-Up Display (HUD) Mini-Camcorder video was not observed by the ground team (IFA STS-119-V-16). Post-flight, the MILA ground station confirmed that there was no modulation in the downlink, indicating no presence of a video signal. The entire entry mini-camcorder video recorded onboard (approximately 2 hr) was reviewed, confirming nominal performance by the camera and video recorder.

During the post-flight crew debriefing, the crew reported that the Re-Hydration (RHS) Shuttle Orbiter Repackaged Galley (SORG) consistently leaked during dispenses (IFA STS-119-V-15). The on-orbit leakage required the usage of towels daily to absorb the water leakage around the cup enclosure.

DEVELOPMENT TEST OBJECTIVES AND PAYLOADS OF OPPORTUNITY

DEVELOPMENT TEST OBJECTIVES

DTO 695 – THRUST OSCILLATION SEAT

The collection of Orbiter seat vibration data will aid in the development of unimpeded crew performance specifications. Testing was done during the Gemini program to determine acceleration and frequency acceptability for crew performance. However, this was never validated with flight data. The Thrust Oscillation Seat (DTO 695) gathers vibration data from accelerometers on three crewmember seats during launch.

Following STS-128, data from the accelerometers were downloaded post-flight and was being assessed by the sponsors when this report was written.

DTO 805 – CROSSWIND LANDING PERFORMANCE

This DTO of opportunity was not performed during landing because of inadequate wind conditions. A 10-knot crosswind at landing is required to meet the requirements of the DTO.

DTO 854 – BOUNDARY LAYER TRANSITION FLIGHT EXPERIMENT

The objective of DTO 854 is to gather flight-based science data on Boundary Layer Transition (BLT) at the high Mach numbers experienced during entry. This effort will play a major role in understanding BLT and catalytic material effects on spacecraft, and influence high-fidelity computational models and benefit hypersonic aerothermal-dynamics interests within NASA.

The OV-103 Orbiter was configured with a special tile bonded on the underside of the port wing, just aft and outboard of the Main Landing Gear (MLG) door. This unique tile was manufactured with a fixed protuberance height of approximately 0.25 in., which was intended to force boundary layer transition at Mach numbers within previous flight experience. Flight data were acquired using surface thermocouples installed in downstream surface tiles on the Orbiter belly. In addition a Catalytic Coating material was sprayed on two instrumented tiles downstream of the turbulent wedge to understand the thermal effects of catalytic material on TPS tiles.

During entry, all instrumentation performed nominally. The thermocouple data were successfully obtained and correlated to Mach numbers and transition times.

The boundary layer transition onset in the turbulent wedge was estimated to have occurred near Mach 16. The tile protuberance measurement indicated the BLT onset near Mach 8.5 (plus/minus 1) about 1 min earlier than nominal vehicle transition, which occurred near Mach 6.5 (plus/minus 1). The Starboard wing BLT onset appears to have

occurred near Mach 11.5 (plus/minus 1). Acreage BLT onset for Discovery occurred near Mach 6.5 (plus/minus 1). Post-flight runway inspections of the BLT Flight Experiment protuberance and downstream tile revealed little if any tile slumping.

DTO 900 – SHUTTLE RSRB CHAMBER PRESSURE, STRAIN GAGE AND ACCELERATION RATES DATA COLLECTION

Additional knowledge of the performance characteristics of the Space Shuttle Solid Rocket Motors will be collected prior to the end of the Shuttle program to give Reusable Solid rocket Booster (RSRB) analysts insight into the discrepancies compiled between motor performance parameters measured during previous Development Flight Instrumentation (DFI) flights and those measured during static ground tests. Simultaneous accelerometers, strain, and RSRB pressure measurements at a higher fidelity than previously obtained are needed to provide this additional insight.

The results from this DTO will be published in a separate document.

PAYLOADS OF OPPORTUNITY

Shuttle Ionospheric Modification with Pulsed Local Exhaust

The first Shuttle Ionospheric Modification with Pulsed Local Exhaust (SIMPLEX) data gathering opportunity occurred during the Orbital Maneuvering System (OMS) NC2 maneuver at approximately 0/16:58 MET. The initial observation radar observations from the SIMPLEX Primary Investigator (PI) were that good data from the NC2 maneuver were received by the radar over the Kwajalein - Altair radar site. However, further assessment showed that the science collection was not optimal for that particular pass. Apparently, the Ionospheric density at that particular time over Kwajalein was not high enough for the OMS exhaust to cause a significant perturbation over the site.

The second SIMPLEX observation opportunity was a dual OMS maneuver on Flight Day 13 over the Millstone Hill site in Massachusetts. The SIMPLEX PI reported the observation of the real time output from the radar and other diagnostics indicated definitive effects from the OMS firing that are expected to produce studies that will advance SIMPLEX goals. This was the first SIMPLEX burn observation since 2002. The results of this Payload of Opportunity will be published by the PI in a separate document.

Maui Analysis of Upper-Atmospheric Injections

No Maui Analysis of Upper-Atmospheric Injections (MAUI) observation opportunities were available during the STS-119 mission.

Shuttle Exhaust on Turbulence Experiments

No Shuttle Exhaust on Turbulence Experiments (SEITE) observation opportunities were available during the STS-119 mission.

POST-LAUNCH PAD INSPECTION

The post-launch inspection of the Main Launch Platform (MLP) -1, Pad A Fixed Service Structure (FSS), and Pad A apron was conducted on March 15, 2009, from Launch +1.30 hr to 4.50 hr. The inspection proceeded relatively quickly while Safing Teams secured the Pad. The entire PAD, FSS and MLP were inspected. The lighting conditions were not satisfactory for the infield and perimeter to be inspected.

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

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

Inspections of the SRB Hold-Down Posts (HDP's) were performed and the results of the inspection shown discussed in the following items.

HDP No. 1 – The EA934 poured sidewalls were nominal (acceptable). The Phenolic shim was nominal and one of the two firing lines was present. No galling or chatter marks were noted in the chamfer of the through-hole and the stud was set down.

HDP No. 2 – The EA934 poured sidewalls were nominal with minor delamination on the West sidewall (acceptable). The Phenolic shim was nominal and both firing lines were present. Approximately 3-ft of the 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 more-than nominal indications of erosion on the RTV-coated blast shield with proper closure.

HDP No. 5 – The EA934 poured sidewalls were nominal with minor pitting on the Southwest (SW) wall (acceptable). The Phenolic shim was nominal with typical erosion and one of the two firing lines was present. 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 are nominal. The Phenolic shim was nominal with two minor impressions that were approximately 6 in. in length) on the Southeast (SE) face and both firing lines were present. No galling or chatter marks were noted in the chamfer of the through-hole and stud was set down.

HDP No. 7 -- This HDP showed nominal indications of erosion on the RTV-coated blast shield 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 are as follows:

The Left-Hand (LH) probe was erect and straight with about 85% of the protective tape layering remaining with no exposed braiding. The o-ring was present.

The Right-Hand (RH) probe was erect and slightly bent to the East with about 85% 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 are as follows:

The LH SRB Lift-off (T-0) GCAs appeared to be in nominal condition with proper demate.

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

The LO₂ and LH₂ Tail Service Masts (TSM's) appeared to be undamaged and both bonnets appeared to have closed properly.

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

The Orbiter Access Arm (OAA) at the 195-ft level was retracted and secured. All slidewire baskets were still secured at the 195-ft level with no evidence of damage. All of the Basket signs were present and all PIP pins were engaged.

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-in 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 and liquid runs on the poppet probe. The ET GUCP exhibited typical blast damage and the pyrotechnic bolt fired nominally.

Special attention was focused on both Left and Right leg pivot assemblies, which exhibited nominal undamaged separation and deceleration cycle.

The Gaseous Oxygen (GOX) vent hood, windows and structure on the Vent Arm (at the 255-ft level) appeared to be in nominal condition, and the latch mechanism locked properly. The seals were able to be inspected and showed no signs of topcoat or foam.

Numerous items were found but overall, the PAD facility was found to be in very good condition while the SRB flame trench experienced nominal erosion and the previous repair areas were intact. In the SW slope near midpoint of arc of the SRB flame trench, three areas had some damage. The most notable debris items using the debris collection criteria are included below.

