

STS-121 SPACE SHUTTLE MISSION REPORT

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**National Aeronautics and
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STS-121

SPACE SHUTTLE MISSION REPORT

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STS-121 SPACE SHUTTLE MISSION REPORT

INTRODUCTION

The Space Transportation System (STS) -121 Space Shuttle Mission Report presents a discussion of the Orbiter activities on the mission, as well as a summary of the External Tank (ET), the Solid Rocket Booster (SRB), the Reusable Solid Rocket Motor (RSRM) and the Space Shuttle Main Engine (SSME) performance during this 115th mission of the Space Shuttle Program. STS-121 was a dual purpose mission for flight testing Space Shuttle subsystems and delivering supplies to the International Space Station (ISS).

STS-121 was the 18th mission to the ISS, and the second mission following the loss of the STS-107 Orbiter and crew. STS-121 was also the 32nd flight of the OV-103 *Discovery* vehicle.

The flight vehicle consisted of the OV-103 Orbiter; the External Tank (ET), which was a super lightweight tank (SLWT) designated ET-119; three Block II SSMEs that were designated as serial numbers (S/Ns) 2045, 2051, and 2056 in positions 1, 2, and 3, respectively; and two SRBs that were designated B1-126. The two RSRMs were designated flight set RSRM-93. The individual RSRMs were S/N 360W093A and S/N 360W093B. Launch pad 39B and Mobile Launch Platform (MLP) 1 were used as the platform for launch of the STS-121 mission.

The primary objectives of the STS-121 mission were as follows:

- Demonstrate the capability to inspect all of the Orbiter reinforced carbon-carbon (RCC) panels and Thermal Protection System (TPS) tiles.
- Transfer water from the Shuttle to the ISS
- Augment the ISS with a third crew member
- Perform three extravehicular activities (EVAs)
- Replace Trailing Umbilical System (TUS) Reel Assembly on the ISS
- Evaluate EVA crewmember stabilization while positioned on the Orbiter Boom Sensor System (OBSS)
- Berth the Multi-Purpose Logistics Module (MPLM) to the ISS
- Transfer logistical assets and supplies to the ISS.

Other objectives included performing DTO 850 – Water Spray Boiler (WSB) cooling with water/propylene glycol Monomethyl ether (PGME) mixture, transfer and install the Oxygen Generation System (OGS) rack, transfer and install the Minus Eighty-Degree Laboratory Freezer (MELFI) rack, transfer and install the starboard common cabin air assembly (CCAA) heat exchanger, and Recharge Oxygen Orifice Bypass Assembly (ROOBA) checkout.

STS-121 included the capabilities developed for STS-114 to monitor for released debris during ascent and any subsequent impacts to the Orbiter Thermal Protection System (TPS). The monitoring capabilities included ground-based cameras, External Tank (ET)-based cameras, radar, and wing leading edge (WLE) impact detection instrumentation. This was the second flight of the Orbiter Boom Sensor System (OBSS), which enabled robotic on-orbit inspections of all areas of the Orbiter TPS. In addition, an R-bar pitch maneuver (RPM) was performed during the rendezvous with the ISS so that the ISS crew could photograph the Orbiter.

STS-121 was the first flight to implement a vehicle modification which provided the capability to downlink low-rate Modular Auxiliary Data System (MADS) during a mission. The MADS ascent data were successfully downlinked during the Orbit period, and MADS entry data was successfully transmitted while on the runway post-landing.

The STS-121 flight was planned to be a 12-day plus 2-contingency-day flight. An additional docked day was approved during the flight by the Mission Management Team (MMT) because consumables were available. Two contingency days were available for landing weather avoidance or other Orbiter contingencies. None of the contingency days were required to be used because landing occurred on the first attempt at Kennedy Space Center.

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, SSME, SRB, RSRM, ET, System Engineering and Integration and Flight Operations and Integration (Payload) in-flight anomalies (IFA's) 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 and abbreviations and definition as used throughout this report.

The seven crewmembers that were on the STS-121 flight were Steven W. Lindsey, Colonel, U. S. Air Force, Commander; Mark E. Kelly, Commander, U. S. Navy, Pilot; Michael E. Fossum, Civilian, Mission Specialist 1; Lisa M. Nowak, Commander, U. S. Navy, Mission Specialist 2; Stephanie D. Wilson, Civilian, Mission Specialist 3; Piers J. Sellers, PhD, Civilian, Mission Specialist 4; and Thomas Reiter, Civilian, European Space Agency, Mission Specialist 5.

STS-114 was the fourth flight for the Commander, the second Space Shuttle flight for the Pilot, and Mission Specialist 4, the first space flight for Mission Specialist 1, Mission Specialist 2, and Mission Specialist 3. STS-121 was the first Space Shuttle flight for Mission Specialist 5, who supplemented the ISS Expedition 13 crew. In addition, Mission Specialist 5 performed a 179-day mission on the MIR Space Station during the 1995-1996 time period.

MISSION SUMMARY

Pre-Launch

The first launch attempt of the STS-121 vehicle on July 1, 2006, was scrubbed for 24 hr to July 2nd during the T-9 min hold because of unacceptable weather conditions around the launch site.

During the first countdown, the Reaction Control System (RCS) vernier thruster L5L heater failed off at approximately 181/23:15 GMT during the launch countdown (STS-121-V 01). The minimum equipment list required all six vernier thrusters be operational for launch, and flight rules require all six thrusters be operational for vernier control while docked to the International Space Station (ISS); however, primary thrusters can be used for control as required for rendezvous or mated operations. The remaining five vernier thrusters were sufficient for Orbiter-alone control operations.

The second launch attempt on July 2nd was also scrubbed because of unacceptable weather conditions. A 48-hr turnaround was initiated to support a July 4th launch attempt.

During each of the loading attempts, the External Tank (ET) liquid hydrogen 5-percent fill-point sensor failed wet when commanded to the dry-state during the prelaunch simulation commands (STS-121-I-006). During the two detanking operations, this sensor was slow to transition to the dry indication. A failed-wet condition of this sensor is acceptable for flight, as it is used only during loading, detanking and post-flight reconstruction purposes.

Following the July 2nd scrub, a 5-in long piece of ET thermal protection system (TPS) foam was found on the Mobile Launch Platform (MLP) deck. Also, TPS damage was noted between the liquid oxygen feedline and feedline brackets 2 and 3. The source of the piece of TPS was to a previously identified 5-in crack with a ¼ in offset at station 1129 of the ET on the inboard side of the feedline bracket. Analysis of the damaged area showed the condition was acceptable for flight and the anomaly was closed.

A second TPS damage site involved a tear in the foam at the gap between the fairing and the ET/Solid Rocket Booster (SRB) cable tray. The tear was 2-in long and ½-in wide at the widest point. No mist or cryogenic pumping was noted at that site. After analysis of this condition, it was determined acceptable for flight because of its aft location and estimated mass.

Ascent and Flight Day 1

The STS-121 mission was launched on the third attempt at 185/18:37:54.987 GMT on July 4, 2006, on the eighteenth Space Shuttle Program (SSP) mission to the International Space Station (ISS), and all systems performed nominally during ascent.

During ascent, the MPS engine 3 inlet pressure showed erratic performance and a pressure drift of 4 psi. The shift began at the end of the thrust bucket and lasted until MECO (STS-121-V-12).

An Orbital Maneuvering System (OMS) assist maneuver was performed following SRB separation. OMS ignition occurred at 185/18:40:07.8 GMT [00/00:02:12.8 Mission Elapsed Time (MET)] and the OMS firing was 149.2 sec in duration.

Main engine cutoff (MECO) occurred at 185/18:46:25.03 GMT (00/00:08:30.116 MET). The Orbiter separated from the ET approximately 21 sec later.

The OMS-2 maneuver was performed at 185/19:15:55.2 GMT (00/00:38:00.225 MET) and was 64.7 sec in duration. The differential velocity (ΔV) was 98.7 feet per second (ft/sec), and the orbit achieved was 85.1 by 124.4 nmi.

Development Test Objective (DTO) 850, Water Spray Boiler (WSB) Cooling with Water/Propylene Glycol Monomethyl Ether (PGME) Antifreeze, was performed using Auxiliary Power Unit (APU) 3. DTO 850 demonstrated for the second consecutive flight the ability to perform a WSB "Hot Re-Start" with PGME/water and the ability to provide APU lubrication oil cooling as soon as 3.5 hr MET.

At 185/20:27 GMT (00/01:49 MET), the Flash Evaporator System (FES) shut down in Primary B Controller full-up mode (high-load and topping cores being operated) (STS-121-V-14). The primary A and secondary controllers were operational. Prior to this event, the FES had been switched from Primary A controller full-up to Primary B controller full-up as part of procedures for supply- water accumulation to support water transfers to ISS. Both Freon loops were configured to radiator flow and the Payload Bay (PLB) doors were opened. Prior to the shutdown, three anomalous temperature excursions occurred. After the shutdown, the FES was switched to Primary B topping mode at 185/20:29 GMT (00/01:51:06 MET), providing stable control of the system. At 185/23:02 GMT (00/04:24:06 MET), the FES core flush procedure was initiated, beginning with the flushing of the topping core and followed by flushing of the high-load core. No indications of ice were observed during the flushing. The FES was left in Primary A topping controller until docking, and the FES was deactivated. A post-undocking troubleshooting plan was begun.

At approximately 185/23:54:54 GMT (00/05:17 MET), the crew reported a leak in the Personal Hygiene Hose (PHH) (STS-121-V-02). The crew stated that the leak was at the dispenser end of the hose, although not out of the end of the dispenser. As a workaround, the PHH was replaced with the spare hose and the contingency water dispenser.

The Remote Manipulator System (RMS) on-orbit initiation procedure was completed. The RMS was powered-up and placed in the pre-cradle position.

Flight Day 2

The OMS-3 (NC-2) maneuver was a dual-engine firing with an ignition time of 186/10:53:31.012 GMT (00/16:15:36.025 MET) and a cutoff time of 186/10:53:55.012 GMT (00/16:16:00.025 MET). The duration of the firing was 24.0 sec with a ΔV of 36.7 ft/sec. The resulting orbit was 85.6 by 140.2 nmi.

The Orbiter Docking System (ODS) was powered up and ring extension to the initial position was nominal.

The OMS-4 (NC-3) maneuver was a dual-engine firing with an ignition time of 186/21:45:59.212 GMT (01/03:08:04.225 MET) and a cutoff time of 186/21:47:47.212 GMT (01/03:09:52.225 MET). The duration of the firing was 108.0 sec with a ΔV of 168.6 ft/sec. The resulting orbit was 134.7 by 183.5 nmi.

The RCS Vernier Thruster L5L was reselected to be available for the ISS rendezvous. The thruster operated satisfactorily on its first firing after being reselected, and the thruster remained available for rendezvous and docking operations.

The RMS checkout was completed with nominal results. The unberthing of the OBSS (Orbital Boom Sensor System) was nominal. The Integrated Sensor Inspection System (ISIS) sensors were checked and all sensors provided good data and were in excellent condition.

The Laser Dynamic Range Imager (LDRI) scanned both Wing Leading Edges (WLE's) and the nose cap. The port-side LDRI Active Common Attach System (ACAS) inspection began at 186/17:34:52 GMT (00:22:56:57 MET). The full procedure was completed without incident. The OBSS was berthed where it remained until after docking on Flight Day (FD) 3.

A gap-filler adjacent to port Radial Carbon Carbon (RCC) panels 16/17 was documented as protruding (STS-121-V-04). No other issues were identified for Thermal Protection System (TPS).

The operation of the Trajectory Control Sensor (TCS) was nominal in preparation for ISS docking. The Handheld Lidar (HHL) failed to function (STS-121-V-03), but once the cable was replaced with a spare cable, the HHL checkout was nominal.

Flight Day 3

The OMS-5 (NC-4) maneuver was a dual-engine firing with an ignition time of 187/10:32:59.612 GMT (01/03:08:04.225 MET) and a cutoff time of 187/10:33:44.412 GMT (01/03:55:48.225 MET). The duration of the firing was 44.8 sec with a ΔV of 70.8 ft/sec. The resulting orbit was 171.7 by 185.3 nmi.

The OMS-6 TI (Terminal Initiation) maneuver was a single-engine firing (left engine) with an ignition time of 187/12:04:46.212 GMT (01/17:26:25.325 MET) and a cutoff time of 187/12:05:03.012 GMT (01/00:16.8 MET). The duration of the firing was 16.8 sec with a ΔV of 13.1 ft/sec. The resulting orbit was 176.3 by 189.7 nmi. Engine performance was nominal.

The Ku-Band pre-rendezvous radar self-test was performed and the system was placed in the radar mode. The system immediately acquired and locked on to the ISS at a range of 131,778 ft (approximately 22.0 nmi). The Ku-Band radar tracked the ISS until the configuration was changed to the communications mode at a range of 280 ft.

The operation of TCS was nominal for the rendezvous and docking activities. The TCS acquired the ISS in the pulsed-laser mode at 3120 ft and a closing velocity of -3.92 ft/sec. The TCS lost track during the R-Bar Pitch Maneuver (RPM), as expected, and began tracking again in CW mode at the low-power level (distance of 468 ft and a closing velocity of -0.46 ft/sec). The TCS continued tracking in this mode until the Shuttle was docked with the ISS.

During the RPM attitude rotation, the Orbiter was photographed by members of the ISS crew as the Orbiter rotated through the pitch maneuver. These photographs were downlinked for analysis by ground personnel.

The ODS was active for a total time of 1 hr 4 min 6 sec. The ISS was captured at 187/14:51:45 GMT (01/20:21:50 MET) and the system operated satisfactorily throughout the docking operations. The Ring Drive-In ran for approximately 8 sec when it was stopped in accordance with the normal procedure. The system was allowed to dampen out and regained alignment after approximately 6 min 30 sec. The final Ring Drive-In command was issued and ring retraction proceeded nominally with good ring alignment for approximately 4 min, 18 sec using dual motors. The hooks were driven closed nominally and final ring extension was performed, releasing the capture latches.

After docking, the OBSS was unberthed by the Space Station Remote Manipulator System (SSRMS) and handed off to the Shuttle Remote Manipulator System (SRMS).

The Power Reactant Storage and Distribution (PRSD) oxygen/hydrogen manifold-2 isolation valves were cycled closed for the crew sleep period beginning at 187/22:02 GMT (02/03:24 MET) and were reopened approximately 10 hours later in preparation for the first extravehicular activity (EVA). This was the first use of the Recharge Oxygen Orifice Bypass Assembly (ROOBA), which is installed within the ISS and permits transfer of oxygen from the Shuttle to the ISS Airlock. During checkout, the oxygen manifold pressure rose to 927 psia. Since the relief valve does not open until pressure reaches 975 psia, this condition was acceptable.

Based on the imagery obtained during the FD2 inspection and the FD3 RPM, a chit was developed to request focused inspections of six areas with the following order of priority:

Nose Cap; Tadpole Gap Filler by FWD ET Attach arrowhead; Ames Gap Filler forward of starboard ET Door; RCC Panel 9R (two places), RCC Panel 5R.

Flight Day 4

The SSRMS successfully unberthed the Multi-Purpose Logistics Module (MPLM) from the Payload Bay (PLB) and berthed the MPLM to the ISS. Also, the Mission Management Team (MMT) approved an additional docked mission day based on sufficient forecasted consumables margin.