1. Minor pieces of SRB throat plug material were found on the PAD surface.
2. West PAD surface – Two bolts were found 100-ft South of the elevators.
3. West PAD surface – One bolt was found 30-ft S of the elevators.
4. West PAD surface – A toolbox lock was found West of the flame deflector.
5. West PAD surface – A small piece of nut was found 130-ft S of the elevator.
6. West PAD surface – A broken stud with attached nut was found West of the flame deflector.
7. West PAD surface – A washer was found near the stairs of the FSS.
8. South PAD surface – Small pieces of fondue fyre were found.
9. South PAD surface – Large pieces of rust scale were found.
10. South PAD surface – Black plastic bagging with orange tape was found that was acceptable appeared to come from PAD pedestals.
11. North East PAD surface – An acceptable waterbag rope and became collection data for the Debris Transport Analysis (DTA).
12. East PAD surface – A pen was found under the East (E) flame deflector.
13. East PAD surface – A braided tie cable was found under the E flame deflector.
14. East PAD surface – Large rust scale was noted.
15. MLP deck level – A missing bolt of the camera flame deflector was found one the NE side).
16. 107-ft level – Large rust scale was identified on the RSS side 4.
17. 135-ft level – An 8-in bolt with washer was found in the crossover area, and two large rust scales were identified on the West side. Also facility insulation foam and a tie wrap were found near the RSS.
18. 175-ft level – A small piece of black asphalt type material was found on the NE side. A larger piece of the same material was found on top of the cable tray on the NE side, and it was not accessible to be retrieved.
19. 195-ft level – Two loose clamps, which secure grating, were found directly in front of stairs on the E side of the FSS). Also, a sheared bolt was found on the E side of the FSS. A washer was found near the bathroom, and a nut was found on the SW side of the FSS.
20. 200-ft level – Temperature transducer was unplugged and hanging loose on the NE side of the FSS, and rust scale was also noted on the E side of the FSS.
21. 275-ft level – A bolt was found on the E side of the FSS.

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

Approximately 1 hr prior to launch, a bat was observed on the -Z side of the External Tank (ET) near Xt 1910. The bat was noted to still be clinging to the vehicle post-launch at tower clear.

Starting at approximately 39 min prior to launch, luminous clouds of buoyant vapor were observed at multiple times at or near the aft skirt of the starboard Solid Rocket Booster (SRB) at the approximate level of the Main Launch Platform (MLP) deck. The vapors appeared on both the north and south sides of the SRB in multiple short durations. This event was evaluated real-time (pre-launch) with the Infrared (IR) cameras and not observed to have a heat signature. This type of event has been seen on other flights. The Kennedy Space Center (KSC) ground operations reported it was sunlight (sunset) refracting through Space Shuttle Main Engine (SSME) vapors, giving them orange appearance.

At lift-off -8.263 sec and lift-off -7.159 sec, black and white Pad debris was observed near the Right (R) SRB and bouncing off the MLP.

At lift-off -4.5 sec, multiple tile chips from the port and starboard stingers on the Orbiter base heat shield were observed during the ignition transient. The end of the port stinger pod appeared to vibrate.

From lift-off -3.1 sec through lift-off, various sources of debris were observed. These included debris released from the cable housing on the outboard side of the LH₂ Tail Service Mast (TSM), debris released from near the Orbiter and LH₂ T-0 Plate. In addition, pad debris was observed near the Left (L) SRB, yellow tape was observed near the port side of Space Shuttle Main Engine (SSME) no. 2, debris was observed from between the Orbiter and the LO₂ T-0 Plate, debris was released from the LH₂ Umbilical, and debris was observed falling from the tower near LH₂ TSM.

At 5.280 sec MET, the Tyvek cover on F4D appeared to partially release and travel aft between the Orbiter and the ET. The partial cover cleared the aft of the Space Shuttle Vehicle (SSV) during this timeframe. At 17.226 sec MET, the remaining portion of the F4D Tyvek released and was observed to travel aft over the starboard wing.

At approximately 59 sec MET, ET TPS debris spray appeared to release from near the aft face of the Xt 1623 bracket Area. At approximately 70 sec MET, ET TPS debris appeared to release from near the Xt 1871 LO₂ Feedline-Bracket Area with no contact to the vehicle. At approximately 77 sec MET, multiple ET TPS debris laws liberated from the Xt 1871 LO₂ Feedline-Bracket vicinity.

At approximately 93 sec MET, ET TPS debris was believed to have originated outboard of the LO₂ feedline, most likely from a location forward of the Xt 1362 feedline flange. At approximately 109 sec MET, ET TPS was observed to be missing from the starboard side of the intertank on panel 3. This was reported to be typical popcorn event and did not appear to be out of family.

At approximately 120 sec and approximately 126 sec MET, debris was observed falling aft of vehicle port wing.

At approximately 126 sec MET, two areas of ET TPS were observed missing on the -Z side of the LH₂ acreage near the intertank flange.

At approximately 127 sec MET, following SRB separation, damaged TPS on the port side inboard elevon was observed.

At approximately 354 sec MET, light-colored ET TPS debris was released outboard of the LO₂ feedline. No contact to the vehicle was noted.

At approximately 548 sec MET, The Digital ET TPS (DET TPS) camera flash was not observed to fire during ET separation.

LAUNCH PAD OBSERVATIONS

The final prelaunch inspection observed that the ET was dry for most tank surfaces. Less than typical ice/frost formations were observed on the aft interface hardware. Surface temperatures ranged from 65 to 95 °F. There were no observations noted on the Ice Frost Ramps (IFR). The LO₂ Feedline brackets looked very clean, with minimal ice/frost formations. All ice/frost formations were within NSTS 08303, "Ice/Debris Inspection Criteria." Some TPS defects were noted by the FIT; all were typical and acceptable per NSTS 08303.

Documentation was written on a bat that was attached to the ET tank foam on the -Z side of the LH₂ tank acreage (XT 1910, Phi -113 deg). The observation violated LCC ICE-01 and NSTS 08303 paragraph 3.3.1.4 which covers miscellaneous debris on the Space Shuttle Vehicle (SSV) and Main Launch Platform (MLP) pad structures. An LCC waiver was approved based on acceptable ascent and lift-off debris risk and the potential superficial TPS damage induced by the bat.

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APPENDIX A
STS-119 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	074/23:38:55.701 074/23:38:56.715 074/23:38:57.918
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	074/23:43:16.079 074/23:43:16.229 074/23:43:16.399 074/23:43:16.559
Main Engine Start	SSME-3 Start Command Accepted SSME-2 Start Command Accepted SSME-1 Start Command Accepted	074/23:43:37.471 074/23:43:37.580 074/23:43:47.711
SRB Ignition	SRB Ignition Command	074/23:43:44.019
Throttle Up 104.5 %	SSME-2 Command Accepted SSME-1 Command Accepted SSME-3 Command Accepted	074/23:43:47.916 074/23:43:47.927 074/23:43:47.927
Throttle Down to 72%	SSME-2 Command Accepted SSME-1 Command Accepted SSME-3 Command Accepted	074/23:44:17.677 074/23:44:17.688 074/23:44:17.688
Throttle Up 104.5%	SSME-2 Command Accepted SSME-1 Command Accepted SSME-3 Command Accepted	074/23:44:35.117 074/23:44:35.128 074/23:44:35.128
Maximum Dynamic Pressure (MAX Q)	Derived Ascent Dynamic Pressure	074/23:44:47
Both SRMs to less than 50 psi	LH SRM Chamber Pressure RH SRM Chamber Pressure	074/23:45:43.459 074/23:45:44.539
End SRM Action	LH SRM Chamber Pressure RH SRM Chamber Pressure	074/23:45:45.719 074/23:45:47.119
SRB Separation Command	SRB Separation Command Flag	074/23:45:49
SRB Physical Separation	RH APU B Turbine Loss of Signal RH APU A Turbine Loss of Signal LH APU B Turbine Loss of Signal LH APU A Turbine Loss of Signal	074/23:45:49.219 074/23:45:49.259 074/23:45:49.259 074/23:45:49.299
OMS Assist Ignition	R Engine Bipropellant Valve Position L Engine Bipropellant Valve Position	074/23:45:59.5 074/23:45:59.5
OMS Assist Cutoff	L Engine Bipropellant Valve Position R Engine Bipropellant Valve Position	074/23:47:27.9 074/23:47:28.1
Throttle Down for 3g	SSME-2 Command Accepted SSME-1 Command Accepted SSME-3 Command Accepted	074/23:51:06.324 074/23:51:06.366 074/23:51:06.339
3G Acceleration	Total Load Factor (g)	074/23:51:10.1
Throttle down to 67 percent for Cutoff	SSME-2 Command Accepted SSME-1 Command Accepted SSME-3 Command Accepted	074/23:52:01.365 074/23:52:01.377 074/23:52:01.380
SSME Shutdown	SSME-2 Command Accepted SSME-1 Command Accepted SSME-3 Command Accepted	074/23:52:07.885 074/23:52:07.897 074/23:52:07.900
Main Engine Cutoff (MECO)	MECO Command Flag MECO Confirmed Flag	074/23:52:09 074/23:52:09

APPENDIX A
STS-119 MISSION EVENTS

EVENT	DESCRIPTION	ACTUAL GMT
ET Separation	ET Separation Command Flag	074/23:52:29
APU Deactivation	APU-1 Gas Generator chamber Pressure APU-2 Gas Generator chamber Pressure APU-3 Gas Generator chamber Pressure	074/23:59:57.271 075/00:00:22.235 075/00:00:48.818
OMS 1 Ignition	L Engine Bipropellant Valve Position R Engine Bipropellant Valve Position	N/A
OMS 1 Cutoff	L Engine Bipropellant Valve Position R Engine Bipropellant Valve Position	N/A
OMS 2 Ignition	L Engine Bipropellant Valve Position R Engine Bipropellant Valve Position	075/00:22:14.1 075/00:22:14.3
OMS 2 Cutoff	L Engine Bipropellant Valve Position R Engine Bipropellant Valve Position	075/00:23:17.6 075/00:23:17.7
Payload Bay Doors Open	Right Payload Bay Door Open 1 Left Payload Bay Door Open 1	075/01:18:25 075/01:19:45
OMS 3 Ignition	L Engine Bipropellant Valve Position R Engine Bipropellant Valve Position	075/03:18:24.3 075/03:18:24.4
OMS 3 Cutoff	R Engine Bipropellant Valve Position L Engine Bipropellant Valve Position	075/03:19:30.0 075/03:19:30.1
OMS 4 Ignition	L Engine Bipropellant Valve Position R Engine Bipropellant Valve Position	075/16:41:41.2
OMS 4 Cutoff	L Engine Bipropellant Valve Position R Engine Bipropellant Valve Position	075/16:41:52.4
OMS 5 Ignition	R Engine Bipropellant Valve Position L Engine Bipropellant Valve Position	076/16:13:13.2 076/16:13:13.3
OMS 5 Cutoff	R Engine Bipropellant Valve Position L Engine Bipropellant Valve Position	076/16:14:21.2 076/16:14:21.3
OMS 6 Ignition	L Engine Bipropellant Valve Position R Engine Bipropellant Valve Position	076/17:03:28.7 076/17:03:28.8
OMS 6 Cutoff	L Engine Bipropellant Valve Position R Engine Bipropellant Valve Position	076/17:04:17.5 076/17:04:17.6
OMS 7 Ignition	L Engine Bipropellant Valve Position R Engine Bipropellant Valve Position	076/18:35:39.1
OMS 7 Cutoff	L Engine Bipropellant Valve Position R Engine Bipropellant Valve Position	076/18:35:50.7
Docking	Capture	076/21:19:50
Undocking	Undock Complete	084/19:53:27
Flight Control System Checkout – APU 1 Start	APU-1 Gas Generator Chamber Pressure	086/13:56:55.351
APU 1 Stop	APU-1 Gas Generator Chamber Pressure	086/14:02:42.251
Payload Bay Door Close	Left Payload Bay Door Close Right Payload Bay Door Close	087/14:00:41 087/14:02:51
APU Activation	APU-2 Gas Generator Chamber Pressure APU-1 Gas Generator Chamber Pressure APU-3 Gas Generator Chamber Pressure	087/18:03:24.915 087/18:29:05.201 087/18:29:08.148
Deorbit Maneuver	L Engine Bipropellant Valve Position R Engine Bipropellant Valve Position	087/18:08:14.2 087/18:08:14.3

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STS-119 MISSION EVENTS

EVENT	DESCRIPTION	ACTUAL GMT
Deorbit Maneuver Cutoff	R Engine Bipropellant Valve Position L Engine Bipropellant Valve Position	087/18:11:13.7 087/18:11:13.8
Entry Interface	Orbital Altitude Referenced to Ellipsoid	087/18:41:57
Blackout End	Data Locked (High Sample Rate)	No Blackout
Terminal Area Energy Management (TEAM)	Major Mode Code (305)	087/19:07:03
Main Landing Gear Contact	Main Landing Gear Left Hand Tire Pressure Main Landing Gear Right Hand Tire Pressure	087/19:13:26 087/19:13:26
Main Landing Gear Weight on Wheels	Main Landing Gear Right Hand Weight on Wheels Main Landing Gear Left Hand Weight on Wheels	087/19:13:26 087/19:13:26
Drag Chute Deployment	Drag Chute Deployment 1 CP Volts	087/19:13:29.3
Nose Landing Gear Contact	Nose Landing Gear Left Hand Tire Pressure 1	087/19:13:34
Nose Landing Gear Weight on Wheels	Nose Landing Gear Weight on Wheels	087/19:13:35
Drag Chute Jettison	Drag Chute Jettison 2 CP Volts	087/19:13:58.7
Wheels Stop	Velocity with respect to Runway	087/19:14:44
APU Deactivation	APU-1 Gas Generator Chamber Pressure APU-2 Gas Generator Chamber Pressure APU-3 Gas Generator Chamber Pressure	087/19:31:59.131 087/19:32:17.835 087/19:32:29.688

APPENDIX B

STS-119 IN-FLIGHT ANOMALIES

INTRODUCTION

This appendix contains listings and discussions of each of the In-Flight Anomalies (IFAs) that were identified for the STS-119 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-119 IN-FLIGHT ANOMALIES

ORBITER

IFA Number	Title	Comments
STS-119-V-01	Fuel Cell 3 O ₂ Flowmeter Off-Scale Low	<p>At 075/01:57:15 GMT (00/02:13:31 MET), the Fuel Cell (FC) 3 O₂ flowmeter failed static to Off-Scale Low (OSL). A slight decrease in Mid Power Controller 3 current was observed coincident with the FC 3 O₂ flowmeter anomaly. The loss of the FC 3 O₂ flowmeter had negligible impact to the crew and a slight impact to the ground controllers. The ground controller used other parameters such as pressure decays, purge line temperatures, and fuel cell performance to verify the FC 3 purges.</p> <p>The most probable cause of the FC 3 O₂ flowmeter OSL reading is a failure of one or more electronic components within the circuitry that are installed in the flowmeter. Failure analyses performed on previous flowmeters have identified a marginal design with overstressed, obsolete EEE components within the circuit.</p> <p>Post-flight: FC 3, S/N 116, was already scheduled to be removed after completion of STS-119 mission because of the operating hours being near the Time Between Overhaul. Post-flight troubleshooting at KSC did not re-create the blown fuse, and was inconclusive due to a damaged MPCA no. 3, F7 fuse cap/holder. Bench testing with no O₂ flow did not re-create the failure. However, vendor testing after the FC 3 Remove and Replace (R&R) resulted in the flowmeter failure (output going to zero due to a blown fuse in the power supply) after approximately 1 hour under load.</p>
STS-119-V-02	Advanced Video Interface Unit (AVIU) S/N 1031 Failure	<p>While attempting to use the camcorder on the Flight Deck, the crew reported that AVIU S/N 1031 did not appear to be on (power light did not illuminate). The flight deck AVIU was replaced by the AVIU from the Mid-Deck Payload General Support Computer (PGSC) (Desktop Downlink), and it successfully powered the camcorder. The flight deck AVIU was tried in the Mid Deck and the AVIU failed to power up. AVIU S/N 1031 was tagged and bagged for the remainder of the flight.</p> <p>There were 6 AVIU's on STS-119. There was one conflict on Flight Day (FD) 2 when the AVIU was needed in two locations (Mid Deck and Flight Deck), one for live Desktop Downlink to support Sensor Package 2 operations during the Orbiter Boom Sensor System (OBSS) survey and one to run the camcorder. The camcorder was operated using battery power. This AVIU has had issues before. A discrepancy report was generated in April 2008 where the AVIU tripped a breaker on the USA Houston test rack. The AVIU was tested and the DR was closed. This is the first flight since that DR.</p> <p>Post-flight: The AVIU was unstowed and shipped to JSC. Troubleshooting indicated the AVIU had a blown fuse. The fuse was replaced and unit tested nominal.</p>