Focused inspections began at 188/16:24:50 GMT (02/21:46:55 MET). Imaging of the 6 areas identified in the focused inspection chit was completed. This was the first flight and operational use of the Integrated Sensor Inspection System (ISIS) Digital Camera (IDC), which provided highly detailed imagery of the focused inspection areas.

A chit was submitted for additional imaging of the Flexible Insulation Blanket (FIB) forward fuselage areas aft of the up-firing FRCS thrusters and the port side upper/sidewall fuselage.

Flight Day 5

The first Extravehicular Activity (EVA) of the mission was performed satisfactorily and the duration was 7 hr 31 min. The planned activities accomplished successfully during the first EVA were:

1. Installed Zenith Integrated Umbilical Assembly (IUA) blade blocker;
2. Rerouted the Trailing Umbilical System (TUS) cable;
3. Perform Detailed Test Objective (DTO)-849 to evaluate OBSS loads and dynamics.

The primary objective of DTO-849 (SRMS/OBSS Performance Synopsis) was to characterize the loads and boom motion/deflection caused by EV crewmembers located at the end of the OBSS/SRMS. Most of the resultant motion was due to flexibility of the system with crew estimations of roughly 1 to 2 ft maximum dynamic displacement amplitude. Nine annunciated brake slips of the RMS wrist yaw and wrist roll joints on the order of 0.5 to 1.1 deg were noted, none of which created any problems during the EVA. Overall, performance of the SRMS/OBSS was very good and the results were effectively bounded by the preflight predictions.

The Leading Edge Subsystem (LESS) Damage Assessment Team (DAT) presented their results of the assessment of the FD4 focused inspection [nose cap, RCC panels 9R and 5R] and cleared these areas were for entry.

The TPS Tile and Blanket DAT presented results of the focused inspection imagery of the two gap fillers. The DAT recommended clearing the two hatch blankets and the

tadpole gap filler near the arrowhead tile. Remaining open items included the gap filler near the ET door and the two FIBs on the forward fuselage.

Flight Day 6

The FD6 activities were primarily transfer of equipment and other items from the Orbiter and MPLM. The remaining gap filler and forward fuselage blanket conditions were also cleared for entry.

Flight Day 7

The second EVA was 6 hr 47 min in duration and was completed satisfactorily, with the crew accomplishing the following planned activities:

1. Removal of Pump Module from Integrated Cargo Carrier (ICC) and installation on External Stowage Platform (ESP) 2;
2. Retraction of the Training Umbilical System (TUS) Cable;
3. Removal and Replacement of the Nadir TUS Reel Assembly (RA); and
4. Removal and Replacement of the Nadir Integrated Umbilical Assembly (IUA).

Nitrogen (N₂) transfer was completed and the transfer of the equipment from the MPLM to the ISS progressed satisfactorily.

During on-orbit monitoring, the Wing Leading Edge System (WLES) sensor failed to communicate via Radio Frequency (RF) with the WLES Payload General Support Computer (PGSC) (STS-121-V-06). The WLES PGSC indicated a "local timeout", meaning it stopped attempting to communicate with the RF unit after a specified amount of time and number of attempts. Troubleshooting efforts to re-establish communication were unsuccessful.

A magenta hue was noted on Camera D imaging and the images/color bars were downlinked for evaluation (STS-121-V-07). The hue shift was especially pronounced in low light areas of scene video, but the camera was still functional for the duration of the mission.

Flight Day 8

A gradual decay in the Auxiliary Power Unit (APU) 1 fuel-tank pressure measurement since APU shutdown was identified (STS-121-V-08). The pressure decayed 21 psi in 7.6 days. An analysis was initiated to determine the cause of the pressure decay.

The APU 3 Gas Generator (GG)/Fuel Line/Pump/Valve heater B failed on, as indicated by an increase in the supply line and bypass line temperatures (STS-121-V-09). The Heater B over-temperature thermostat operated for approximately 10 minutes, during

which time the temperature dropped and control returned to the heater B thermostat. After two normal heater cycles, heater B thermostat again failed on, prompting the over-temperature thermostat to again regain control. The heater was switched from B to A, but continued to operate with the over-temperature thermostat in control. This condition did not impact the vehicle/mission.

Flight Day 9

The third EVA was 7 hr 11 min in duration and was completed satisfactorily, with the crew accomplishing the following planned activities:

1. Five samples were acquired for the Non-Oxide Adhesive Experimental (NOAX) DTO and Infra-Red (IR) camera imagery was obtained; and
2. Since cleanup took less time than expected, the grapple bar was transferred to the ISS.

One of the spatulas used during the DTO was inadvertently released. Based on crew reports and ISS video, this item cleared the payload bay.

Flight Day 10

This day was an off-duty day for the crew. The crew performed the final transfers and the clean-up of the MPLM in preparation for the return of the module to Discovery's payload bay on FD11.

Flight Day 11

The forward-plan for the APU 1 fuel tank pressure decay was presented and accepted at the July 14 MMT.

Two anomalies were identified following the review of the Modular Auxiliary Data System (MADS) ascent data. This was the first mission to downlink MADS data during the flight. The first MADS anomaly was an off-scale-high instrumentation failure associated with the forward fuselage overhead vent pressure (STS-121-V-10). The loss of this measurement prevented the determining the effects of the window redesign on the external window pressure environment. The loss of these data was not a concern for the completion of the planned mission.

The second MADS data issue (STS-121-V-11) was differential pressure (ΔP) across the Xo 376 bulkhead indicating that loads across the bulkhead may have exceeded limits. A stress analysis was performed and indicated that under worst-case conditions, the bulkhead was expected to withstand entry loads including nose gear "slap-down" loads. There were no impacts to mission duration and no changes to existing procedures.

The MPLM was unberthed from the ISS and returned to Discovery's payload bay prior to the MPLM being ungrappled, the Space Station Remote Manipulator System

(SSRMS) experienced a failure with the Arm Computer Unit (ACU) on the primary string. The ACU was power cycled without success, and the SSRMS was then transitioned to the redundant string to complete the day's operations.

The SSRMS ungrapple issue delayed the start of the late inspection of the port WLE RCC using the LDRI. This was the first inspection performed late in the flight to look for Micro Meteoroid Orbital Debris (MMOD) impacts. The survey extended into the crew sleep period, but was completed without issue. The Damage Assessment Team (DAT) reviewed the port wing survey imagery, and no problem areas were identified.

Flight Day 12

The Orbiter successfully undocked from the ISS. The ODS performed satisfactorily.

The late inspections of the starboard WLE and nose cap RCC with the LDRI were performed nominally. The OBSS was stowed on Discovery's starboard sill and the RMS was powered down.

The DAT reviewed the data for the starboard wing and nose cap and identified no concerns for MMOD damage for that area.

The Flight Control System (FCS) checkout performance was nominal. APU 1 was selected for FCS checkout, and all parameters were nominal. There was no indication of any change in the APU 1 fuel-tank pressure-decay following FCS checkout. The APU 1 run time was 4 min 47 sec and 18 lb of fuel were used.

The RCS Hot Fire was performed satisfactorily. All 38 thrusters were fired at least twice for a total firing time of 0.320 sec for each pulse.

FES troubleshooting was also performed. During the troubleshooting, FES Primary A's performance was steady. FES Primary B was steadier than on FD 1. The FES did not shutdown. An oscillation was observed on FES Secondary High Load, as observed on FD1. There were no issues with Primary A and Secondary. Primary B was functional and usable, if necessary, for entry.

Flight Day 13

The External Airlock/Vestibule ΔP transducer in the airlock drifted low. The transducer read 13.1 psi and should have been between 14.8 and 15.0 psi (STS-121-V-13). This sensor is used for the vestibule leak check and was not required for the remainder of the flight.

During a simultaneous condensate dump, the A and B nozzle temperatures were observed to indicate possible ice on the nozzle. The nozzles received additional bake-out time to ensure that no ice was present.

Flight Day 14

The Payload Bay Doors (PLBDs) were closed at 198/09:34:32 GMT (12/14:56:37 MET) in preparation for the first landing opportunity at KSC. The operation of the doors was nominal.

The deorbit firing for the first landing opportunity at KSC, a dual-engine straight-feed firing, was performed on orbit 202 at 198/12:06:55.212 GMT (12/17:29:00.225 MET). The duration of the deorbit firing was 182.80 sec and the ΔV was 308.7 ft/sec. The orbit following the deorbit firing was 189.2 by 22.9 nmi. Entry interface occurred at 198/12:42:49 GMT (12/18:04:54 MET),

Prior to deorbit maneuver ignition, all APU heaters that were operating on the 'A' system were reconfigured to 'B'. When the APU 3 GG fuel pump (FP) switch was moved back to system 'A', erratic heater operation was observed. The APU 3 GG/FP heaters, which had been operating in the over-temperature thermostat temperature range (12), were turned off by crew switch action prior to entry interface. APU parameters were nominal during entry. The APU's were shut-down approximately 18 min 29 sec after landing.

During entry when the air data probes were deployed, the left probe deployed normally; however, the right probe initially failed to fully deploy (STS-121-V-15). The crew temporarily commanded the right probe to stow, then again to deploy. The motors drove for an additional 2 min 27sec in the deploy direction until both deployed limit switches were obtained. Both probes provided satisfactory data.

Entry was completed satisfactorily. The main landing gear touchdown occurred on runway 15 at 198/13:14:42.106 GMT (12/18:36:47.119 MET) on July 17, 2006. The drag chute was deployed at 198/13:14:45.275 GMT (12/18:46:50.288 MET). The nose gear touchdown occurred at 198/13:14:53.149 GMT (12/18:36:56.152 MET). Wheels stop occurred at 198/13:15:56.977 GMT (12/18:38:00.990 MET). The rollout was normal in all aspects. Flight duration was 12 days 18 hr 36 min 47 sec.

After wheels stop, the Backup Flight System (BFS) logged over 90 General Purpose Computer (GPC) errors.

PAYLOADS AND EXPERIMENTS

FLIGHT OBJECTIVES

For this second Return-to-Flight mission, the primary Space Shuttle Program (SSP) objectives of the mission were to test and evaluate Shuttle Thermal Protection System (TPS) inspection and repair capabilities. In addition, the International Space Station (ISS) Utilization and Logistics Flight 1 (ULF1.1) Launch Package delivered International Space Station (ISS) payloads, cargo and an additional crewmember required to continue payload, assembly and maintenance tasks on the ISS.

Mission success criteria were met by completion of the following primary objectives:

1. Inspect Orbiter Reinforced Carbon Carbon (RCC) surfaces on both wings and nose cap using the Orbiter Boom Sensor System (OBSS). This inspection was performed after launch to survey the Orbiter surfaces for damage caused by ascent debris as well as prior to landing for damage caused by Micro-Meteoroid Orbital Debris (MMOD). Also, the Orbiter TPS tiles on the underside were inspected for loose tiles and ascent damage using the OBSS. Downlink digital and wing leading edge (WLE) sensor data were used for analysis.
2. Transfer mandatory quantities of water from the Orbiter to the ISS.
3. Transfer the 3rd ISS crewmember and mandatory survival items to the ISS and perform the mandatory safety and handover briefings.
4. Remove and replace the failed Trailing Umbilical System Reel Assembly (TUSRA) and Interface Umbilical Assemblies (IUAs) on the ISS with the new TUS RA and IUA and return the failed TUS RA and the failed IUA to the ground.
5. Transfer all mandatory cargo in the Multi Purpose Logistics Module (MPLM) and middeck to the ISS and return all mandatory cargo in the MPLM and middeck back to the ground.
6. Perform DTO 849 [OBSS Shuttle Remote Manipulator System (SRMS) Loads Characterization with EVA Crewmember].
7. Perform DTO 850 [Water Spray Boiler Cooling with Water/Propylene Glycol Monomethyl Ether (PGME) Antifreeze].
8. Install the pump module with the fixed grapple bar on the ISS External Stowage Platform 2 (ESP2).

9. Transfer and install the Oxygen Generation System (OGS), the Minus Eighty-Degree/Laboratory Freezer for ISS (MELFI), the European Space Agency (ESA) European Modular Cultivation System (EMCS), and the Common Cabin Air Assembly (CCAA) from the MPLM to the ISS.
10. Perform Recharge Oxygen Orifice Bypass Assembly (ROOBA) checkout.
11. Transfer required nitrogen (N₂) from the Orbiter to the ISS airlock High Pressure Gas Tank (HPGT).
12. Transfer remaining cargo from the MPLM and middeck to/from ISS.
13. Disassemble and exchange Cycle Ergometer w/Vibration Isolation System (CEVIS) on the ISS.
14. Perform Station DTO 12004-U (Orbiter Booster Fan Bypass).
15. Remove and replace the Microgravity Science Glovebox (MSG) front window on the ISS.
16. Swap the ISS and Orbiter printers.
17. Perform Ram Burn Observations (RAMBO) payload operations.
18. Perform MAUI Analysis of Upper-Atmospheric Injections (MAUI) payload operations.
19. Perform United States Orbiting Segment (USOS)/Russian Segment (RS) payload research operations tasks.
20. Perform DTO 852 (SRMS On-Orbit Loads, Heavy Payloads).
21. Perform SDTO 13005-U, ISS Structural Life Validation and Extension for Orbiter Undocking.

CREW ACTIVITIES

There were two scheduled ISS airlock-based Extravehicular Activities (EVAs) planned for the mission and one unscheduled EVA, and these were all performed. The crew successfully performed DTO 849 on the first EVA, which demonstrated that the OBSS can be used as a platform to perform EVA tile and RCC repair techniques. DTO 851 was also performed and the data gathered from the SRMS instrumentation will be evaluated on the ground. Also, during EVA 1 the crew successfully installed the blade blocker on the zenith IUA and routed the cables to the zenith TUS. During the second EVA, the crew successfully replaced the failed nadir IUA and the nadir TUS RA with the

new hardware that was brought up in the Orbiter and moved the pump module from the Orbiter to the ISS. After it was determined that the mission could be extended an extra day, the third EVA was performed. During this EVA, the crew successfully performed DTO's 848 and 851 (EVA Infrared Camera) and had time to perform a get-ahead task; the installation of the second fixed grapple bar on the ISS and an added task, EVA Infrared Camera imagery of the ISS radiator.

The following table summarizes the completion status of the tasks assigned to Flight LF1 in the Mission Integration Plan (MIP) plus real-time processes:

MIP AND REAL-TIME TASK ACCOMPLISHMENT

Source of Tasks	Approved	Completed	Withdrawn	Deferred	Not Complete
MIP Baseline	25	21	3	2	0
Added in Real Time	5	5	0	0	0
Totals	30	26	3	2	0

A. Tasks completed in addition to the MIP requirements:

1. TUS-Disconnect-Actuator removal from the IUA.
2. EVA Infrared Camera imagery of the ISS radiator.
3. Test of the Space Vision System Artificial Vision Unit camera.
4. EVA installation of the second fixed grapple bar on the ISS.
5. DTO 848 added after energy-dependent day was achieved.

B. Tasks Withdrawn:

1. Transfer of oxygen to the ISS – The crew did not perform this task as the mission was extended one day and no excess oxygen was available for transfer.
2. ISS Reboost- The crew did not perform ISS reboost to save fuel in case a re- rendezvous with ISS was required to repair MMOD damage to the Orbiter after the TPS inspection was performed following undocking.
3. ISS Flyaround - The crew did not perform a complete ISS flyaround since the TPS inspection was required after undocking.