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STS-119 IN-FLIGHT ANOMALIES

IFA Number	Title	Comments
STS-119-V-03	Ergometer Pedal Restricted Movement	<p>After assembly of the Shuttle Cycle Ergometer (SCE), the crew reported that the ergometer appeared to be jammed or locked internally. The pedals moved without any problem in the reverse direction, but could not be moved in the forward direction (with or without the Manual Control Knob, and with or without power). The crew confirmed the correct orientation of the ergometer. On-orbit troubleshooting was attempted, and the crew reported a “grinding” noise which sounded like it was coming from within the Ergometer when they attempted to pedal forward. Without the SCE, the Shuttle crew is unable to perform aerobic exercise when not docked to the ISS; while docked, they crew could use the ISS Cycle Ergometer with Vibration Isolation and Stabilization (CEVIS) ergometer as an alternate method for exercise. In-Flight Maintenance (IFM) troubleshooting procedures were uplinked to the crew on Flight Day (FD) 5. The IFM procedure was executed and it was determined that the calibration strap was bound up inside the ergometer against a circuit board. The binding was cleared and the ergometer was operating nominally.</p> <p>Post-flight: During ground troubleshooting, when the unit was powered, a loud, grinding sound was heard and the resistance was less than expected. When the unit was opened, there was evidence of a groove in the flywheel with a metallic burr which indicated some additional obstruction was binding the flywheel. The stepper motor brackets were readjusted back to the nominal position which fixed the off-nominal noises heard during the powered mode.</p>
STS-119-V-04	ET Umbilical Well Camera Flash Download Problem	<p>Following ET Separation, the DETTIPS Camera/Flash System did not appear to function. The Tank Centerline Camera appeared to show some flash actuations, but the Main Bus B telemetry did not indicate flash operation. Additionally, the crew was unable to establish contact between the Camera and the PGSC. The loss of illumination of the External Tank by the DETTIPS Camera Flash prevents any usable data to be collected from the DETTIPS Camera imagery. The inability of the DETTIPS to communicate with the PGSC will prevent the download of the images from the camera, the downlink of the images and the loss of the analysis of potential ET foam loss prior to entry. A second attempt was made to download images from the Umbilical Well Digital Camera, but the attempt was unsuccessful.</p> <p>Post-flight: Troubleshooting was performed while the camera was still on the vehicle. The camera was subsequently removed and sent to JSC for further troubleshooting which determined that the camera 5-ampere (A) fuse on the power board output was open. There were no pictures in the camera memory, indicating a failure after checkout in the Vertical Assembly Building (VAB) and before the first photograph to be taken 4 sec after ET separation. The root cause was determined to be that the fuse on the output of the power supply opened due to an over-current condition. Further investigation found that a capacitor had been soldered backwards on the controller board, and a loose intermittent shuttle trigger cable connector on the camera body was also noted.</p>

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IFA Number	Title	Comments
STS-119-V-05	MADS Base Heat Shield External Pressure Sensor Off-Scale Low	<p>The Modular Auxiliary Data System (MADS) Base Heat Shield External Pressure Sensor failed to Off-Scale Low (OSL) approximately 1 sec into the flight, and remained OSL during the next MADS PCM recording session, which was from near entry to wheel stop. On the Last flight of this vehicle, this sensor worked nominally. The sensor is located on the aft bulkhead</p> <p>Post-flight: Inspection in the aft compartment revealed that the connector closest to the pressure transducer was demated and should have been mated. This explains the OSL condition near T-0 of this launch. Inspection of the demated connector showed no damage to either the plug or receptacle. However, some of the tape restraints securing the harness close to the connector were separated from structure and some of the harness convoluted tubing appeared to be damaged, which suggests that contact with the harness close to the transducer connector occurred prior to STS-119. This caused the connector to partially uncouple prior to aft closeout. The vibration environment of launch then resulted in the full demating of the harness.</p> <p>The last recorded mating operation of this plug and receptacle was in 2000 when this same connector was demated during STS-103. After STS-103, the connector pair was inspected and re-mated and the measurement worked properly for 8 flights until STS-119. Two in-flight demates of the exact same connector suggest that either this connector is exposed to significant traffic above and beyond what is considered normal or that something is mechanically wrong with the coupling mechanism with this particular connector pair. A mate/de-mate feel test was performed and nothing abnormal was noted. The vehicle plug was R&R'd, but the receptacle was not because it is hard mounted to the transducer. The pair was mated and the assembly was safety wired. The subsequent retest of the pressure sensor failed out of limits. The connector was determined to be mis-pinned. It was re-pinned, re-safety wired, and the retest was good.</p>
STS-119-V-06	TPS Tile and Blanket Anomalies	<p>A complete listing of the Thermal Protection System (TPS) Tile, Blanket, and Reinforced Carbon-Carbon (RCC) Regions of Interest (ROI) evaluated by the Tile and RCC Damage Assessment Teams (DAT's) are documented in the TPS Imagery Inspection Management System (TIIMS) Database located at: http://isal-web1.jsc.nasa.gov/tiims/TIIMS.htm.</p> <p>A total of 10 TPS items were identified that exceeded pre-defined screening criteria and were entered into the TIIMS Database. Seven of these items were cleared using standard procedures/tools, and the following three items required additional analysis:</p> <p>D-119-RPM-751-001 - Tile is Damaged on Left Inboard Elevon D-119-RPM-751-002 - Ames Gap Filler is Protruding D-119-RPM-340-001 - Aft Fuselage Stub Tile is Broken</p> <p>No focused inspection was required based on the data available from FD 3 R-Bar Pitch Maneuver (RPM) images and the FD 2 inspections. The remaining TPS tile damage sites (listed above) were cleared based on additional analysis.</p>

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IFA Number	Title	Comments
STS-119-V-07	WLES Sensor (1033) Clock Time Error	<p>After requesting an On-Orbit Summary from Sensor unit S/N 1033 at ~79/15:06:59 GMT, the sensor was not in the On-Orbit monitoring mode as expected. This error was attributed to the internal clock time of Sensor 1033 running about 2 hr 14 min behind the primary laptop time that was used for programming. The file for S/N 1033 from programming the unit shows that the unit clock did synchronize with the laptop at 78/20:37:09 GMT. A subsequent diagnostic just prior to entering on-orbit mode shows the laptop time at 79/11:47:05 GMT and the sensor unit RTC time at 79/09:33:50 GMT. Sometime in between those two requests, the clock time for the sensor unit drifted/changed by about 2 hr 14 min. All of the other 21 programmed units for Group 2 worked nominally. An additional command was sent to Sensor 1033 to start the on-orbit monitoring immediately for 2.5 hr, once the problem had been identified. The unit accepted the command and monitored for 2.5 hr starting 79/15:42:47 GMT. The command also resynchronized the sensor internal clock with the laptop time. As a result of the unit clock time being off initially, it missed a total of 1 hr and 42 min of planned monitoring time during the Solar Array Wing (SAW) deployment. Post Flight: The sensor was removed and replaced is currently undergoing troubleshooting.</p>
STS-119-V-08	Partial F4D Thruster Tyvek Rain Cover Release	<p>Ground imagery showed that when thruster F4D's Tyvek rain cover released at 5.28 sec MET (approximately 93 ft/sec or 63 mph), a approximately 21 in. by 7.4 in. Tyvek piece remained attached to the thruster lip.. This piece is believed to have separated by 17.3 sec MET (approximately 380 ft/sec or 259 mph). Imagery shows that the piece did not impact the Orbiter. No vehicle/mission impacts ensued.</p> <p>Testing and analysis of 5-gram Tyvek remnants released up to 1000 ft/sec have low risk of producing unacceptable damage; however, the estimated size for the F4D remnant is 6.5 to 10 grams. Impact testing using full-sized covers on RCC samples up to 240 mph (352 ft/sec) produced no damage. Similar impact testing on LRSI tile produced minor pitting for impacts between 216 and 268 mph (317 and 393 ft/sec). Since the F4D Tyvek piece that released at approximately 259 mph was enveloped by full-cover impact testing in terms of both mass and velocity, any impact damage would not be expected to be worse than these ground test results.</p> <p>No TPS damage was attributed to Tyvek cover releases, and this failure did not affect Forward Reaction Control System (FRCS) thruster performance. Thruster F4D was first fired at ET Separation and performed nominally throughout the mission.</p> <p>Post-Flight: Additional analysis and Imagery estimates indicate a 6 to 10 gram piece remained until 17.3 sec MET. The remnant did not impact the Orbiter, but did release at approximately 380 ft/sec, which is beyond the impact testing for some shuttle components. Testing has been up to 5 grams. A redesign effort for the F3D/F4D covers was initiated.</p>

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STS-119 IN-FLIGHT ANOMALIES

IFA Number	Title	Comments
STS-119-V-09	WLES Sensor SN 1024 Unexpected Mode Change	<p>During Micrometeoroid/Orbital Debris (MM/OD) monitoring with Group 2 sensors, Sensor S/N 1024 on the port wing dropped out of the on-orbit mode after 5 to 6 hr of monitoring rather than the expected 12 hr. A health check of the sensor was performed via diagnostic command, and initially following the command the sensor was still in idle mode, but later was regained and became operational.</p> <p>Wing Leading Edge System (WLES) is categorized as criticality 3/3 and poses no threat to crew, vehicle, or mission.</p> <p>Post Flight: The sensor was removed and replaced off of OV-103. Troubleshooting is in the lab</p>
STS-119-V-10	APU 2 Fuel Pump B Heater Thermostat Dithering	<p>At 085/16:46 GMT (10/17:02 MET), the Auxiliary Power Unit (APU) 2 fuel pump B-string heater circuit primary thermostat began to dither. The fuel pump B-string heater circuit thermostat cycle range shifted from a 11.2 °F control band as measured by the bypass line temperature reading to a 3.2 °F band. Following the Flight Control System (FCS) Checkout (C/O) the thermostat stopped dithering and began operating in an 11.2 °F band, which is likely due to the vibration of APU 1 which was used for FCS C/O. Dithering is a known design condition, caused by the high vibration environment, and is a typical early end-of-life indicator. There was no impact to the vehicle/mission.</p> <p>Post-flight: The dithering thermostat was replaced during normal turnaround activities.</p>
STS-119-V-11	APU 2 EGT 1 Erratic Transducer	<p>The APU 2 Turbine Exhaust Temperature (EGT) No. 1 transducer became erratic during entry and remained erratic throughout the landing. Postlanding, the EGT suddenly recovered and trended according to the expected temperature profile. There was no impact to entry or landing. This instrumentation is used for engineering information only and measures the temperature of the hot decomposed hydrazine fuel gases exiting the APU through the exhaust duct to indicate the health of the gas generator and turbine wheel assembly. The STS-119 entry signature was typical of damaged wiring insulation at the exit of the sensor, causing intermittent contact of the thermocouple wires in that location. This results in temperature readings at the point of contact. When the wires separate, readings return to normal.</p> <p>Post-Flight: The APU 2 EGT 1 sensor was removed and replaced during normal turnaround activities.</p>

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STS-119 IN-FLIGHT ANOMALIES

IFA Number	Title	Comments
STS-119-V-12	APU 3 Z-Axis Accelerometer Trending High	<p>During the higher APU loading periods of entry between Terminal Area Energy Management (TAEM) and wheel stop, the APU 3 Z-Axis Accelerometer readings were elevated with several (96 total) peak readings of Off-Scale High (OSH). All of the OSH excursions were between 0.1 and 0.2 sec in duration. This signature had no effect on APU 3 performance, which was nominal during its 1 hr 3 min 23 sec run time. The Shuttle Operational Data Book (SODB) Vol. 1 documents that an APU should not be operated for extended periods of time above 100 g's peak-to-peak in either the X or Z axis. The upper limit for the on-board instrumentation is 100 g's peak-to-peak (GP-P). The total amount of APU operation seen on the Z-axis above 100 GP-P during entry was 11.6 sec, which does not violate the SODB limit. Vibration on the X-axis was below 50 GP-P during the entire entry run. There was no impact to safety or to APU operation during the mission. This measurement provides engineering information used for long-term health monitoring and is not used for control. This particular APU has a history of higher vibration levels, though not at the level seen during entry of this flight.</p> <p>Post-Flight: APU 3 was removed and replaced, and during which the M1 attach bracket bearing was found damaged. The bracket was removed and replaced. Structural evaluation concluded that the bearing was unlikely the sole cause of the high z-axis vibration. Vibration levels at vendor testing were in-family with previous testing on this unit, although it had a historically higher vibration level than other APU's.</p>
STS-119-V-13	ET/Orbiter Umbilical LH ₂ Forward Outboard Actuator did not Retract into Mechanical Locks	<p>During OV-103 Hydraulic inspections in High Bay 3, the LH₂ Forward Outboard ET Actuator was not in the fully retracted and locked position. The retract commands were issued from the Master Events Controllers (MECs) after ET separation. The ET Retract Actuator are inspected every flow to verify the actuators retracted into the locks.</p> <p>Post-Flight: A thorough visual inspection of the wiring to the actuator was performed of both the Extend and Retract wires. Measurements were taken to verify the position of the locking fingers to the retract lock ramp. Resistance checks were also performed at the terminal board-to-actuator. The MECs were powered and extend and retract commands with clamp-on ammeter at the actuator were sent. Troubleshooting indicated that abnormal internal leakage from the supply to the return prevented the actuator from achieving full retraction. The actuator was removed and replaced.</p>

APPENDIX B

STS-119 IN-FLIGHT ANOMALIES

IFA Number	Title	Comments
STS-119-V-14	MADS Main Engine 3 Gimbal Bearing Accelerometer Data Erratic During Ascent	<p>Space Shuttle Main Engine (SSME) 3 gimbal bearing accelerometer data were erratic starting near 074/23:43:45 GMT during the start-pop time window (Engine Start + 1.15 sec to Engine Start + 1.87 sec). This is similar to a problem on STS-120 in the SSME-1 position. There was no impact to the mission as a failure of this measurement during flight causes loss of data only. This measurement is routed through the MADS FDM (Frequency Division Multiplexer) data system and is reviewed post-flight using the MADS playback data. There are no other anomalies that affect this problem.</p> <p>Post-flight: Troubleshooting isolated the problem to a wire cable on the Orbiter side of the interface. The cable was replaced and a retest of the subject measurement performed. Further troubleshooting found a loose connector with a broken epoxy bead at the input of the WBSC input. The affected wire cable was removed and replaced.</p>
STS-119-V-15	Shuttle Orbiter Repackaged Galley (SORG) Dispense Leakage	<p>During the STS-119 Crew Debriefing, the crew reported that the Re-Hydration Station (RHS) SORG consistently leaked when dispensing. The on-orbit leakage required the use of towels daily to absorb the water leakage around the cup enclosure. The crew further reported that when a gentle force was applied to further mate the RHS interface, the leakage stopped and the drink/food packages were well re-hydrated. While the cup enclosure contains any leakage, the crew can easily absorb any water leakage with towels. A similar leak was reported on this SORG, S/N 1003, during STS-124. An extensive post-flight investigation failed to re-create the leak reported by the crew.</p> <p>Post-Flight: The OV-103 integrated SORG S/N 1003 was found to have a needle without a shoulder. Per RHS drawing, this "shoulder-less" needle was supposed to fly one time on STS-65; however, it was never replaced post STS-65 and remained installed. The SORG PRT concluded that the discrepant needle is the most probable cause of the STS-119 SORG dispense leakage. The needle was replaced, and several dispenses were taken. No leakage occurred during ground testing.</p>
STS--V-16	Heads Up Display (HUD) Mini-Cam Video not Downlinked to Ground During Entry	<p>During entry, the HUD Mini-Cam video was not observed by the ground team.</p> <p>Post-Flight: The MILA ground station confirmed that there was no modulation in the downlink, indicating no video signals were present. The entire entry mini-cam video recorded onboard (approximately 2 hr) was screened and is complete with no dropouts. This confirms the successful operation of the camera, tape recorder, and video cabling/equipment. The remaining portions of the downlink equipment are the Audio/Video Interface Unit (AVIU) output, the Government Furnished Equipment (GFE) Y-power/video cable), and the Orbiter cabling to the S-Band FM signal processor. Post flight testing of the flown Y cable was successful. Subsequent vehicle testing of the HUD downlink components was completed, both separately and back in the vehicle, and all test results were nominal. The team 'wiggled' the Y cable for both the STS-128 and STS-119 configurations, and no video dropouts were noted. This is considered an unexplained anomaly.</p>

**APPENDIX B
STS-119 IN-FLIGHT ANOMALIES**

SOLID ROCKET BOOSTER

IFA Number	Title	Comments
STS-119-B-001	Ten-Second Delay Cutters from Lot ACF Functioned Early.	<p>During the Solid Rocket Booster (SRB) recovery phase of launch, at least one of the first stage 10-sec Delay Cutters from Lot ACF did not function within the $\pm 10\%$ of the average delay time for Lot ACF (8.87 sec minimum). The two 10-Second Delay Cutters were installed on Left-Hand Main Parachute no. 3. Using onboard video and accelerometer data, the function time (cutting the reefing line) was determined to be within a range of 8.68 to 8.89 sec. The average delay times (at ambient, high, and low temperatures) for original Lot Acceptance Testing (LAT) of Lot ACF were as follows:</p> <ol style="list-style-type: none">1. Ambient temperature of 9.86 sec.2. Low temperature of 10.46 sec.3. High temperature of 9.19 sec.