C Tasks Deferred:

- 1 Installation of the Rotary Joint Motor Controller (RJMC) - The crew did not perform this get-ahead EVA task due to its low priority and lack of EVA time.
- 2 Perform SDTO 13005-U, ISS Structural Life Validation and Extension for Orbiter reboost was not performed since reboost was not performed.

D. Orbiter consumables transferred to the ISS were:

1. Water – A total of 15 CWCs were transferred.
2. Nitrogen – A total of 74.0 lbm were transferred to ISS airlock high pressure gas tanks.
3. Lithium Hydroxide (LiOH) – A total of 10 canisters were transferred From the MPLM to the ISS

TRANSFER WEIGHT SUMMARY

The weight summary for ISS pressurized cargo that was transferred between both vehicles during the mission is shown in the following tables:

Part 1 (Ascent)

Transferred from Orbiter to ISS	Planned, lbm	Actual, lbm
Middeck	1,863	1,863
MPLM Cargo and Payloads	7,424	7,424

Part 2 (Return)

Transferred from ISS To Orbiter	Planned, lbm	Actual, lbm
Middeck	1,820	1,820
MPLM Cargo	4,389	4,389

SIGNIFICANT FIRSTS

The significant firsts that were accomplished during the mission both for the Space Shuttle and ISS programs are detailed in the following items:

1. Four new ET cameras (on thrust panels and ET attach rings).
2. EVA crewmembers positioned on the OBSS (DTO 849)
3. EVA demonstration of RCC repair
4. EVA crewmember use of the EVA IR camera
5. Tile Repair Ablator Dispenser (TRAD)
6. ISIS Digital Camera
7. Transition to 3 ISS crewmembers (since Return to Flight)
8. MELFI and OGS rack (in MPLM)
9. ROOBA
10. TPS inspection for MMOD damage
11. Instrumented RMS (DTO 850)
12. Orbiter undocking from ISS with OBSS grappled at the end of the uncradled RMS (OBSS not berthed in starboard MPMs)

VEHICLE PERFORMANCE

SOLID ROCKET BOOSTERS

All Solid Rocket Booster (SRB) systems performed nominally during the launch countdown and ascent. The SRB pre-launch countdown was nominal. No SRB Launch Commit Criteria (LCC) or Operational Maintenance Requirements and Specification Document (OMRSD) violations occurred during the countdown.

This was this first flight of the following design changes for the SRB:

1. A new Nozzle Structural Adhesive System, applicable to the left-hand forward nozzle assembly only; and
- 2 The SRB Camera System (SCS) consisting of the forward skirt aft-looking camera.

Both SRBs were successfully separated from the External Tank (ET) and reports from the recovery area, based on visual sightings, indicated that the deceleration subsystem performed as designed. Both SRBs were observed during descent, and were retrieved and returned to KSC for inspection and disassembly.

Both gaseous nitrogen (GN₂) purge probes were seen in the vertical position on pad video cameras after launch. Inspection of the SRB holddown posts was performed, and the south holddown studs were visually assessed and verified as having no indication of hang-up. Erosion was typical for both the north and south posts. North holddown post blast covers exhibited nominal erosion from SRB exhaust plume damage; however, HDP 4 exhibited more erosion than the other three HDPs with blast covers due to lack of red colorization from the RTV laminate system. A piece of red laminate approximately 4 in by 4 in was found on the east Pad apron. HDP 5 exhibited approximately 2 in diameter of lifted/missing EPON shim material.

Power up and operation of all igniter and field joint heaters was accomplished routinely. However, the joint heater power circuit for the primary mobile launch platform (MLP) was lost at approximately 6 hr 26 min (185:12:11:00 GMT) prior to launch. All RSRM temperatures were maintained within acceptable limits throughout the countdown. The heated, ground supplied, aft skirt purges maintained the case/nozzle joint and flex bearing temperatures within the required LCC ranges.

Two IFA's were identified. Data were not obtained from one of two RH Enhanced Data Acquisition System (EDAS) (STS-121-B-001). Paper-based Phenolic shim material was observed missing from Left Hand Aft Skirt Hold Down Post (HDP) Shoe no.5 (STS-121-B-002).

REUSABLE SOLID ROCKET MOTORS

The Reusable Solid Rocket Motors (RSRMs) performed nominally with no violations of the RSRM LCC. Data indicate that the flight performance of both RSRMs was well within the allowable performance envelopes and typical of the performance observed on previous flights. However, during the postflight inspection and RSRM disassembly, one in-flight anomaly was identified and it is discussed in the following paragraphs.

In-Flight Anomaly

Non-distinct gas penetrations were observed in joint 2 through the Room Temperature Vulcanizing (RTV) material on both RSRM nozzles (STS-121-M-001).

The RSRM-93B occurrence was identified as non-distinct intermittent gas penetrations through the dogleg from 305 to 0 to 85 degrees and from 126 to 215 degrees of the circumference. A small area of heat-affected virgin CCP was found on the nose cap at 165 degrees. No other heat effects to the adhesive, paint, metal, or O-rings were noted. Soot to the primary O-ring was observed at 158 degrees, but no soot was observed past the primary O-ring.

The RSRM-93A occurrence was identified as non-distinct intermittent gas penetrations around the full circumference through the dogleg. No heat effects to phenolics, adhesive, paint, metal, or O-rings were found. Soot to the primary O-ring was observed intermittent from 45 degrees to 315 degrees. No soot was observed past the primary O-ring.

These gas penetrations were through the Nozzle-Joint-2 RTV material with soot to the primary O-ring of both RSRM-93A and RSRM-93B. The RTV did not function as designed, thus resulting in an unsatisfactory condition. It should be noted that both gas penetrations on RSRM-93A and RSRM-93B are understood and are within the previous envelope of experience for joint 2.

RSRM Performance

Data indicate that the flight performance of both RSRMs were well within the allowable performance envelopes, and were typical of the performance observed on previous flights. The delivered burn rates at 80°F Propellant Mean Bulk Temperature (PMBT) and 625 psia were 0.3750 and 0.3763 in/sec for the left and right motors respectively.

Data also indicate that SRB separation was nominal. The SRB separation time was T+122.53 seconds.

The motor performance parameters were within the Contract End Item Specification limits for this flight. The delivered burn rates at 83 °F propellant mean bulk temperature (PMBT) were nominal. Adaptive guidance throttling (AGT) did not make any corrections that were due to off-nominal thrust.

The ambient temperatures recorded during the 90 hrs prior to launch varied from 72 °F to 86 °F. The data recorded during this time frame were in the -1.0σ range from historical July average hourly temperatures. At the time of launch, the ambient temperature was 83 °F, which is 4 °F below the historical ambient temperature for the time of launch in July.

The field joint heaters operated for 13-hr 42-min during the launch countdown. Power was applied to the heating elements 35 percent of the time, which is average, to maintain the igniter joints in the normal operating range during the LCC time-frame of the countdown.

The igniter joint heaters operated for 13 hr 52 min during the launch countdown. Power was applied to the heating elements 25 percent of the time, which is average, to maintain the igniter joints in the normal operating range during the LCC time-frame of the countdown.

During the Launch Commit Criteria (LCC) time frame, the left and right motor nozzle/case joint sensor temperatures ranged from 80 °F to 86 °F and 83 °F to 86 °F, respectively. The final Flex Bearing Mean Bulk Temperature (FBMBT) was calculated to be 83 °F.

The calculated PMBT at launch was 77° F. The maximum trace shape variation of pressure vs. time during the 16- to 30-sec timeframe was calculated to be 0.886 percent at 26.5 sec for the left motor and 1.127 percent at 22.0-sec for the right motor. These values were within the 3.2 percent allowable limits.

Reconstructed motor performance parameters adjusted to a 60° F propellant mean bulk temperature (PMBT) are shown in the following table.

RSRM PERFORMANCE PARAMETERS AT 60° F PMBT

Parameter	CEI specification limit, 60 °F	Left motor delivered	Right motor delivered
Web time, sec	105.4 – 116.7	119.2	109.6
Action time, sec	115.2 – 131.2	122.3	122.2
Head end pressure, psia	847.9 – 965.7	915.2	920.5
Maximum sea level thrust, Mlbf	2.88 – 3.26	3.07	3.08
Web time average pressure, psia	629.9 – 700.5	668.9	670.8
Web time average vacuum thrust, Mlbf	2.46 – 2.74	2.62	2.63

RSRM PERFORMANCE PARAMETERS AT 60° F PMBT (Concluded)

Parameter	CEI specification limit, 60 °F	Left motor delivered	Right motor delivered
Maximum sea level thrust, Mlbf	2.88 – 3.26	3.07	3.08
Web time average pressure, psia	629.9 –700.5	668.9	670.8
Web time average vacuum thrust, Mlbf	2.46 – 2.74	2.62	2.63
Web time total impulse, Mlbf sec	285.8 – 291.6	288.6	287.9
Action time impulse, Mlbf sec	293.7 – 299.7	296.4	295.8
ISP average delivered, lbf sec/lbm	266.5 – 270.3	268.1	267.5
Loaded propellant weight, lbm	>1103840	1106171	1106454

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

The predicted and actual propulsion system performances are shown in the following RSRM Propulsion Performance table.

RSRM PROPULSION PERFORMANCE

Parameter	Left motor, 72 °F		Right motor, 72 °F	
	Predicted	Actual	Predicted	Actual
Impulse gates				
I-20, 10 ⁶ lbf-sec	66.23	66.06	66.46	66.19
I-60, 10 ⁶ lbf-sec	176.96	176.08	177.48	176.47
I-AT, 10 ⁶ lbf-sec	296.11	296.71	297.19	296.18
Vacuum Isp, lbf-sec/lbm	268.6	268.2	268.6	267.7
Burn rate, in./sec @ 60 °F at 625 psia	0.3701	0.3700	0.3708	0.3714
Event times, sec ^a	0.232	N/A	0.232	N/A
Ignition interval	107.9	108.2	107.6	107.7
Web time ^b	117.9	118.0	117.5	117.9
50 psia cue time	120.0	120.1	119.7	120.1
Action time ^b	120.0	120.1	119.7	120.1
Separation command	122.3		122.3	

RSRM PROPULSION PERFORMANCE (Concluded)

Parameter	Left motor, 72.°F		Right motor, 72.°F	
	Predicted	Actual	Predicted	Actual
PMBT, °F	77	77	77	77
Maximum ignition rise rate, psia/10 ms	90.8	N/A	90.8	N/A
Decay time, sec (59.4 psia to 85 K)	3.1	3.0	3.1	3.1
Tailoff impulse imbalance differential ^c	Predicted N/A		Actual 735.0	

^aAll times are referenced to ignition command time except where noted by footnote b.

^bReferenced to liftoff time (ignition interval).

^cImpulse imbalance = integral of the absolute value of the left motor thrust minus right motor thrust from web time to action time.

All ground environmental instrumentation (GEI) and operational flight instrumentation (OFI) performed within established requirements during the flight.

EXTERNAL TANK

During each of the loading attempts, the External Tank (ET) liquid hydrogen 5-percent fill-point sensor failed wet when commanded to the dry-state during the prelaunch simulation commands. During the two de-tanking operations, this sensor was slow to transition to the dry indication. A failed-wet condition of this sensor is acceptable for flight, as it is used only during loading, de-tanking and post-flight reconstruction purposes.

Following the July 2nd scrub, a 5-in long piece of ET thermal protection system (TPS) foam was found on the Mobile Launch Platform (MLP) deck. Also, TPS damage was noted between the liquid oxygen feedline and feedline brackets 2 and 3. The source of the piece of TPS was to a previously identified 5-in crack with a ¼ in offset at station 1129 of the ET on the inboard side of the feedline bracket. Analysis of the damaged area showed the condition was acceptable for flight and the anomaly was closed.

ET-119 performed satisfactorily during the ascent phase of the mission. All propellant loading and flight operations objectives and requirements were met. No significant oxygen or hydrogen concentrations were detected in the intertank. All ET electrical equipment and instrumentation operated satisfactorily. Purge and heater operations were monitored and performed properly. No ET LCC or OMRSD violations occurred.

This was this first flight of the design change to add to the SRB the External Tank Attach (ETA) Ring Camera for photographing the External Tank (ET).

This was the first flight of the redesign removing the Protuberance Air Load (PAL) ramps adjacent to the liquid oxygen (LO₂) and liquid hydrogen (LH₂) cable trays. Additionally, there were several other design changes that were flown for the first time on STS-121. They include the bipod heater zinc chromate paste application, the bipod wire cryogenic-ingestion mitigation, bipod-to-tank fastener length, and the bipod strut fastener hardware.

Developmental Flight Instrumentation was flown in both the LO₂ and LH₂ cable trays to provide data for understanding the performance of the PAL ramp redesigns. These data were recorded on data acquisition equipment located on both SRBs.

The ice/frost red team reported one ICE team observation of a TPS tear at the gap between the fairing and the ET/SRB Cable Tray. This observation was in the vicinity of the ET/SRB Upper Aft Strut. Evaluation determined that this condition would have no impact on the flight, and it was flown as-is.

ET separation was nominal. MECO occurred within expected tolerances, and the ET impact point was within the predicted footprint at 35.844 deg S latitude, 157.26 deg W longitude and that was 24 nmi. from the predicted impact point.

SPACE SHUTTLE MAIN ENGINES

All Space Shuttle Main Engine (SSME) parameters were nominal throughout the pre-launch countdown and were typical of previous flights. There were no LCC or OMRSD violations. Engine "Ready" was achieved at the proper time, all LCC's were met, and thrust build-up was nominal. The SSME specific impulse tag value was 451.85 seconds at 104.5 percent power level.

This was the first flight for the nozzle ablative removal redesign to reduce the debris likelihood from the SSMEs.

Flight data indicate that SSME performance during mainstage, throttling, shutdown, and propellant dump operations was nominal. The high pressure oxidizer turbopump (HPOTP) and high pressure fuel turbopump (HPFTP) temperatures appeared to be well within specifications throughout engine operation. There were no significant SSME problems noted. MECO occurred 511 sec after engine start. Commanded maximum Q throttle-down was performed in one step to 67-percent thrust.

The SSME Project identified one in-flight anomaly. During ascent, MPS E-3 LH₂ inlet pressure showed an erratic performance and a pressure drift of 4 psi (STS-121-E-01). The drift only occurred during this flight when compared to the previous six flights. The shift began at the end of the thrust bucket and lasted until MECO.

SHUTTLE RANGE SAFETY SYSTEM

The Shuttle Range Safety System (SRSS) closed-loop testing was completed during the launch countdown. An error occurred during the test, that was caused by a failure of ground System A equipment. System B was activated and no further problem was noted. There were no OMRSD or LCC violations.

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

ORBITER SYSTEMS

Main Propulsion System

The Main Propulsion System (MPS) performed satisfactorily. The overall prelaunch system performance for the three launch attempts was nominal. There were no OMRSD or LCC violations during the three loadings for STS-121.

The overall gaseous hydrogen (GH₂) system in-flight performance was nominal. All three flow control valves performed nominally. The cycle count was engine 1 with 8 cycles; engine 2 with 28 cycles; and engine 3 with 29 cycles.

The maximum hydrogen concentration level in the Orbiter aft compartment, with the normally elevated system backpressure used for fast-fill, was 83 ppm (uncorrected). This compares favorably with previous data for this vehicle. Preliminary data indicate that the Liquid Oxygen (LO₂) system performed as planned. The Liquid Hydrogen (LH₂) pre-pressurization cycle count was 10 cycles, and 14 cycles is the LCC limit. Engine inlet net positive suction pressure requirements were met throughout the flight.

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.

Helium system performance for the SSME and Pneumatic Helium systems was nominal. Entry helium usage was 64.3 lbm, which is within the requirements. All other parameters were nominal.

One prelaunch anomaly and one in-flight anomaly were identified and neither of the anomalies had any impact on the MPS performance. The two anomalies are discussed in the following paragraphs.

During the first launch attempt, the LH₂ 5-percent sensor circuit indicated fail-wet during the replenish checkout (STS-121-I-006). Troubleshooting was performed to verify the functionality of all other liquid-level sensors and no anomalies were noted. Approximately 2 hours after the tank draining was completed, the LH₂ 5-percent sensor transitioned to dry indication. Additional troubleshooting was performed and no anomalies were noted.

The timer was used when loading LH₂ for the second launch attempt. During the second launch attempt, the LH₂ 5-percent sensor again indicated fail-wet during the replenish checkout. No troubleshooting was performed since the failure was expected. Following the completion of the LH₂ tank drain after the second launch attempt, the LH₂ 5-percent sensor indication toggled from wet to dry and fail-wet again. Approximately 20 minutes after the drain was completed, the LH₂ 5-percent sensor indication transitioned to dry.

The timer was also used for the third launch attempt. During the third launch attempt, the LH₂ 5-percent sensor again indicated fail-wet during the replenish checkout and no further troubleshooting performed. During ascent, the sensor also indicated fail-wet. Troubleshooting of the Orbiter circuits during postflight turnaround activities confirmed good functionality of the point sensor box and associated wiring.

During ascent, the MPS engine-3 LH₂ inlet pressure showed erratic performance and a pressure drift of 4 psi (IFA STS-121-V-12). The drift only occurred during this flight when compared to the previous six flights. The shift began at the end of the thrust bucket and lasted until Main Engine Cutoff (MECO). During postflight turnaround activities, the inlet-pressure transducer will be removed and replaced.

Evaluation of prelaunch and flight data (MECO, post-MECO and entry/landing) revealed no anomalous valve movements. All valve timings were within the required specification and within the current historical database.

The aft hazardous gas concentrations during all three launch attempts were nominal with no hazardous conditions noted. Analysis data for the three launch attempts is shown in the following table.

HAZARDOUS GAS CONCENTRATIONS DURING LAUNCH ATTEMPTS

First Launch Attempt		
Parameter	Peak, ppm	Steady State, ppm
Helium	7919	6200
Hydrogen	95	10
Oxygen	11	11
LD54/55	-1250/-1250	-1250/-1250

Second Launch Attempt		
Parameter	Peak, ppm	Steady State, ppm
Helium	6839	6200
Hydrogen	100	10
Oxygen	13	12
LD54/55	N/A	N/A

Third Launch Attempt		
Parameter	Peak, ppm	Steady State, ppm
Helium	6257	5300
Hydrogen	74	8
Oxygen	38	11
LD54/55	N/A	N/A

Gas Sample Analysis

The redesigned gas sampler system functioned as expected. All six measured pressures that were within the range of acceptable pressures established by the Propulsion Systems Integration Group (PSIG) Subcommittee in March 1995.

A summary of bottle pressure and gas concentration for STS-121 is given in the following table.

SUMMARY OF BOTTLE PRESSURES AND GAS CONCENTRATIONS

Number	Position	Pressure, psia	Helium, %	Measured oxygen, %	Hydrogen, %
1	RH1	3.45	0.53	2.06	0.03
2	LH1	1.47	0.70	1.90	0.05
3	RH2	1.35	1.03	2.01	0.07
4	LH2	0.78	1.24	2.59	0.07
5	LH3	0.17	1.93	1.10	0.08
6	RH3	0.05	5.25	1.21	0.55

The Ascent Hazard Analysis indicates the maximum hydrogen firing leak rate for STS-121, the 32nd flight of OV-103, was 1680 SCIM. The maximum allowable firing leak rate on ascent is 57,000 SCIM. The estimated firing leak rates for all sample bottle data from this flight are summarized below.

ESTIMATED FIRING LEAK RATES FOR SAMPLE BOTTLE DATA

Number	Position	Hydrogen firing leak rate, scim
1	RH1	1470
2	LH1	1260
3	RH2	1680
4	LH2	1140
5	LH3	345
6	RH3	820

Results of the gas chemical analysis from the Kennedy Space Center Materials and Chemical Analysis Branch laboratory are included in the table on the following page.

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, %
1092 FLT-2	RH1	178.5	0.08	8.35	0.53	<0.01	<0.01	<0.01	1.75	2.06	0.04	0.03
1080 FLT-3	LH1	76.13	0.06	6.53	0.70	<0.01	<0.01	0.01	1.37	1.90	0.05	0.05
1097 FLT-2	RH2	69.82	0.07	7.28	1.03	<0.01	<0.01	0.01	1.53	2.01	0.07	0.07
1086 FLT-3	LH2	40.29	0.10	10.60	1.24	0.01	<0.01	0.01	2.23	2.59	0.08	0.07
1090 FLT-3	RH3	8.6	0.05	4.82	1.93	0.35	<0.01	0.01	1.01	1.10	0.27	0.08
1098 FLT-2	LH3	2.77	0.06	6.75	5.25	0.08	<0.01	0.01	1.42	1.21	0.59	0.55

Note: All values are given in percentages by volume, and the balance is nitrogen.

Purge, Vent and Drain System

The purge, vent and drain system performed satisfactorily. No anomalies were noted during the evaluation of the performance.

Reaction Control System

Launch Countdown

During the first launch countdown attempt after the start of ET loading, the Reaction Control System (RCS) vernier thruster L5L heater was found to be failed off (STS-121-V-01). The L5L thruster temperature was cool and was not responding to the environment as expected. All other vernier thruster heater temperatures increased, thus indicating L5L heater operation had failed. The heater switch was cycled in an attempt to clear the problem; however, Injector temperatures on the affected thruster did not change. The temperatures appeared to remain at ambient (approximately 80 °F) while the remaining vernier thrusters were at approximately 110 °F.

The minimum equipment list required all six vernier thrusters be operational for launch, and flight rules require all six thrusters be operational for vernier control while docked to the International Space Station (ISS); however, primary thrusters can be used for control as required for rendezvous or mated operations. The remaining five vernier thrusters were sufficient for Orbiter-alone control operations.

During crew sleep on FD1 and FD2, the Orbiter was placed in -Y axis Solar Inertial attitude to warm the L5L vernier thruster. The thruster was above 90 °F when the crew was awakened on FD3 and the thruster was reselected for rendezvous. The L5L thruster fired nominally throughout rendezvous, docking, and post docking. The thruster injector temperatures increased with subsequent firings. After docking, the thruster

temperature dropped below 90 °F during the extended periods of vernier inactivity and the thruster was manually deselected. Troubleshooting during the turnaround activities isolated the failure to the thruster.

Mission Operations

The RCS performed nominally during the flight with no other in-flight anomalies identified. This was the first flight of the redesigned Forward Reaction Control System (FRCS) Tyvek weather covers. The covers released as predicted with nominal performance. Cover release times and speeds are given in the following table.

TYVEK COVER RELEASE TIMES AND VEHICLE VELOCITIES

Cover	MET, sec	Velocity, miles/hr
F1D	4.9	62
F3D	5.2	66
F2D	5.6	72
F4D	5.7	73
F1L	6.3	83
F3F	6.6	86
F4R	6.7	88
F2F	6.7	88
F1F	7.0	92
F3L	7.0	92
F2U	7.7	103
F2R	7.7	104
F1U	8.1	109
F3U	8.7	119

The RCS window-protect maneuver was initiated at 185/18:39:56.6 GMT (00/00:02:01.6 MET) for a duration of 2.08 sec. This maneuver was performed with thrusters F1U, F2U and F3U and thruster performance was nominal. The window-protect maneuver deflects the exhaust from the SRB separation motors away from the windows during SRB separation. The ET separation maneuver was performed at 185/18:46:46.3 GMT (00/00:08:51.313 MET) and was a 3 sec, 10-thruster translation. The ET photography maneuver was performed at 185/18:48:29 GMT (00/00:10:34 MET).

The RCS preflight propellant load was 4390.2 lb of oxidizer and 2750.9 lb of fuel, for a total of 7141.1 lb of propellant loaded for the mission. The residual propellants, as calculated by the Primary Avionics Software System (PASS), were 2189.4 lb. The propellant used was 5488.3 lb of which included 536.6 lb used from the OMS during RCS interconnect operations.

RCS firings, times initiated, ΔV s, and firing times are listed in the following table.

RCS MANEUVERS AND FIRING DATA

Firing	Time of ignition, GMT	ΔV , ft/sec	Length, sec
RCS window protect	185/18:39:56.6	N/A	2.08
ET separation	185/18:46:46.3	N/A	3.0
ET photo maneuver, +X	185/18:48:29	N/A	N/A
NC1	Not required		
NCC	187/11:07:04.7	2.5	4.0
MC1	187/12:24:46.851	1.14	4.3
Out-of-plane null	187/12:38:51.131	N/A	N/A
MC2	187/13:01:40	1.55	5.3
MC3	187/13:18:39	1.4	5.7
MC4	187/13:28:39	0.65	0.01
ISS Undock	196/10:07:47	N/A	N/A
ISS Flyaround	¼ maneuver performed	N/A	N/A
Separation 1	196/10:29:01		6.2
Final separation	196/10:57:15	1.5	4.0
NC5	196/19:24:11	0.6	2.3
RCS hotfire	197/08:49:57	N/A	All thrusters had at least one 0.320-sec pulse
FRCS Dump	198/12:25:10		69.12

Attitude control responsibilities between the ISS and Shuttle are summarized in the following table.

CONTROL RESPONSIBILITIES BETWEEN ISS AND SHUTTLE

Control vehicle	Control start, GMT	Control end, GMT	Elapsed time, hr:min:sec	Comments
ISS	187/14:51:44	187/15:18:28	00/00:26:44	Docking
Shuttle	187/15:18:28	187/15:25:04	00/00:06:36	Vernier maneuver
ISS	187/15:25:04	187/15:25:19	00/00:00:15	DAP to Free Drift
ISS	187/15:36:27	187/15:36:34	00/00:00:57	DAP to Free Drift
Shuttle	187/15:36:34	187/15:47:18	00/00:10:44	DAP to Auto
ISS	187/15:47:18	187/15:47:25	00/00:00:07	DAP to Free Drift
Shuttle	187/15:47:25	187/15:58:30	00/00:11:05	DAP to Auto
ISS	187/15:58:30	187/15:59:27	00/00:00:57	DAP to Free Drift
Shuttle	187/15:59:27	187/16:04:05	00/00:04:38	DAP to Auto

CONTROL RESPONSIBILITIES BETWEEN ISS AND SHUTTLE (Concluded)

Control vehicle	Control start, GMT	Control end, GMT	Elapsed time, hr:min:sec	Comments
ISS	187:16:04:05	195/18:10:19	08:02:06:14	DAP to Free Drift
Shuttle	195/18:10:19	195/20:05:01	00/01:54:52	OBSS Inspection
ISS	195/20:05:01	196/08:24:25	00/12:19:24	End of OBSS inspection
Shuttle	196/08:24:25	196/08:55:03	00/00:30:38	
ISS	196/08:55:03	196/08:56:11	00/00:01:08	
Shuttle	196/08:56:11	196/10:05:00	00/01:08:49	Orbiter in Control
ISS	196/10:05:00	196/10:07:47	00/00:02:47	
Shuttle	196/10:07:47	EOM	N/A	Undock
Total Mated Attitude Control Time		ISS Shuttle	08/04:18:20 00/14:57:43	

The total firing time during the mission for the vernier thrusters was 13,224.80 sec. The total firing time during the mission for the primary thrusters was 1,308.424 sec.

Orbital Maneuvering System

The OMS functioned satisfactorily, with one anomaly noted, which is discussed in this section. The standard OMS configuration is provided in the following table.

OMS CONFIGURATION

Vehicle/equipment	Flight	Orbital Maneuvering Engine (OME)	Ancillary data
OV-103	32 nd		
Left Pod (LP) 01	35 th	L-OME S/N 115	2 nd rebuilt flight, 17 th flight
Right Pod (RP) 03	33 rd	R-OME S/N 106	6 th rebuilt flight, 30 th flight

The OMS firings and interconnect operations are given in the table on the following page.

OMS MANEUVERS

Maneuver designation	Configuration	Time of ignition, GMT	Firing time, sec	ΔV , ft/sec or interconnect usage, %
Assist	Dual OME	185/18:40:08	149.2	N/A
OMS-2	Dual OME	185/19:15:56	64.7	98.7
OMS-3 (NC2)	Dual OME	186/10:53:31	24.0	36.7
OMS-4 (NC3)	Dual OME	186/21:45:59	108.0	168.6
OMS-5 (NC-4)	Dual OME	187/10:33:00	44.8	70.8
OMS-6 (TI)	Left OME	187/12:04:46	16.8	13.1
Deorbit	Dual OME	198/12:06:55	182.8	308.7
Left interconnect				0.985 %
Right interconnect				3.159 %

Official propellant residuals and propellant usage are shown in the following table.

PROPELLANT DATA

Parameters	Left OMS pod		Right OMS pod	
	Oxidizer	Fuel	Oxidizer	Fuel
Loaded, lbm	7707	4694	7722	4696
Residual, lbm (aft gage)	548	303	629	382
Total Oxidizer and Fuel Usage	7199	4391	7093	4314

The GN₂ regulator outlet pressure for the right engine was in the normal operating band during the OMS engine starts and post maneuver purges. However, the left engine GN₂ regulator exhibited signs of undershoot during the Assist maneuver purge and the OMS-2 ignition. Following the OMS Assist maneuver, a left OMS tank pressure flag was triggered when the left engine GN₂ accumulator pressure momentarily dropped to 296 psia, which is 3 psi below the Backup Flight System (BFS) Fault Detection and Annunciation (FDA) alarm level of 299 psia. This undershoot is an explained condition and is caused by the time required by the regulator to recover from the demand caused by the post-maneuver purge of the engine fuel regenerative cooling channels. The actual undershoot value reached was 305 psia, exaggerated by the 9 psi transducer low-bias measured at KSC. The behavior repeated on OMS-2 during the initial bipropellant valve actuation, reaching 294 psia (303 psia actual) for approximately 1 sec. This undershoot was of insufficient duration to trigger the FDA. There is no specification requirement for regulator undershoot. Regulator flow pressure and lockup were nominal during both OMS Assist and OMS-2. The FDA protects the ability to

restart the engine one additional time, if the purge is inhibited on the firing where the regulator fails. This limit is born out by test data and is documented in the Shuttle Operational Data Book. Similar undershoot behavior was seen on STS-101.

Auxiliary Power Unit System

The Auxiliary Power Unit (APU) subsystem performance was nominal throughout the STS-121 mission. Two In-flight Anomalies (IFAs) were identified during the mission, and these are discussed later in the section of the report. The run times and fuel consumption for the APUs during STS-121 are summarized in the tables below.