**APPENDIX B
STS-119 IN-FLIGHT ANOMALIES**

REUSABLE SOLID ROCKET MOTOR

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

APPENDIX B
STS-119 IN-FLIGHT ANOMALIES
SPACE SHUTTLE MAIN ENGINE

No Space Shuttle Main Engine anomalies were identified during the review and analysis of the data.

APPENDIX B STS-119 IN-FLIGHT ANOMALIES

EXTERNAL TANK

IFA Number	Title	Comments
STS-119-T-001	During Initial Launch Attempt of STS-119/ET-127, a GH ₂ Leak was Detected at Approximately One Minute after Start of LH ₂ Topping	During the initial launch attempt of STS-119/ET-127, a GH ₂ leak was detected at approximately 1 min after start of LH ₂ topping. The leak detectors LD23 and LD25 (umbilical) indicated leakage greater than 60,000 parts per million (ppm) at 3 min into LH ₂ topping. This is a HAZ-09 Launch Commit Criteria (LCC) violation. The LCC limit is 40,000 ppm. The measuring capability of the instrumentation was exceeded. Initial troubleshooting revealed that the lower half of the ET Flight seal, which interfaces between the 7-inch Quick Disconnect (QD) bellows and ET, had deformations from the 5:00 to 7:00 positions. The seal and 7 inch QD were removed and replaced. There were no leaks during the second launch attempt.

APPENDIX B STS-119 IN-FLIGHT ANOMALIES

SYSTEM ENGINEERING AND INTEGRATION

IFA Number	Title	Comments
STS-119-I-001	Unexpected and Expected Debris Exceeding Mass Allowable Prior to Pad Clearance (Liftoff Debris)	STS-119 experienced unexpected debris and expected debris exceeding the mass allowables prior to pad clearance. Post-flight investigation identified several areas for improvement. This Integration In-Flight Anomaly (IIFA) was closed outside of board for the Shuttle Integration Control Board (SICB) on April 17, 2009, based on the following rationale. The 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 was mitigated for identified potential sources of critical debris by performing repairs and adding inspections for system-level components (e.g. camera flame deflector bolts, conduit clamp, and bolts on the elevator machine room walls). Ongoing mitigations include Foreign Object Debris (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.
STS-119-I-002	LH ₂ Leak at ET Ground Umbilical Carrier Plate	During the first launch attempt for STS-119 (March 11, 2009) hydrogen leak detectors 23 and 25, which are located at the External Tank (ET) Ground Umbilical Carrier Plate (GUCP) interface, were observed to have leakage exceeding 60,000 ppm when the LH ₂ fill flow-rate transitioned from fast-fill to topping. The Launch Commit Criteria (LCC) Hazard limit is 40,000 ppm. During the subsequent 96-hour recycle, the ET Mechanical personnel disassembled the GUCP and found the flight seal had deformations between the 5:00 to 7:00 o'clock position. The GUCP Quick Disconnect (QD) and flight seal were removed and replaced (R&R'd) using an improved technique and the new installation was successfully retested. On the second launch attempt (March 15, 2009), no leaks were detected at tank transition from fast-fill to topping. A detailed fault tree investigation was established. Seals for the STS-125 and 127 QD were selected from available spares and installed using the inspection-intensive technique used for STS-119. Both were installed and verified leak-free.

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STS-119 IN-FLIGHT ANOMALIES

IFA Number	Title	Comments
STS-119-I-003	MPS LH ₂ Orbiter Umbilical Plate Gap Pressure LCC Violation	<p>During pre-launch operations for the STS-119 second launch attempt, three of four LH₂ ET/Orbiter plate-gap differential purge sensors (two low-fidelity and one high-fidelity) read a low delta pressure, which violated the LCC MPS minimum pressure limit of 0.026-psid. The LCC requires three of four sensors above this limit. The plate-gap supply pressure was increased and the differential pressure measurements increased to approximately 0.07 psid. An LCC waiver was written to approve the LCC violation and to identify that only the two high-fidelity measurements must remain above the LCC limit for the remainder of the countdown. The LCC violation was deemed acceptable since the plate-gap pressure was positive at all times, meeting the intent of the redline derivation of LCC. No additional violations occurred during the remainder of the launch countdown. Postflight, the LCC was updated to retain plate-gap measurement insight while removing measurement conservatism. Also, the update defined instrumentation priority [high range, low range, Ground Support Equipment (GSE)], and it added an auxiliary purge pre-plan.</p>
STS-119-I-004	Partial F4D Tyvek Release	<p>During ascent, the parachute portion of the Forward Reaction Control System (FRCS) thruster F4D Tyvek cover released at 5 sec MET (approx 93 ft/sec) and the remaining piece of the cover released at approximately 17 sec MET (370 ft/sec), exceeding the certification requirement of 170 mph. The F4D Tyvek remnant that released at 17 sec was measured as approximately 2-in. by 7.4-in., and the mass was estimated to be between 6 and 10 grams. Imagery showed the remnant did not impact the Orbiter and no in-flight action was required. This failure mode has been seen on many previous flights. Based on recent flight experience, the probability of failure for the current Tyvek cover design is high. Tyvek failures are not well understood since there is generally no physical evidence post launch and imagery resolution is insufficient to see detail. These factors make determining the actual failure-root-cause that could lead to a successful redesign of the F3D and F4D covers very unlikely. Post-flight debris transport analysis and impact testing (up to 10g at 1000 ft/sec on the Reinforced Carbon-Carbon (RCC) demonstrated that the Tyvek remnants have a very low likelihood of impacting the Orbiter with sufficient velocity to cause damage. Efforts are underway to develop an alternate rain-cover concept for the FRCS F3D and F4D thrusters.</p>

APPENDIX B STS-119 IN-FLIGHT ANOMALIES

IFA Number	Title	Comments
STS-119-I-005	Stub Tile Damage	<p>On FD 3, inspection imagery revealed damage to a stub tile above the elevon. There is no allowable for stub tile debris in the Program documentation. This damage was cleared for entry by the Debris Assessment Team (DAT) without additional inspection. Post-flight inspections confirmed that the damage to the over-hanging portion of the tile was similar to the damage on STS-117 and STS-123 flights. No thermal degradation to the Thermal Protection System (TPS) or structural components was observed. After carrier panel removal, a closer inspection of the tile showed an in-plane crack above the densification layer. During manipulation, the crack propagated. The aft Felt Reusable Surface Insulation (FRSI) edge member continued to retain the tile to the carrier panel. This tile is located in an area of relatively high traffic, and preflight work in this area is considered to be a potential cause for damage initiation. To prevent tile damage from going undetected, documentation was written to perform a micro/tactile inspection on the launch pad specifically looking for cracks that extend into the tile substrate.</p> <p>The TPS Problem Resolution Team (PRT) assessment is that the potential failure mode(s) associated with this problem could not result in a critical or catastrophic effect. Flight experience has shown that at various locations along the interface, the entire overhang portion can be missing with no adverse effect on TPS, structure, or internal components.</p>

APPENDIX B
STS-119 IN-FLIGHT ANOMALIES

FLIGHT SOFTWARE

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

APPENDIX B STS-119 IN-FLIGHT ANOMALIES

FLIGHT OPERATIONS AND INTEGRATION

IFA Number	Title	Comments
STS-119-N-01	Vernier RCS Elevated Propellant Usage following ISS CMG Saturation	<p>During the second EVA (FD 7), the ISS experienced Control Moment Gyro (CMG) saturation and a subsequent Loss of Attitude Control (LOAC). Attitude control was handed to the Orbiter for approximately 5 hr, during which time the actual VRCS propellant usage was approximately two times what was expected (6 lb/hr vs. 13 lb/hr). The extra propellant usage was a concern due to an already propellant-tight flight. The presence of the crew and the Mobile Transporter (MT) at the end of the truss were believed to be the likely cause of the CMG saturation.</p> <p>Post-flight: Analyses by Draper & Boeing verified that the ISS CMG mode was DRIFT Local Vertical-Local Horizontal (LVLH), and that this mode places a continual disturbance on the stack. These simulations demonstrated that the ISS CMG disturbance accounts for the difference in the propellant usage. The GN&C community is making the Orbiter and ISS community aware of this effect, and will add recommendations to DAP Modes on CMG moding. In addition, Boeing created a JMEWS monitoring aid for CMG control.</p>

**APPENDIX B
STS-119 IN-FLIGHT ANOMALIES**

MISSION OPERATIONS

IFA Number	Title	Comments
STS-119-D-001	Inadvertent Abort Light Command Sent From FDO Workstation	At approximately 074/18:02 GMT, an abort light indicator command was issued from the Flight Dynamics Officer (FDO) workstation to the Orbiter. No impact occurred from this command as the Orbiter was still on the pad and the crew had not yet ingressed. The role of the command is for ground controllers to illuminate the onboard abort indicator light.