APU RUN TIMES

APU S/N	Ascent, hr:min:sec	DTO-850, hr:min:sec	FCS Checkout, hr:min:sec	Entry, hr:min:sec	Total, hr:min:sec
310	00:19:17	00:00:00	00:04:47	01:31:17	01:55:21
403	00:19:30	00:00:00	00:00:00	01:03:17	01:22:51
208	00:19:35	00:08:14	00:00:00	01:03:23	01:31:12

APU FUEL CONSUMPTION

APU S/N	Ascent, lb	DTO-850, lb	FCS Checkout, lb	Entry, lb	Total, lb
310	49	0	18	167	234
403	56	0	0	137	193
208	57	22	0	150	229
Total	162	22	18	454	656

APU 1 start for Flight Control System (FCS) checkout occurred at 197/07:57:58 GMT with a duration of approximately 4 min 47 sec. A total of 18 pounds of APU Hydrazine fuel was consumed for the FCS Checkout, resulting in a fuel tank ΔP of 24 psi and an ending pressure of 208 psia. Due to the short APU run time, APU lubrication oil spray cooling was not required. The maximum lubrication oil return temperature after APU shutdown was approximately 199 °F.

The APU 1 fuel tank pressure measurements began to decay shortly after APU ascent shutdown (STS-121-V-08). The decay, seen on both the fuel tank pressure sensor and the GN₂ pressure sensor, was greater than what can be accounted for by the decrease in fuel tank temperature, and indicated a potential leak of either GN₂ or hydrazine fuel. The condition was not noted until flight day 9 when it had decayed 22 psi (254 to 232 psia) in 7.6 days, with a total decay of 26 psi seen during the mission. This condition did not impact the vehicle or mission. APU 1 was used for nominal FCS checkout and as the pre-entry start APU so that the leak-driving pressure as well as the amount of fuel in the tank would be minimized. Post landing toxic vapor checks found no indications of hydrazine.

At approximately 193/04:34:00 GMT (07/09:57:05 MET), the APU 3 Fuel Line/Pump/Valve heater B (controlled by thermostat S37B) failed on (STS-121-V-09). This anomaly was indicated by the Gas Generator Valve Module (GGVM) fuel supply line temperature increasing from 82 °F to 190 °F, and the APU fuel line temperature 3 (bypass line temperature) increasing from 82 °F to 165 °F in 21 minutes. The over-temperature thermostat controlled for about 10 minutes, when the temperature dropped and was again controlled by S37B. After two normal heater cycles, thermostat 37B again failed on and thermostat 35B began controlling. Approximately 4.5 hr later, the heater switch S3 on panel A12 was switched from B Auto to A Auto. The heater then began to cycle on the A over-temperature thermostat, rather than controlling thermostat S37A, the expected. Since the B heaters were selected earlier than normal on FD1, the 'A' heaters did not cycle earlier in flight. The A over-temperature thermostat controlled for the remainder of the flight with the supply line temperature operating in a bandwidth of 142 °F to 167 °F.

Hydraulics/Water Spray Boiler System

Overall Hydraulic and Water Spray Boiler (WSB) systems performance during STS-121 was nominal. STS-121 is the second mission to use the Propylene Glycol Monomethyl Ether (PGME) additive to the water in the WSB system 3 water tank to preclude post-ascent freeze-ups in the boiler container. DT0 850 was performed to demonstrate the early return capability of the WSB.

Hydraulic performance during ascent was nominal. There were no unexpected decreases in reservoir quantity indicating no gross leaks in the hydraulic system. Priority valve cracks at APU activation were all less than the 1-sec specification limit. Priority valve reseats on all three systems at APU shutdown were also within specification (≥ 2675 psia).

WSB cooling performance during ascent was nominal on all three systems. All three WSB system cores were loaded with approximately 5 lb of the PGME/Water azeotropic (47/53) mixture. Initial water tank load for System 1 was 118 lb water; System 2 was 118.1 lb water. The maximum specification usage is 8 lb/system. WSB coolant usages for the three WSB systems were for each system:

1. System 1 – 1.4 lb;
2. System 2 – 1.7 lb; and
3. System 3 – 4.5 lb.

WSB cooling performance during ascent was nominal on all three systems. Water usage during entry for spray cooling was 22.6 lb for System 1, 10.1 lb for System 2 and 41.3 lb for system 3.

Following touchdown, a suspected overflow of PGME/water mixture from the WSB 3 vent was discovered as indicated by the observance of a rust-colored flow pattern

extending from the WSB vent toward the APU 3 vent, the smell of PGME and dampness of the Orbiter TPS blanket in the area between the OMS pod and vertical tail (STS-121-V-17). Flight data indicate that the boiler operated nominally during the initial stages of active hydraulic cooling, but failed to secure spraying when the boiler core was full. Data review also showed the bypass valve failed to return to the bypass mode when expected, this failure was reproduced during troubleshooting after the flight.

Power Reactant Storage and Distribution System

The OV-103 Power Reactant Storage and Distribution System (PRSD) performance was nominal during STS-121. There were no PRSD system anomalies during this mission. The PRSD subsystem supplied the fuel cells with 2836 lb of oxygen and 357 lb of hydrogen for the production of 4172 kWh of electrical energy. The average power level for the 306.63-hour mission was 13.6 kW. The Environmental Control and Life Support System (ECLSS) was supplied with 205 lb of oxygen. Oxygen and hydrogen tank sets 4 and 5 were depleted to residual quantities. A top-off of hydrogen tanks 2, 3, 4, 5 was performed prior to the third launch attempt with the fuel cells operating. The initial loading of the five PRSD tank sets was performed on June 29, 2006. The prelaunch hydrogen and oxygen reactant boiloff rate averaged 0.056 lb/hr per tank for hydrogen and 0.21 lb/hr per tank for oxygen.

The tank quantities at the end of loading, launch, and landing are listed in the following table.

PRSD TANK QUANTITIES

Event	Oxygen Tank 1	Oxygen Tank 2	Oxygen Tank 3	Oxygen Tank 4	Oxygen Tank 5	Total Mass, lb
Loading, percent	102.2	102.2	100.9	101.4	102.2	3975
Launch, percent	99.2	98.7	97.9	98.7	99.2	3856
Landing, percent	32.2	31.3	29.1	5.9	5.9	815
Loading, percent	102.3	102.3	102.3	102.3	103.2	471.4
Launch, percent	93.5	100.6	101.0	101.5	101.9	458.6
Landing, percent	28.1	40.0	39.6	1.1	1.5	101.5

The O₂/H₂ manifold isolation valves were cycled for the crew sleep periods, which satisfied the OMRSD File IX In-flight Checkout requirement.

The Orbiter landed with 815 lb of oxygen and 101.5 lb of hydrogen remaining in the PRSD subsystem. A 57-hour mission extension capability existed at landing, based upon the PRSD O₂ (the limiting reactant) tank landing quantities and the average flight power of 13.6 kW. At an extension day power level of 12.98 kW, a 60-hour mission extension was available.

A pressure spike was observed 187/21:20 GMT on PRSD O₂ manifold 1 and 2 in which pressures increased to 927 and 924 psia respectively. This occurred while O₂ tank 5, was at 75-percent quantity, and was controlling the manifold pressures. The Recharge Oxygen Orifice Bypass Assembly (ROOBA) was being utilized and it routes Orbiter O₂ directly to the International Space Station (ISS) Airlock. The ROOBA bypasses the ECLSS flow restrictor and is used to support ISS-based EVAs. The ROOBA's high flow demand from O₂ tank 5 caused cold, dense fluid to enter the warm manifold where it expanded and increased the manifold pressure to slightly above the nominal upper pressure range of 875 psia. The manifold pressure remained well below the manifold relief valve cracking pressure of 975 psia. This is a typical occurrence when an instantaneous high flow rate demand is put on an oxygen tank at a relatively high quantity.

Fuel Cell System

The overall performance of the OV-103 fuel cell subsystem was nominal for STS-121. No anomalies were identified from the analysis of the data. After the scrub of the first and second launch attempts, hydrogen tanks 2, 3, 4, 5 were topped off with the fuel cells operating. The fuel cells were not shut-down for the launch scrubs and cryogenics top-off.

The fuel cells installed in OV-103 for STS-121 were serial numbers 114, 125, and 115 in positions 1 through 3, respectively. Fuel cell startup was initiated on June 30, 2006 at 182:04:51:39 GMT and was completed less than 3 ½ hr later. Startup and prelaunch operations were nominal. Fuel cell operating times, which are the times accumulated on the fuel cells prelaunch, on-orbit, and postlanding, were 405:27:53 for fuel cell 1, 405:18:51 for fuel cell 2, and 404:17:30 for fuel cell 3. The end-of-mission accumulated operating times for these fuel cells are 412, 412, and 1374 hours, respectively.

The Orbiter electrical power level averaged 13.6 kW and the total Orbiter load averaged 439 amps. For the 306.63-hour mission, the fuel cells produced 4172 kWh of electrical energy and 3193 lb of potable water. The fuel cells consumed 2836 lb of oxygen and 357 lb of hydrogen. Five purges were performed, occurring at approximately 17, 75, 155, 226, and 298 hours MET. The actual fuel cell voltages at the end of the mission were 0.10 V above predicted for fuel cell 1, 0.10 V above predicted for fuel cell 2, and 0.15 V above predicted for fuel cell 3. The voltage margins above the minimum performance curves at 200 amps at the end of the mission were 1.20 V above minimum for fuel cell 1, 1.20 V above minimum for fuel cell 2, and 1.10 V above minimum for fuel cell 3.

The overall thermal performance of the fuel cell water relief, water line, and reactant purge heater systems was nominal. System "A" on the water relief and water line systems was used during prelaunch, and until 16 hr 25 min aft liftoff. The heaters were

reconfigured to the B system until approximately 2 days prior to entry at which time the fuel cell water relief line heaters were switched back to system A because no cycles had been observed on the relief line and valve because of the thermal environment. All of the water system heaters cycled to satisfy the in-flight checkout requirements, except for the fuel cell 1, 2, and 3 water-relief valve A heaters.

The alternate water line temperatures indicated some slight leakage through the alternate water check valves. The leakage was shown to occur when potable water tank A was full or isolated. This condition causes the pressure upstream of the check valve to increase above the downstream pressure enough to crack the check valve and leakage of the 140 °F product water affects the nominal heater cycles of the line heaters. This was observed on all three fuel-cell alternate water line temperatures but more pronounced on fuel cell 3, less pronounced on 2, and even less on 1. This is in family with observations from STS-114, the previous flight of this vehicle.

The prelaunch baseline Cell Performance Monitor (CPM) values for fuel cell 1 were 4, 4, and 24 mV, for fuel cell 2 were 8, 2, and 40 mV, and for fuel cell 3 were 18, 8, and 16 mV (second CPM baseline). They were established approximately one hr after the loads adjustment on the first launch attempt. The fuel cells had been operating for four hr before the values were changed.

The Fuel Cell Measurement System (FCMS) was used to monitor individual cell voltages during the prelaunch, on-orbit, and postlanding operations. Full-rate on-orbit data were recorded for 12 minutes late in the mission. All of the cell voltages were nominal. Fuel cell 2, cell 25, was biased 12 mV low due to an OV-103 vehicle specific FCMS instrumentation bias.

Electrical Power Distribution and Control System

The Electrical Power Distribution and Control (EPDC) system performed nominally during all mission phases. All File IX In-Flight Checkout requirements, with the exception of the excessive AC 3 phase C current which is an explained condition, were met. The data review and analysis of all available EPDC parameters showed no anomalies. As a minimum, the following EPDC parameters were analyzed following the mission:

- a. Fuel cell voltages and currents
- b. Essential bus voltages
- c. Control bus voltages
- d. Forward power control assemblies voltages and currents
- e. Mid power control assemblies voltages and currents
- f. Aft power control assemblies voltages and currents
- g. AC bus voltages and currents
- h. AC bus Monitor/auto switch status and overload/over-voltage alarm
- i. Main bus to control bus Remote Power Controller (RPC) status
- j. Forward, mid and aft motor control assemblies operations status

- k. Fuel cell to essential bus switch status
- l. Main bus to essential bus RPC and switch status
- m. Drag chute pyrotechnic controller functions

At 195/18:10:04 GMT (09/23:32:09 MET), AC 3 phase C current increased to 6.56 A with an estimated power factor of 0.78 – 0.80 lagging, placing it above the continuous ac inverter operational limit of 6.41 A (MER-23). It remained at this value for 2 hr 24 min and led to a violation of a flight rule covering ac inverter operational limits. This flight rule allows operation above the limit for 30 minutes at power factors between 0.7 and 0.8 lagging. This excessive current draw was caused by increased lighting during the Flight Day (FD) 11 OBSS inspection operations. This condition is not an issue for the EPDC, as it has been experienced several times since the beginning of the Space Shuttle Program. Testing was performed on the inverter by running it at 8.0 A with a 0.7 power factor and it has proven that the inverters can manage a 125-percent overload (8.0 A) for 8 hr or longer with temperatures remaining within their de-rated temperature limits.

Orbiter Docking System

The Orbiter Docking System (ODS) performed satisfactorily during all docking and undocking activities. No in-flight anomalies were noted during the evaluation of the performance.

On Flight Day 2, the ODS Docking Control Panel (DCP) Circuit Breakers were activated at 186/16:02:37 GMT (00/21:24:42 MET) Ring extension to the initial position was nominal, beginning at 186/16:08:31 GMT (00/00:21:30:56 MET) and ending 3 min, 35 sec (dual-motor time) later. The Ballscrew Linear Position measurements increased from 4.4 to 77.2 percent for all ball-screws. The Circuit Breakers were de-activated at 186/16:13:39 GMT (00/21:35:44 MET) for a total activation time of 11 min 2 sec.

On Flight Day 3, the ODS was activated at 187/14:16:20 GMT (01/19:38:25 MET) and de-activated at 187/15:20:26 GMT (01/20:42:31 MET) for a total activation time of 1 hr, 4 min, and 6 sec. The ISS was captured at 87/14:51:45 GMT (01/20:13:50 MET) and the system operated satisfactorily throughout the docking operations. The Ring Drive-In began at 187/14:56:32 GMT (01/20:18:37 MET), running for approximately 8 sec when it was stopped in accordance with the normal procedure. The system was allowed to dampen out and regained alignment after approximately 6 min 30 sec. A Ring Drive (Ring Out) command was given beginning at 187/15:03:15 GMT (01/20:25:20 MET), operating for 5 sec, clearing stuck dampers as per procedure.

The final Ring Drive-In command was issued at 187/15:04:55 GMT (01/20:27:00 MET), and ring retraction proceeded nominally with good ring alignment for approximately 4 min, 18 sec using dual motors. Prior to hard mating (5-percent ballscrew linear advancement), during ring retraction, ring alignment was momentarily lost for approximately 5 seconds, and then regained. This behavior has been seen on the

previous flight of OV-103 (STS-114). This condition meets the requirements of Flight Rule A10-344, Section B, Item 2.

The hooks were driven closed nominally, ending at 187/15:10:18 GMT (01/20:32:23 MET), and final ring extension was performed, releasing the capture latches at 187/15:12:22 GMT (01/20:34:27 MET) (estimated due to loss of data). Ring final position was acquired at approximately 187/15:13:29 GMT (01/20:35:34 MET) (estimated due to loss of data).

On Flight Day 12, the ODS was powered up at 196/09:34:26 GMT (10/14:56:31 MET) for undocking. Hook drive was nominal, and the Orbiter successfully undocked from the ISS. The ODS was powered at 196/10:25 GMT (10/15:47:05 MET) and the ODS performed satisfactorily.

Atmospheric Revitalization, Atmospheric Revitalization Pressure Control, and Airlock Systems

The Pressure Control System (PCS) and Airlock system performed nominally throughout the mission. PCS System 1 was configured and used for the entire mission, as there were no Orbiter-based EVAs. An Orbiter-to-ISS tank-to-tank transfer of approximately 74 lb of nitrogen (N₂) was performed. The Vestibule was leak and pressure verified for docking and undocking operations. Three ISS-based Extravehicular Activities (EVAs) were provided Oxygen (O₂) by the Orbiter. The O₂ was transferred via the Airlock Transfer panel and the ISS Recharge Oxygen Orifice Bypass Assembly (ROOBA). An ISS repressurization was performed prior to undocking that also was completed through the Orbiter PCS. The repressurization was performed to approximately 14.9 psi using both N₂ and O₂ to support the ISS atmosphere pressure mixture.

After undocking, the Airlock-to-Vestibule differential pressure (ΔP) measurement drifted low (STS-121-V-13). This condition did not impact the remainder of the mission since that measurement is only monitored during the docking and undocking operations.

Supply and Waste Water System

The Supply Water and Waste Management Systems performed nominally throughout the mission and all of the scheduled in-flight checkout requirements were satisfied. Supply water was managed through the use of the Flash Evaporator System (FES), water transfer to the ISS and the overboard nozzle-dump system. Two supply-water tank dumps were performed at a nominal dump rate of 1.6 percent/min (2.64 lb/min). During the mission, four Payload Water Reservoirs (PWRs) containing Shuttle iodinated water were dumped through the supply-water dump nozzle. The line heater maintained the supply water dump line temperature between 67 °F and 95 °F throughout the mission. Fifteen Contingency Water Containers (CWCs) were filled with supply water and transferred to the ISS, for a total of 1454.9 lbm. All of the CWCs transferred were

technical water. In addition, four PWRs containing a total of 90 lbm of Shuttle iodinated water were transferred to the ISS for Extravehicular Mobility Unit (EMU) use. The vacuum vent line temperature was maintained between 61 °F and 80 °F.

Three waste water tank nozzle dumps at an average rate of 2 percent/min (3.3 lb/min) were performed. During this mission, two CWCs, containing Shuttle condensate, were dumped through the waste water dump nozzle.

During the condensate separation setup, the bag connection was inadvertently hooked to the waste water line cross-tie Quick Disconnect (QD) and approximately 21 lb of waste water (urine) was drained from the waste tank to the condensate separation bag. The crew was informed of the problem and the line was disconnected. At the time of the hookup, the waste-tank isolation valve was positioned to open in the nominal water management configuration.

During the PWR dump on FD 12 through the supply dump line and the CWC shuttle condensate dump through the waste dump line, there were indications of an off-nominal nozzle signature on both the supply and waste dump nozzles. A CWC overboard-dump of 82 lb of Shuttle condensate was initiated through the waste dump line. When the bag was empty and the waste dump valve closed, the waste water nozzle temperatures did not start to increase until about 3 min later, which was longer than the typical 25-30 sec maximum (MER-17). A small drop in nozzle temperatures was seen 6 min later while baking out between the CWC dumps. Later, the second CWC, which contained approximately 96 lb of Shuttle condensate and waste water, was successfully dumped and the subsequent bakeout was nominal. Two bakeout periods at 250 °F were performed and the nozzle temperature profile indicated smooth and linear temperature increase at the expected rate (20 °F/min) with no plateau of the temperature. The Mission Management Team (MMT) requested a third waste-water nozzle bakeout period for verification and it also was nominal. The troubleshooting indicated no icing problem surrounding the nozzles and the performance of the hardware was satisfactory.

Smoke Detection and Fire Suppression System

Smoke Detection and Fire Suppression (SDFS) operated nominally with no failures during the mission.

During the post-insertion Smoke Detection Circuit Test, The Right Flight Deck Smoke Detector light on panel L1 did not illuminate and the ground did not receive the Smoke Detector – Right Flight Deck telemetry. The other three B smoke detector lights did illuminate and the ground received the telemetry 3 sec later, which was then followed by the L1 detector light 1 sec later. During Smoke Detection Circuit Test A Parts 1 and 2, the telemetry for the detectors was received nearly simultaneously. The Smoke Detection Circuit Test B Part 2 was performed with nominal results. The Smoke Detection Circuit Test B Part 1 was repeated and all the panel L1 B lights illuminated. The Ground received the telemetry simultaneously, indicating that the Right Flight Deck smoke detector was working satisfactorily.

The staggered Smoke Detection and Fire Suppression indications are common as the contacts can be engaged at different times depending on how the switch is being depressed. It is common with a momentary rolling switch that, if the switch is not held long enough or if the resistance in the switch is not fully overcome (reaching the hard stop), then the contact may not have been engaged. Upon retest, all contacts were engaged as indicated when all the lights on Circuit "B" illuminated. According to D&C subsystem personnel, this scenario is common and likely with these types of switches.

Active Thermal Control System

The Active Thermal Control System (ATCS) performed nominally and one in-flight anomaly was noted and it is discussed in the following paragraph. The Orbiter had the nominal ATCS configuration. The cargo Heat Exchanger (HX) was installed and the plumbing for the cargo cooling loop was flown, but it was not serviced.

The ATCS had a Flash Evaporator System (FES) Primary B shutdown during post-insertion operations (STS-121-V-14). The FES Primary B was re-started successfully using only the Topper. Just before the crew sleep period, the FES cores were flushed and no indication of ice was observed. The crew switched over to FES Primary A to support the rest of the mission. A troubleshooting procedure was performed on FD13 which resulted in operating the FES in all known modes of primary and secondary controller operation. No shutdowns occurred. The troubleshooting procedure provided data to ensure confidence in the Primary B controller being able to support deorbit/entry operations, if required.

Displays and Controls System

The display and controls (D&C) subsystem, which also includes lighting, performed nominally during all phases of the mission.

Flight Software

Performance of all flight software [Primary Avionics Software System (PASS), and Backup Flight System (BFS)] was nominal throughout the STS-121 mission. No undocumented or unexplained PASS or BFS General Purpose Computer (GPC) errors or Input/Output (I/O) errors were encountered, nor were any in-flight anomalies identified.

Following the STS-121 ascent phase, a detailed analysis of BFS uplink- command handling revealed that the BFS was not properly constructing the BFS Network Signal Processor (NSP) validity word. This condition can provide false indications of a problem with the word count received from the NSP. There is adequate insight from other telemetry to determine when a false indication has been received. While the condition has been present since STS-1 and had no impact to mission success, the BFS was not

operating in accordance with requirements. An Operations Note and Waiver were prepared for STS-115 and the remaining missions using the OI-30 version of the software. This condition will be remedied on the OI-32 version of the software.

During the R-Bar Pitch Maneuver (RPM) prior to docking, the three PASS Guidance Navigation and Control (GNC) GPCs annunciated two GPC errors. The errors were documented in a PASS User Note, which this known condition of GPC errors caused by un-normalized body-to-inertial quaternion.

The BFS GPC logged 91 B1 errors from the end of the landing rollout to BFS Operational Sequence (OPS) 0 transition (MER-19). The GPC errors observed were the result of an attempt to take the square root of a negative number. Although this is a known condition documented in a BFS User Note, the number of GPC errors was significantly greater than past experience. Analysis by BFS personnel determined that the reason for the excessive number of GPC errors was caused by the continuous GPS incorporation into the BFS during this period. Since the GPS solution continuously refreshed the BFS navigation state vector (instead of average-g propagation) and kept the relative velocity near zero, BFS was more exposed to this condition.

Data Processing System Hardware

The Data Processing System (DPS) hardware performed nominally throughout the STS-121 mission. This hardware includes the General Purpose Computers (GPC), Multiplexer Interface Adapters (MIA), Data Bus Couplers (DBC), Data Bus Isolation Amplifiers (DBIA), Keyboard units (KBU), Multiplexer-/Demultiplexers (MDM), Engine Interface Units (EIU), and Master Events Controllers (MEC) / Backup Flight Controllers (BFC).

Multifunction Electronic Display System

Performance of the Multifunction Electronic Display Subsystem (MEDS) was nominal throughout the STS-121 mission. Post-flight review of MEDS fault logs confirmed the nominal performance observed via telemetry.

Flight Control System

The flight control hardware/effector systems performed nominally throughout the mission. During ascent, the SRB Thrust Vector Controller (TVC), MPS TVC, and aerosurface actuators were positioned exactly where the General Purpose Computers (GPCs) 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 Solid Rocket Booster Rate Gyro Assemblies (RGAs) tracked each another normally, and there were no Spin Motor Rotation Detector (SMRD) dropouts. The outputs of the four Accelerometer Assemblies (AAs) also tracked each other normally. The operations of the Reaction Jet Drivers (RJDs) were

also normal with no thruster fail indications or other anomalies noted. The Data Display Unit (DDU) and controller operation was nominal, and the Rotational Hand Controller (RHC) and Translation Hand Controller (THC) were both used and exhibited normal channel tracking.

The OMS-TVC File IX no-back requirements were met and the OMS-TVC actuator rates were normal. Flight control actuator temperatures were also normal. Rudder Speedbrake Power Driver Unit (RSB PDU) motor backdrive did not occur during the hydraulic systems shutdown.

Entry hardware and software performance was nominal. The pre-Time of Ignition (TIG) OMS gimbal profile was as expected with the OMS actuator active and standby channels reaching nominal drive rates. All aerosurface actuators performed normally. Secondary differential pressures for all actuators were well within the equalization threshold and all actuator positions closely tracked GPC commands. Entry hydraulic system temperatures were comparable to previous flights with aerosurface actuator temperatures being within the normal limits. The MPS TVC actuator performance was normal with secondary differential pressures within the threshold and TVC actuator positions and GPC commands followed each other closely.

Although the right air data probe did not deploy when commanded (STS-121-V-15), the left air data probe data was nominal and GNC was able to take air data for Terminal Area Energy Management (TAEM) and landing. Air data was also taken from the right probe once it deployed.

Air Data Assembly

The Air Data Transducer Assembly (ADTA) entry performance was nominal from deorbit through wheel-stop. All 16 transducers tracked during the pre-probe deployment phase of entry. No ADTA dilemmas or redundancy management failures occurred during the period from deployment through wheel-stop. ADTA entry data was retrieved and reviewed, and no anomalies were observed.

The right and left air data probe (ADP) deployments were initiated at approximately Mach 4.97 using the deploy switch positions. The left ADP deployment was nominal, and deployment timing was at less than 15 sec (within specification). The right ADP did not achieve a fully deployed position as indicated by the deploy limit switches and the right ADTA 2 and 4 pressure measurements (STS-121-V-15). The crew attempted to stow and re-deploy the ADP. During the stow attempt, the stow limit switches did not indicate that the ADP reached the fully stowed position in the 19 sec that the stow command was present; however, the ADTA pressure measurements indicate that the probe was out of the air stream. During the second deployment attempt, the deploy-with-heaters-on switch position was selected, but both the deploy limit switches and the ADTA pressure measurements showed that the ADP again did not achieve the full deployment position. Because AC current draw was normal for both motors, the probe was apparently jammed in an intermediate position. Comparisons between the left

ADTA 1 and right ADTA 2 center alpha pressure measurements show that the right ADP was approximately 20 degrees short of full deployment.

The crew made no further attempts to deploy the right ADP and incorporated the air data into the guidance and control (G&C) and the navigation (NAV) systems with only the left-side data valid at Mach 2.73. At approximately Mach 1.22, while in the air data system (ADS) Mach jump region, the right ADP became fully deployed. Because the ADS software was operating in AUTO, the right-side data was immediately also incorporated into G&C and NAV.

After wheel-stop, the right ADP deploy switch was taken from the heater position to the deploy position, which deactivated the ADP heaters. The ADTAs were subsequently powered off. The left ADP was stowed prior to rolling into the OPF, but the right ADP remained deployed to prevent destroying causes of the deploy failure.

Initial postflight testing of the switch indicated that the switch did not operate in an irregular manner. The physical examination of the right ADP found tile damage both forward and aft of the ADP opening. Raised metal on the ADP trunnion assembly matched witness marks on the tile and probe cavity thermal barrier. Based on the nature of the raised metal, the trunnion assembly damage most likely occurred during pre-mission operations.

Inertial Measurement Unit System

The performance of the Inertial Measurement Units (IMUs) during the STS-121 mission was satisfactory. The preflight calibrations of the accelerometers during the launch scrubs and the launch day countdowns resulted in good calibrations of the IMU parameters. During the on-orbit operations, the IMUs required only one adjustment of the onboard IMU accelerometer compensation values. One adjustment of the IMU drift compensation values was also required.

Global Positioning System Navigation

The Global Positioning System (GPS) operation during STS-121 was nominal. The system was powered 5 hr 42 min prior to launch. The GPS remained powered for the entire mission until 21 min 05 sec after landing. The GPS on this flight consisted of Miniaturized Airborne GPS Receiver (MAGR) (located in Avionics Bay 3B) and two preamplifiers (located on the Xo576 bulkhead). This is a Single String GPS configuration.

A major milestone for GPS on this flight was the auto-incorporation of the GPS state vector into the Backup Flight System (BFS) state vector during entry. The GPS state was incorporated into the BFS after performance confirmation with high-speed C-band tracking. This occurred at 21 min 51 sec after entry interface (approximately 10 min before touchdown), at 139,000-foot altitude. The effect was that the BFS navigation state vector errors (compared to the ground-filter state vector) were reduced from

approximately 2500 feet to less than 100 feet. The BFS navigation state vector errors remained consistently below 100 ft from GPS incorporation through rollout.

There were five occurrences where the Data Valid flag went OFF momentarily, and the longest duration was 1 min 42 sec. All five instances occurred while the Orbiter was docked to ISS, which is not unexpected since the ISS will occasionally block the GPS satellite signals and prevent the MAGR from tracking the minimum configuration of satellites. There were ten occurrences of Figure of Merit (FOM) "Chimneys", where the FOM was greater than 5 for a period of time greater than 138 seconds. Again, all but one of these FOM Chimneys occurred while docked to ISS and experiencing satellite-signal blockage by the ISS. However, one FOM Chimney occurred after undocking, and it was due to a desired satellite being in the Orbiter wing plane and temporarily "hidden" from both the upper and lower antennas. No FOM Chimneys occurred during the critical phase of entry (below 140,000 feet altitude), where GPS updates would be required.

Communications and Tracking System and Navigation Aids

During STS-121, the Communications and Tracking systems performed nominally.

The S-Band system 1 was in operation for approximately 24 hours, which satisfied the File IX requirement to operate the S-Band backup string continuously for 24 hours \pm 4 hours.

During postflight data review, the Ku-Band personnel discovered that the Ku-Band had radiated slightly inside the built-in 5-degree buffer in the Radio Frequency (RF) Protect Box (IFA STS-116-I-011). The event was the result of a command error. The hardware and software operated nominally.