APPENDIX C

DOCUMENT SOURCES

MER DAILY REPORTS

The following STS-119 MER Daily Reports by David S. Moyer, Lead MER Manager:

First Daily Report (Ascent Plus 2-Hour Report), dated March 15, 2009
Second Daily Report, dated March 16, 2009
Third Daily Report, dated March 17, 2009
Fourth Daily Report, dated March 18, 2009
Fifth Daily Report, dated March 19, 2009
Sixth Daily Report, dated March 20, 2009
Seventh Daily Report, dated March 21, 2009
Eighth Daily Report, dated March 22, 2009
Ninth Daily Report, dated March 23, 2009
Tenth Daily Report, dated March 24, 2009
Eleventh Daily Report, dated March 25, 2009
Twelfth Daily Report, dated March 26, 2009
Thirteenth Daily Report, dated March 27, 2009
Fourteenth Daily Report, dated March 28, 2009
Landing Plus 2 Hour Report, dated March 28, 2009
Mission Summary Report, dated March 31, 2009

ET/SRB/RSRM/SSME REPORTS

STS-119 Anomalies, David W. Morr, USA-Huntsville, June 8, 2009
STS-119 External Tank Impact Data, David W. Morr, USA-Huntsville, June 8, 2009
STS-119 MSFC Console Flash Report, Charles E. Martin, USA-Huntsville, March 15, 2009
STS-119 RSRM Flash Report, Dave Guttman, Boeing-KSC, March 16, 2009

ORBITER REPORTS

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STS-119 Descent Postflight Summary, Shawna Frame, NASA-JSC, April 24, 2009
STS-119 Displays and Controls and Lighting Report, J. E. Cornejo, Boeing-Houston, April 20, 2009
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STS-119 OI/MADS MUX and Timing Report, Bruce S. Woods, Boeing-Houston, April 15, 2009
STS-119 Data Processing System Integrated Report, Daniel A. Wood, Boeing-Houston, April 16, 2009
STS-119 EPDC Mission Report, William D. Peterson, Boeing-Houston, April 13, 2009
STS-119 ATCS Post-Flight Mission Report, Carmelo Asuncion, Boeing-Houston, April 17, 2009

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STS-119 Orbiter Docking System Summary, Robert E. Davis, NASA-JSC, April 15, 2009
STS-119 OMS Report, Donald E. Varanauski, Boeing-Houston, April 17, 2009
STS-119 RCS Mission Report, James M. Garza, Boeing-Houston, April 17, 2009
STS-119 Final Aeroheating Report, Kuo Wang, Boeing-Houston, April 1, 2009
STS-119 Fuel Cells Mission Report, Johnny D. Wong, Boeing-Houston, April 17, 2009.
STS-119 Global Positioning System Report, Ray Nuss, NASA-JSC, April 8, 2009
STS-119 Thermal Control System Summary, Dan Reynolds, Boeing-Houston, May 4, 2009
STS-119 Purge, Vent and Drain Report, C. C. Heinol, Boeing-Houston, April 8, 2009
STS-119 Flight Controls and ADTA Mission Report, Donald E. Marquith, Boeing-Houston, April 14, 2009
STS-119 Final Mission Events List, Vernon C. Hill, ESCG-Houston, March 15, 2009
STS-119 WLE IDS Post Flight Report, Jennifer C. Hodge, Boeing-Houston, June 12, 2009
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STS-119 Orbiter Debris Assessment, Thomas F. Ford, NASA-KSC, March 30, 2009
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STS-119 EVA 3 Summary Report, Alicia E. Ruiz, Hamilton Sundstrand, March 23, 2009
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STS-119 Final Extravehicular Activity Report, David A. Foltz, NASA-JSC, May 27, 2009
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STS-119 L-1 Day Walk Down, Thomas F. Ford, NASA-KSC, March 14, 2009
STS-119 By The Numbers, David S. Moyer, NASA-JSC, April 13, 2009
STS-119 Imagery Integration Daily Reports, David Melendrez, NASA-JSC, March 16-20, 2009
STS-119 Mission Operations Directorate Anomalies, Gregory Lange, NASA-JSC, June 8, 2009
STS-119 Post-Drain Inspection, Thomas F. Ford, NASA-KSC, March 11, 2009

APPENDIX D

STS-119 ACRONYMS, ABBREVIATIONS, AND UNITS OF MEASURE

Acronym/ Abbreviation	Explanation
A	Ampere
AA	Accelerometer Assembly
ABS	Ammonia Boiler System
ADTA	Air Data Transducer Assembly
AFPR	Articulating Portable Foot Restraint
AHMS	Advanced Health Monitoring System
APCA	Aft Power Control Assembly
APCU	Auxiliary Power Converter Unit
APU	Auxiliary Power Unit
ARPCS	Atmospheric Revitalization Pressure Control System
ATCS	Active Thermal Control System
AVIU	Audio Visual Interface Unit
BBC	Bolt Bus Controller
BET	Best Estimate Trajectory
BFS	Backup Flight System
BGA	Beta Gimbal Assembly
BITE	Built-In Test Equipment
BLT	Boundary Layer Transition
C&W	Caution and Warning
CDR	Commander
CDT	Central Daylight Time
CETA	Crew Equipment Translation Assembly
CGBA	Commercial Generic Bioprocessing Apparatus
CO ₂	Carbon Dioxide
CMG	Control Moment Gyroscope
C/O	Checkout
COMM	Communications
CSI	CGBA Science Insert
CWC	Contingency Water Container
D & C	Display and Control
DAP	Digital Autopilot
DAT	Debris Assessment Team
DCS	Debris Containment System
DDU	Data Display Unit
DESIG	Designate
DET	Data Elapsed Time
DMHS	Dome Mounted Heat Shield
DTN	Data Trend Notice

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STS-119 ACRONYMS, ABBREVIATIONS, AND UNITS OF MEASURE

Acronym/ Abbreviation	Explanation
DETTPS	Digital External Tank Thermal Protection System (Camera)
DPS	Data Processing System
DTA	Debris Transport Analysis
DTO	Development Test Objective
ΔP	Differential Pressure
ΔV	Differential Velocity
ECLSS	Environmental Control and Life Support System
ECO	Engine Cut-off
ECU	Electronic Control Unit
E	East
EE	End Effector
EFGF	Electrical Flight Grapple Fixture
EGT	Exhaust Gas Temperature
EI	Entry Interface
E/O	External Tank/Orbiter
EOM	End-of-Mission
EPDC	Electrical Power Distribution and Control
ET	External Tank
EV	Extravehicular (Crewmember)
EVA	Extravehicular Activity
FCE	Flight Crew Equipment
FCMS	Fuel Cell Monitoring System
FCS	Flight Control System
FCV	Flow Control Valve
FD	Flight Day
FDO	Flight Dynamics Officer
FE	Flight Engineer
FES	Flash Evaporator System
FHRC	Flex Hose Rotary Coupler
FI	Focused Inspection
FID	Failure Identifier
FN	Flight Night
FOM	Figure of Merit
FOV	Field of View
FPCA	Forward Power Control Assembly
FRCS	Forward Reaction Control System
FRR	Flight Readiness Review
FSS	Fixed Service Structure