The Navigation Aids (NAVAIDS) data analysis was successfully completed with nominal performance and all File IX requirements satisfied.

Operational Instrumentation and Modular Auxiliary Data System

The Operational Instrumentation (OI) hardware, which consists of the Pulse Code Modulation Master Unit (PCMMU), Payload Data Interleaver (PDI), and Master Timing Unit (MTU), performed nominally throughout the STS-121 mission.

Modular Auxiliary Data System (MADS) PCM ascent data were recorded on the Solid State Recorder (SSR) as on past flights. For the first time, these data were dumped to the ground following ascent (DTO 702). Evaluation of the MADS ascent data showed satisfactorily performance with the exception of two measurement anomalies discussed in the following paragraphs.

The Forward Fuselage Overhead Vent Pressure data were Off-Scale-High (OSH) during all of ascent (IFA STS-121-V-10). The telemetry measurement is Criticality 3/3 and was no impact to the vehicle, mission or crew.

During ascent, the 376-Bulkhead Differential Pressure (ΔP) measurement showed a higher negative ΔP across the bulkhead when compared to historical and predicted pressures (IFA STS-121-V-11). In addition, there were several transient excursions to Off Scale Low (OSL) limit. The ΔP observed would result in loads beyond certification. In-flight assessment confirmed that the observed excessive load would not cause hardware damage or deformation. During postflight inspection, it was discovered that two 376 bulkhead blankets near the vent port were incorrectly installed and blocked the port. The blankets were reconfigured without removing the Forward Reaction Control System (FRCS) module.

The Fuselage Left-Hand Surface Pressure dropped to OSL after reaching the near-nominal pressure during entry (IFA STS-121-V-18). The measurement is Criticality 3/3 and was no impact to the vehicle, mission or crew.

Mechanical Systems

The structures and mechanical systems performed nominally throughout the mission. No in-flight anomalies or significant problems were identified.

The port and starboard External Tank (ET) doors nominally closed following ET Sep. This was the first flight where yellow paint striping was added to the sidewall edges of the forward and aft outboard ET door perimeter corner tiles to aid visual verification of door closure during flight.

The payload bay doors (PLBDs) commenced opening as planned at 185/20:14:42 GMT (00/01:36:47 MET). All AC currents and limit switches were nominal and the motors opened the doors in dual motor time. The PLBDs commenced closing at 198/09:30:34 GMT (12/14:52:39 MET) in preparation for the first landing opportunity at KSC. The operation of the doors was nominal.

The port and starboard Manipulator Positioning Mechanism (MPM) were deployed on Flight Day 1 prior to RMS Uncradle and Checkout. They were stowed on Flight Day 12 following the completion of the OBSS late inspection for MMOD damage. All MPM deploy and stow run times were nominal dual motor time.

All Manipulator Retention Latch (MRL) release and latch operations associated with the port and starboard MPMs were nominal run time (dual motor time for Port MRLs, and single motor time for starboard MRLs).

Landing and Deceleration System

The main landing gear touchdown and drag chute deployment and rollout at KSC was normal. Both nose landing gear tires were in good condition and performed nominally. The new Improved Main Landing Gear (IMLG) tires and wheels also performed satisfactorily.

Since the new design IMLG tires do not contain "grooves" in the treads, their flat surfaces are very easy to assess for possible anomalies. Several areas of cords were observed. The cords visible on the IMLG tires are tread reinforcing cords and it is expected that these cords will be visible after most landings. Nominal wear can expose the tread reinforcing cords. Tread reinforcing cords are not the same as the carcass ply cords sometimes visible after high wear landings on the previous MLG tire design.

During landing, the Sabot and pilot chute bag became detached/separated after pilot chute deployment from the mortar firing tube. Post-landing inspection indicated that one Kevlar tie was missing and three beackets/loops were torn off the pilot deployment. This did not impact parachute deployment.

The following table presents the pertinent data on the landing of the Orbiter.

LANDING PARAMETERS

Parameter	From threshold, ft	Speed, keas ^a	Sink rate, ft/sec	Pitch rate, deg/sec
Main landing gear touchdown	3373.5	196.9	1.58	N/A
Nose landing gear touchdown	6387.0	145.0	N/A	-4.92
Parameter		Data		
Brake initiation speed		105.2 keas		
Brake-on time		53.94 sec		
Rollout distance		8950.4 ft (touchdown to wheel stop)		
Rollout time		74.87 sec		
Runway		15 (concrete) KSC		
Orbiter weight at landing		226,866.5lb		
Parameter	Maximum Brake Pressure, psia	Total Brake Energy, M ft/sec		
Left inboard	647.6	11.71		
Left outboard	568.3	10.66		
Right inboard	1044.0	21.24		
Right outboard	925.1	16.02		

^aKnots equivalent air speed.

Entry Aeroheating/Thermal

The post-flight inspections indicate that the overall Orbiter TPS appeared normal with no signs of excessive local heating. The lower structural temperature data indicated normal entry heating. The recorded temperatures were within the flight experience of OV-103. From the Modular Auxiliary Data System (MADS) surface thermocouple data, transition from laminar to turbulent flow occurred around Mach 7.1 and was symmetric. The two protruding Ames gap fillers that were observed on-orbit were the only two notable from the postflight assessment. Most of the protruding gap filler in front of the right-hand ET door area was gone as a result of entry heating. The other Ames gap filler at the left-hand wing, inboard of panels 16 and 17 was protruding and bent over along the forward edge and appeared to be intact. The following table shows the maximum temperatures and maximum temperature rise during entry.

ENTRY MAXIMUM TEMPERATURE AND MAXIMUM TEMPERATURE RISE DATA

Thermal Sensor Identifier and Location	Maximum Temperature, °F	Maximum Temperature Rise, °F
B1 Lower fuselage forward center	140.2	126.5
B2 Lower fuselage forward left-hand	187.5	179.5
B3 Lower fuselage forward mid left-hand	161.4	172.6
B4 Lower fuselage mid center	158.2	160.8
B5 Lower fuselage mid aft center	180.1	171.4
B6 Lower fuselage aft center	180.1	150.8
LW Left-wing center	119.5	133.8
RW Right wing center	124.7	136.6
B6 Lower fuselage aft center	180.1	150.8
LW Left-wing center	119.5	133.8
RW Right wing center	124.7	136.6
P1 Port side FRCS forward	164.2	144.9
P2 Port side fuselage forward center	101.5	105.9
P3 Port side fuselage forward mid center	96.1	100.5
P4 Port side fuselage mid aft center	75.1a	82.0a
P5 Port side fuselage aft center	77.8	64.5
S1 Starboard side FRCS forward)	180.0	135.7
S2 Starboard side fuselage forward center	142.7	126.5
S3 Starboard side fuselage forward mid center	121.1	83.8
S4 Starboard side fuselage mid-aft center	80.5	61.3
S5 Starboard side fuselage aft center	96.1	72.2
Left-hand OMS pod side forward	83.1	62.1
Right-hand OMS pod side forward	80.2	38.6
Lower body flap center	111.5 ^a	87.8 ^a

ENTRY MAXIMUM TEMPERATURE AND MAXIMUM TEMPERATURE RISE DATA (CONCLUDED)

Thermal Sensor Identifier and Location	Maximum Temperature, °F	Maximum Temperature Rise °F
Right-hand OMS-pod side forward	80.2	38.6
Left-hand OMS-pod side forward	83.1	62.1
Right-hand PLBD forward	75.4 ^a	102.5 ^a
Left-hand PLBD forward	72.8 ^a	125.1 ^a
Right-hand PLBD aft	82.7	97.2
Left-hand PLBD aft	80.6 ^a	110.0 ^a
Right wing upper center	96.2 ^a	113.0 ^a
Left wing upper center	95.9 ^a	115.5 ^a
FRCS forward center	98.5 ^a	72.1 ^a
Forward fuselage upper center	77.8 ^a	94.8 ^a

^a Maximum temperature occurred 30 minutes after landing.

Aerodynamics and Aerothermodynamics

The evaluation of the aerodynamics and aerothermodynamics showed nominal performance in both areas.

The Orbiter Boundary Layer Transition (BLT) onset time was confirmed at 1274 sec after entry interface or Mach 7.15 based on the location of X/L = 0.6. This transition time was based on the MADS data and the STS-121 best estimated trajectory (BET).

Based on the surface thermal sensor, the BLT occurred on the outboard Left-Hand (LH) wing near the trailing edge at 1230 sec after entry interface, corresponding to Mach 8.2. There was no sensor at the corresponding Right-Hand (RH) wing location. Final review of the aileron deflection data and yaw thruster firings indicated a symmetrical BLT.

The lower structural temperature data indicated normal entry heating and was within the range expected for this weight and inclination. The recorded temperatures were within the flight experience of the OV-103 vehicle.

Thermal Control System

The thermal control system controlled and maintained temperatures satisfactorily throughout the missions. No in-flight anomalies were noted in this system. Notable items are discussed in the following paragraphs.

During pre-launch operations on July 1, data showed that the Forward Reaction Control System (FRCS) Vernier thruster L5L heater was failed off (IFA STS-121-V-01). The launch was able to proceed because the failure had operational workarounds to

maintain the proper environment for the thruster. The port-side-Sun attitudes were used for the first two sleep periods during the pre-docked period to maintain the acceptable L5L thruster temperatures. These attitudes maintained the thruster-valves temperature above 40 °F and raised the injector temperature above 90 °F to allow firings during the rendezvous operations. The thruster was used for rendezvous and the manifold remained open because the injectors were maintained above 40 °F throughout the mission.

The APU 3 fuel bypass line heater over-temperature thermostat (OT) on system B started operating at approximately 193/04:38 GMT (007/10:00 MET). The OT thermostat continued operating for three cycles at which time the heater resumed cycling on the control thermostat. The heater again began operating on the OT thermostat on system B approximately 3.5 hr later and continued until the heater was switched to system A 46 min later. The A control thermostat was open when switching occurred because the temperature was above the control thermostat temperature range. Before the temperature range of the sensor dropped to the normal CT range, the A heater began operating on the OT. Control was switched back to system B occurred at 198/10:59 GMT (12/16:21 MET) and the heater operated on the OT thermostat and exhibited a dithering signature (IFA STS-121-V-09).

The APU 1 tank/service line pressure decay could not be identified as coming from the nitrogen side or the hydrazine side, although during ground processing, the nitrogen side had a minor leak, which was cleared. The APU 1 and APU 2 heater duty cycles were compared with the STS-105 duty cycles (same vehicle and beta-angle profile) and good comparison was found that indicated if the leak were on the hydrazine side, it was not affecting the sensors or thermostats. The adjacent APU 2 heater duty cycles were also compared and no anomalous signatures were noted. Port side Sun with the vehicle rolled 45 deg to the top (Sun in bay) was satisfactorily used for 10 hr on the first post-undocking sleep period and 5 hr on the second post-undocking sleep period to help warm the port sidewall area and thereby to help sublime/evaporate any potential hydrazine in that area (IFA STS-121-V-08).

STS-121 was the first flight using the improved Main Landing Gear (MLG) tires with a higher pressure at launch (425 psia vs. 385 psia). Since the mission was flown at a low beta angle, there was no need for end-of-mission (EOM) bottom Sun during the EOM period. The new MLG tire leak rates were within specification and the pressure vs. temperature response was consistent with the test data.

Thermal Protection System

The Thermal Protection System (TPS) performed satisfactorily. No significant areas of damage occurred.

Tile and Blanket Flight Assessment

Three protruding gap fillers were assessed by the TPS Damage Assessment Team (DAT) (IFA STS-116-V-04). The results of engineering assessments (thermal, boundary layer transition, stress, etc.) were presented to the MMT. All items were determined acceptable for entry.

An Ames Gap Filler aft of Port Reinforced Carbon Carbon (RCC) Carrier Panels 16/17 was discovered during LDRI inspection of the left/port wing on FD 2 (D-121-RPM-700_3-01). The gap-filler protrusion was 0.5 in tapering to 0.43 in.

A second Ames Gap Filler Forward of the right (Starboard) ET Door was identified during the FD 3 RPM maneuver was protruding 0.48 in tapering to 1.0 in (D-121-RPM-240-01).

The Left Outboard corner of the RCC arrowhead plate had a tadpole-shaped gap filler protruding between the tile and RCC (D-121-RPM-130_4-01). The protrusion was measured as 0.41 in \pm 0.3 in. The rooster-tail end stitching appeared to be damaged or missing and the fabric had started to fray. The maximum height of fraying did not appear to exceed 0.10 in.

Four blanket anomalies were assessed and cleared for entry by the TPS DAT (IFA STS-116-V-05), and the results of the assessments were presented to the MMT, which also were determined acceptable for entry.

Two Flexible Insulation Blanket (FIB) patches were identified to be partially torn during RPM imagery: blanket V070-391134-046 located aft of Forward RCS module thruster F1U (D-121-RPM-560-01); and blanket V070-391138-071 on the side of the port forward fuselage just aft of the FRCS module (D-121-RPM-140-02).

On-orbit imagery also identified two defects on AFRSI blankets on the port side of the vehicle at the crew hatch location. The door blanket appeared in the imagery to have a puffy condition (D-121-RMS-130_6-02), but no anomaly existed on this blanket when it was inspected during the post flight inspections. The second blanket appeared in the imagery to have a dark spot possibly indicating a piece of fabric or something lifted (D-121-RMS-130_6-01). A small tear was identified on the blanket during the postflight inspections..

RCC Flight Assessment

The Wing Leading Edge (WLE) Impact Detection System (IDS) performed very satisfactorily for ascent impact monitoring, allowing the ascent report to be published at 18 hr MET. The reported impacts were all near the 1.0 Grms reporting threshold. The report findings were considered by the TPS DAT when recommendations for focused inspections were made. Because the FD 2 wing survey had clear imagery for these

locations, a FD 4 focused inspection of the WLE IDS probable impact panel locations was not recommended by the DAT.

The Micrometeoroid Orbital Debris (MMOD) monitoring capability was limited for this flight because of the lack of continuous wing coverage associated with battery/thermal considerations, gaps in coverage due to lack of Ku-band communications and the time required to request units be brought out of and placed into the MMOD monitoring mode as well as excessive invalid triggering of the units. Substantial resources were required for this flight to downlink and evaluate the windows of recorded raw data to determine trigger validity. No valid triggers were detected.

The FD 2 Laser Dynamic Range Imager (LDRI) inspection resulted in five RCC regions of Interest (ROIs) (MER-24) for focused inspection and further analysis. The five regions of interest included one item on the Nose Cap, two items on Panel 5R, and two items on Panel 9R. The Leading Edge Subsystem (LESS) DAT presented the results of their engineering assessments MMT, and all items were cleared for entry.

STS-121 was the first flight to perform an RCC inspection late in the flight to look for MMOD impacts. The LDRI surveys of the port RCC (while docked) and starboard and nose-cap RCC (after undocking) were completed without issue. The LESS DAT reviewed the survey imagery, and identified no concerns for MMOD damage for those areas.

Post-flight, all focused inspection sites were examined and photographed during the postflight inspection on the runway. The panel 9R and nose-cap ROIs were not readily visible. The Panel 5 ROIs were still present. During additional post-flight inspections, an anomaly was found on the panel 10R T-Seal. The anomaly appeared to be a large crack (0.150 in long by 0.080 in wide) on the slip side of the T-Seal.