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STS-119 ACRONYMS, ABBREVIATIONS, AND UNITS OF MEASURE

Acronym/ Abbreviation	Explanation
FSW	Flight Software
G or g	Gravity
GAPS	Group Activation Packs
GCA	Ground Carrier Assembly
GFE	Government Furnished Equipment
GH ₂	Gaseous Hydrogen
GLACIER	General Laboratory Active Cryogenic ISS Experiment Refrigerator
GMT	Greenwich mean time
GN&C	Guidance, Navigation and Control
GN ₂	Gaseous Nitrogen
GO ₂ /GOX	Gaseous Oxygen
GPC	General Purpose Computer
GPS	Global Positioning System
Grms	Gravity root mean square
GSE	Ground Support Equipment
GUCP	Ground Umbilical Carrier Plate
H ₂	Hydrogen
HDP	Holddown Post
HPFTP	High Pressure Fuel Turbopump
HPOTP	High Pressure Oxidizer Turbopump
HUD	Heads-up Display
HYD	Hydraulic
ICHX	Interchanger Heat Exchanger
IDP	Integrated Display Processor
IDT	Image Dissector Tube
IFA	In-Flight Anomaly
IFM	In-Flight Maintenance
IMU	Inertial Measurement Unit
I/O	Input/Output
IPR	Interim Problem Report
IR	Infrared
ISS	International Space Station
ITS	Integrated Truss Segment
ITVC	Intensified Television Camera
IWIS	ISS Wireless Instrumentation System
JAXA	Japanese Aerospace Exploration Agency
JLP	Japanese Experiment Logistics Module – Pressurized

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Acronym/ Abbreviation	Explanation
KSC	Kennedy Space Center
L	Launch
Lada-MIS ORZS	Optimization of Root Zone Substrates
LCC	Launch Commit Criteria
LDRI	Laser Dynamic Range Imager
LEE	Latching End Effector
LH	Left Hand
LH ₂	Liquid Hydrogen
LiOH	Lithium Hydroxide
LO ₂ /LOX	Liquid Oxygen
LP	Left Pod/Launch Package
MADS	Modular Auxiliary Data System
MAUI	Maui Analysis of Upper Atmospheric Modification
Max Q	Maximum Dynamic Pressure
MBS	Mobile Base System
MC	Midcourse Correction
MDM	Multiplexer/Demultiplexer
MEC	Master Events Controller
MECO	Main Engine Cutoff
MEDS	Multifunction Electronics Display System
MET	Mission Elapsed Time
MILA	Merritt Island Launch Area
MLG	Main Landing Gear
MLI	Multilayer Insulation
MLP	Main Launch Platform
MLS	Microwave Landing System
MM/OD	MicroMeteoroid/Orbital Debris
MMT	Mission Management Team
MPCA	Mid Power Control Assembly
mph	mile per hour
MPM	Manipulator Positioning Mechanism
MPS	Main Propulsion System
MS	Mission Specialist
MSFC	Marshall Space Flight Center
MSU	Mass Storage Unit
MT	Mobile Transporter
MTU	Master Timing Unit
N ₂	Nitrogen

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STS-119 ACRONYMS, ABBREVIATIONS, AND UNITS OF MEASURE

Acronym/ Abbreviation	Explanation
NASA	National Aeronautics and Space Administration
NAV	Navigation
NAVAID	Navigation Aids
NC	Nominal Correction
NCC	Nominal Correction Combination
NE	Northeast
NH	Nominal Height
NLP	National Laboratory Pathfinder
NSTS	National Space Transportation System
O ₂	Oxygen
OAA	Orbiter Access Arm
OBSS	Orbiter Boom Sensor System
ODS	Orbiter Docking System
OI	Operational Instrumentation
OME	Orbital Maneuvering Engine
OMRSD	Operational Maintenance and Requirements Specification Document
OMS	Orbital Maneuvering System
OPCU	Orbiter Power Converter Unit
OPO	Orbiter Project Office
OPS	Operations
ORGA	Orbiter Rate Gyro Assembly
OSL	Off-Scale Low
OSH	Off-Scale High
P	Port
PAS	Payload Attachment System
PASS	Primary Avionics Software System
PCDF-PU	Protein Crystallization Diagnostic Facility Processing Unit
PCM	Pulse Code Modulation
PCMMU	PCM Master Unit
PCTAP	Personal Computer Based Thermal Analyzer Program
PCS	Pressure Control System
PDGF	Power and Data Grapple Fixture
PDI	Payload Data Interleaver
PDU	Power Drive Unit
PGME	Propylene Glycol Monomethyl Ether
PGSC	Payload and General Support Computer
PI	Principal Investigator

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STS-119 ACRONYMS, ABBREVIATIONS, AND UNITS OF MEASURE

Acronym/ Abbreviation	Explanation
PLBD	Payload Bay Door
PMA	Pressurized Mating Adapter
PMBT	Propellant Mean Bulk Temperature
PPS	Primary Power System
PRSD	Power Reactant Storage and Distribution System
PRT	Problem Resolution Team
PSIG	Propellant Systems Integration Group
PTU	Power Transfer Unit/Pan-Tilt Unit
PV&D	Purge, Vent and Drain
PWR	Payload Water Reservoir
QD	Quick Disconnect
RCC	Reinforced Carbon-Carbon
RCS	Reaction Control System
RH	Right Hand
RHC	Rotational Hand Controller
RHS	Rehydration System
RJD	Reaction Jet Driver
RM	Redundancy Management
RP	Right Pod
RPC	Remote Power Controller
RPM	R-Bar Pitch Maneuver
RSB	Rudder Speed Brake
RSRM	Reusable Solid Rocket Motor
RSS	Range Safety System
RTV	Room Temperature Vulcanizing (material)
S	South/Starboard
S&A	Safe and Arm
SABB	Solar Array Blanket Box
SAIL	Shuttle Avionics Integration Laboratory
SAW	Solar Array Wing
SDBI	Short Duration BioAstronautics Investigations
SDFS	Smoke Detection and Fire Suppression
SE	Southeast
SEITE	Shuttle Engine Ion Turbulence Experiment
SIMPLEX	Shuttle Ionospheric Modification/Pulsed Local Exhaust
SLWT	Super Lightweight Tank
SMRD	Spin Motor Rotation Detector
S/N	Serial Number

APPENDIX D

STS-119 ACRONYMS, ABBREVIATIONS, AND UNITS OF MEASURE

Acronym/ Abbreviation	Explanation
SODB	Shuttle Operational Data Book
SORG	Shuttle Orbiter Repackaged Galley
SRB	Solid Rocket Booster
SRGA	Station Rate Gyro Assembly
SRMS	Shuttle Remote Manipulator System
SRSS	Shuttle Range Safety System
SSARJ	Starboard Solar Array Rotary Joint
SSAS	Segment-to-Segment Attachment System
SSME	Space Shuttle Main Engine
SSP	Space Shuttle Program
SSPTS	Station-to-Shuttle Power Transfer System
SSRMS	Space Station Remote Manipulator System
SSU	Sequential Shunt Unit
SSV	Space Shuttle Vehicle
ST	Star Tracker
STBD	Starboard
STS	Space Transportation System
SW	Southwest
SWMMS	Supply Water and Waste Management System
TACAN	Tactical Air Navigation System
TBO	Time Between Overhaul
TCS	Thermal Control System/Trajectory Control Sensor
TAEM	Terminal Area Energy Management
TEA	Torque Equilibrium Attitude
THC	Translation Hand Controller
TI	Terminal Phase Initiation/Transfer Initiation
TIG	Time of Ignition
T-0	Time of Ignition
TPL	Transfer Priority List
TPS	Thermal Protection System
TSM	Tail Service Mast
TVC	Thrust Vector Controller
TVIS	Treadmill with Vibration Isolation and Stabilization
UCCAS	Unpressurized Cargo Carrier Attachment System
V	Volt
VDC	Voltage Direct Current
VDT	Vehicle Data Table
VRCS	Vernier Reaction Control System

APPENDIX D

STS-119 ACRONYMS, ABBREVIATIONS, AND UNITS OF MEASURE

Acronym/ Abbreviation	Explanation
WCL	Water Coolant Loop
WIF	Worksite Interface Fixture
WLE	Wing Leading Edge
WLEIDS	Wing Leading Edge Impact Detection System
WLES	Wing Leading Edge Subsystem
WMC	Waste Management Compartment
WSB	Water Spray Boiler

APPENDIX D

STS-119 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
keas	knots estimated air speed
Kgs	knots ground speed
kW	Kilowatt
kWh	Kilowatt hour
lb	pound
lb/hr	pound per hour
lb _m /lbm	pound mass
lb/min	pound per minute
lb _m /hr	pound per hour
min	minute
mph	miles per hour
M/E	meter/second
nmi	nautical mile
%	percent
%/min	percent per minute
ppCO ₂	partial pressure carbon dioxide
ppm	parts per million
psi	pound per square inch
psia	pound per square inch absolute
psid	pound per square inch differential
psig	pound per square inch gravity
psi/hr	pound per square inch per hour
psi/min	pound per square inch per minute
scim	standard cubic inch per minute
sec	second
Vdc	Volt direct current