Post-Landing Inspection

A runway walk down and preliminary post-landing inspection of Discovery was conducted at Kennedy Space Center on Shuttle Landing Facility (SLF) runway 15. The Orbiter sustained 117 total hits, of which 12 had a major dimension of 1-in or larger, both within family. In general, damage occurred evenly between the right and left hand sides of the vehicle.

ORBITER DEBRIS DAMAGE

Orbiter Surface	Hits > 1in.	Total hits
Lower surface	10	87
Upper surface	N/A	N/A
Window area	1	21
Right side	1	6
Left side	0	3
Right OMS pod	N/A	N/A
Left OMS pod	N/A	N/A
Totals	12	117

N/A – not available prior to roll-in

There was a door chip on the right-hand (RH) nose landing gear door that measured 2.0 by 0.6 by .25 in. This is not considered to be a debris hit.

The tiles directly forward and aft of the RH air data probe had chips out of them. The tile forward had a chip of 1.2 by 0.3 by 0.2 in. The tile aft had a chip of 1.5 by 0.4 by 0.2 in. Neither of these is considered debris hits.

There were two protruding gap fillers. This first was located on the lower surface near tile 191021-026. The second was located near tile 395037-171. Both of these were seen on orbit.

The tile located between the left-hand (LH) inboard elevon and fuselage had large edge damage that was found on runway surface. This was not considered a debris hit.

The thermal barrier at the RCS thruster F4R was severely degraded, with a 3 in frayed area.

The nose cap, at approximately the 9 o'clock position, had a 1.5 in mark on it.

The ET/Orbiter umbilical pyrotechnics were nominal with minor charring on both sides. The EO (External Tank/Orbiter) -2 and EO-3 umbilical wells both had condensation inside the wells.

The SSME dome heat shield closeout blankets were nominal with minor fraying occurring at the 9 and 11 o'clock positions of engine 3.

The RCC panels were nominal with minor streaking and light scrapes noted.

Post flight inspection of the Orbiter Discovery lower surface following the STS-121 mission indicated the following:

1. Nominal performance of tiles and barriers installed on the nose landing gear, main landing gear and External Tank (ET) doors;
2. No apparent adverse effect of the gap filler protruding in front of the RH ET doors;
3. No damage on the chin panel carrier panel tiles from contact with the RCC panel;

4. The gap filler between the chin panel and nose cap exhibited typical shrinkage, and no outboard flow was detected after removal of the LH and RH carrier panels at the chin panel and nose cap interface
5. The protruding gap filler at the port wing near the RCC panels 16 and 17 caused early BLT at Mach 17.2 and elevated local heating resulted in tile slumping on acreage and elevon leading edge tiles on the left outboard elevon downstream of the protruding gap filler. Hardening of the captive gap fillers in the area was also noted.

Windows

The thermal and crew module windows performed as designed. Thermal windows (exterior) W1 through W6 were removed and taken to the NASA Shuttle Logistics Depot (NSLD) for detailed inspection and the remaining windows were inspected on the Orbiter. The detailed inspection of all of the thermal windows revealed a total of 160 impacts, of which four were defined as hypervelocity impacts and resulted in the windows (W1 and W6) being scrapped. Additionally, Window 3 was also scrapped. The window had 11 damage sites having depths equal or greater than 0.0002 in and one site that was 0.0082 in deep.

None of the crew module (interior) window glass had any new damage since the previous flight; however, damage to the window coatings were noted on Window 4 and 6. This damage was found to be within the acceptable criteria of the window inspection documentation and the windows will be flown in their present condition.

Waste Collection System

The Waste Collection System (WCS) performed satisfactorily with no anomalies noted.

EXTRAVEHICULAR ACTIVITY

The three Extravehicular Activities (EVAs) were satisfactorily completed for a total of 21 hr 29 min of extravehicular operations for each of the two crewmembers,

FIRST EXTRAVEHICULAR ACTIVITY

Space Shuttle Mission Specialists Piers Sellers and Michael Fossum completed the first of three scheduled EVAs on flight day 05. The total EVA-1 time was 7 hr and 31 min. The main objectives of the first EVA were:

1. Safe, replace and reroute the IUA cable on the MT so that the MT can be from worksite 4 to worksite 5 in preparation for the second EVA; and
2. Perform the Orbiter Boom Sensor System (OBSS) loads evaluation (Detailed Test Objective (DTO) 849).

The activities began with the installation of a blade blocking device on the zenith Interface Umbilical Assembly (IUA) to restore single string functionality to the Mobile Transporter (MT) and allow the MT to translate from worksite 4 to worksite 5. Following the first task, the crew configured the OBSS for the Worksite Stabilization by installing an Articulating Portable Foot Restraint (APFR) and Instrumented Worksite Interface (I-WIF) on the OBSS. The crew also installed a Tool Stanchion and APFR Ingress Aid on the OBSS to allow the performance of EVA maneuvers that would simulate inspection and repair input loads to determine the acceptability of the OBSS to be used as a potential Orbiter Thermal Protection System (TPS) inspection and repair platform while it is grappled by the Shuttle Remote Manipulator System (SRMS). The test included one and two crewmember configurations on the end of the OBSS at two different arm positions covering a range of system stiffness. The crewmembers were also positioned near the ISS P1 truss structure to enable additional input loads and also to quantify the force using a hand-held load measurement device. The RMS for this flight was instrumented with strain gauges to collect data on Data from the instrumented RMS loading conditions during the various EVA crewmember activities was obtained in accordance with per DTO 852 Shuttle Remote Manipulator System On-Orbit Loads, Heavy Payloads

SECOND EXTRAVEHICULAR ACTIVITY

The two extravehicular crewmembers completed the second of three scheduled EVAs on flight day 07. The total EVA-2 time was 6 hr and 47 min. The main objectives of the second EVA were:

1. Install Thermal Control System (TCS) Pump Module (PM);
2. Remove and replace nadir Trailing Umbilical system – Reel Assembly (TUS-RA)

During the second EVA, the two crewmembers successfully transferred the PM to the External Stowage Platform 2 (ESP-2) and removed and replaced the nadir IUA and Trailing Umbilical Reel Assembly (TUS RA). The crew began by installing a Fixed Grapple Bar (FGB) that was retrieved from the nadir side of the Integrated Cargo Carrier (ICC) and attached the grapple bar to the forward face of the PM. The Space Station Remote Manipulator System (SSRMS) maneuvered the PM to ESP-2 where the crew secured it using a Flight Releasable Attachment Mechanism (FRAM). The crew also performed the removal and replacement of the nadir IUA and TUS RA. The cable from the new TUS RA was routed to the MT and the severed TUS RA was reinstalled onto the ICC for return to Earth.

THIRD EXTRAVEHICULAR ACTIVITY

The Shuttle EVA crewmembers completed EVA 3 on flight day 9 in 7 hours and 11 minutes. This EVA was originally unscheduled but was inserted into the flight plan after it was determined that sufficient consumables were available to achieve the energy dependant day and the mission was extended to 13 days. The main objectives of the third EVA were:

1. Use the EVA Infrared (IR) Camera to video the Wing Leading Edge as a part of DTO 851;
2. Perform Thermal Protection System (TPS) Radial Carbon Carbon (RCC) Demonstration (DTO 848); and,
3. Install the second FGB from the ICC onto the Ammonia Tank Assembly on the S1 Truss Segment (Get-Ahead Task).

The crew used the EVA Infrared (IR) Camera to capture video of the Shuttle Wing Leading Edge (WLE) as part of the activities for DTO 851. This DTO was designed to test the IR Camera system for detecting backside Reinforced Carbon Carbon (RCC) damage and/or delamination. The IR Camera was used at different points during the EVA to capture additional images including the RCC samples in the Sample Box Assembly (SBA) installed on the Lightweight Multipurpose Experiment Support Structure Carrier (LMC) and also of ISS and SSP radiators. The second task performed was the TPS RCC Repair Demonstration (DTO 848). A manual caulk gun was used to dispense Non-Oxide Adhesive Experimental (NOAX) material to prepare simulated repaired samples of pre-damaged RCC coupons. A thermal sensor was used to ensure that the NOAX material was at the right working consistency before extruding the NOAX material onto a palette and applying it to the damaged samples. The samples remained stowed in the SBA in the payload bay and were returned to the ground for further analysis. The final task the crew performed was a get-ahead task that installed the second FGB from the nadir side of the ICC onto the Ammonia Tank Assembly on the S1 truss segment.

REMOTE MANIPULATOR SYSTEM AND ORBITER BOOM SENSOR SYSTEM

The Shuttle Remote Manipulator system (SRMS) performed nominally during the mission. STS-121 was the 71st flight of the Shuttle Remote Manipulator System (SRMS) and the 2nd flight of the Orbiter Boom Sensor System (OBSS). No in-flight anomalies were identified from the analysis of the data.

On Flight Day (FD) 1, the on-orbit initialization of the arm was performed. The port and starboard Manipulator Positioning Mechanisms (MPMs) were deployed and the SRMS shoulder brace was released.

On FD 2, the checkout of the SRMS was completed in less than 1 hr, and SRMS performance was nominal. The SRMS was then used to unberth the OBSS and complete the port and starboard Wing Leading Edge (WLE) RCC and nose cap surveys. The SRMS re-berthed the OBSS, and the SRMS and its cameras were used to perform the crew-cabin survey.

On FD 3, the Shuttle Discovery docked with the International Space Station (ISS) with the SRMS in the pre-cradle position. The Space Station Remote Manipulator System (SSRMS) grappled the OBSS Flight Releasable Grapple Fixture (FRGF), and the SRMS was maneuvered from the pre-cradle position to the pre-grapple position in preparation for the handoff of the OBSS to the SRMS. During this maneuver, the elbow joint was driven into an elbow-pitch singularity and through the soft stop, and an Elbow Pitch Tachometer Data Check Fail was annunciated. Analysis of this annunciation determined that the annunciation was a false alarm caused by the Elbow being driven at coarse joint rates through the soft stop while the vernier tachometer data check threshold was in effect. This explained condition can occur when the arm approaches a singularity and no hardware problem occurred.

On FD 4, the SRMS/OBSS performed focused inspection of five locations on the underside and nose cap of the Shuttle that had been noted in ascent imagery and during the RPM maneuver. The inspection was successfully completed in 4.5 hr after which the SRMS/OBSS was returned to the Multipurpose Logistics Module (MPLM) viewing position.

On FD 5, DTO-849 tests of the SRMS/OBSS as a work platform were performed during the first Extravehicular Activity (EVA). EV1 ingressed the Articulating Portable Foot Restraint (APFR), and the SRMS/OBSS was moved to position 1, where EV1 performed several movements to simulate inspection and repair actions. The SRMS/OBSS was then moved to the starboard sill for EV2 to take EV1's place in the APFR. The SRMS/OBSS was then maneuvered to position 3 (in front of the station's IP1 truss segment) for more test maneuvers with both crewmembers on the tip of the boom. The SRMS/OBSS was next maneuvered to the P1 Push-On Structure position to simulate repair maneuvers on the P1 Truss. As expected, several SRMS brake slips

occurred during the EVA (5 in wrist roll and 5 in wrist pitch). Following the EVA, the SRMS/OBSS was maneuvered to the EVA 2 viewing position. Data from the instrumented RMS loading conditions during the various EVA crewmember activities was obtained in accordance with per DTO 852 Shuttle Remote Manipulator System On-Orbit Loads, Heavy Payloads.

There were no SRMS/OBSS operations on FD 6. On FD 7, the SRMS/OBSS provided camera views during EVA 2, and was subsequently maneuvered to the MPLM Viewing Position. There were no SRMS/OBSS operations on FD 8, 9, or 10.

On Flight Day 11, the SRMS/OBSS performed the late inspection of the port RCC using Laser Dynamic Range Imager (LDRI), which required 1 hr 10 min. Following this operation, the SRMS/OBSS was maneuvered to the handoff position, where it remained through undocking.

On FD 12, following undocking, the SRMS/OBSS performed the late LDRI starboard and nose cap RCC surveys. The surveys required approximately 1 hr to complete. Following the survey, the SRMS berthed the OBSS, and the SRMS was cradled and powered down. The port and starboard MPMs were subsequently stowed, thus completing SRMS/OBSS activities for the mission.

WING LEADING EDGE IMPACT DETECTION SYSTEM (WLE IDS)

ASCENT MONITORING

Ascent analysis requests, downloads, downlinks, and analysis began at MET 7.5 hr, and continued until MET 18 hr, when the ascent report was published indicating six probable impacts ranging in magnitude from 0.9 to 1.6 Grms.

MMOD MONITORING

MER Documentation was repaired on the “WLEIDS Transition To On-Orbit Monitoring Mode” to initiate on-orbit monitoring earlier than FD 5 specified by the Flight Rule. MMOD monitoring of the starboard wing began at approximately 64 hr MET after approval of the MER Documentation. MMOD monitoring of the port wing began at approximately 108 hr MET, because of thermal considerations. Each WLE was monitored with groups of three units covering nine RCC panel interfaces. The sensor unit battery life limitations, which are highly dependent upon the thermal environment, prevented continuous on-orbit monitoring of each RCC panel.

IMPACT ANALYSIS – ASCENT DEBRIS IMPACTS

A total of five probable debris impacts above 1.0 Grms (three on the port and two on the starboard wing) were found and reported during ascent monitoring. One additional case just below 1.0 Grms on the port wing was reported during the mission because it had been previously reported to management as a probable impact above 1.0 Grms based on the summary data. Events similar to this will not be reported in future missions. The summary of probable and questionable impacts above 1.0 Grms for this flight is shown in the table on the following page.

Post-flight analysis concluded that all cases found during flight had been analyzed correctly. In addition to the five impacts above 1.0 Grms found during flight, post-flight analysis found another three impacts. These impacts were not found by reviewing the summary data during the flight because they were close to the aero-acoustic noise floor around the time of Max Q α . Automatic scanning of the full set of post-flight data allowed these impacts to be detected.

All units triggered on Main Engine Ignition and began recording data at launch within 0.1 sec of each other, except for the chine units and unit 1043. The chine units were expected to trigger differently because their accelerometers are not mounted to the WLE spar panel, and unit 1043 triggered about 1.7 sec late. Sensor unit 1043 was used to collect APU startup data pre-flight, and may not have completed processing prior to main engine ignition. During the flight, data from this unit was manually shifted to align it with the other units. The small errors between the other units allowed analysis to proceed without additional synchronization. Mission Elapsed Time was set to 8.6 sec behind Data Elapsed Time (MET=DET-8.6 sec).

ASCENT DEBRIS IMPACTS ABOVE 1 GRMS

Time (s)		Location			Magnitude		Criteria				Impact [†]	
MET	DET	Wing	RCC	Unit-Channel	Maximum Grms	Maximum G	Transient	Local	Spectral	Shock	In-flight	Post-flight
62.4	71.0	Port	2-3	1028-J2	1.3	4.5	+	+	+	+	U	P
68.9	77.5	Port	15-16	1031-J1	1.2	3.0	+	+	+	+	U	P
104.4	113.0	Port	6-7	1034-J3	1.6	6.2	+	+	+	+	P	P
110.4	119.0	Port	6-7	1023-J3	1.2	3.7	+	+	+	+	P	P
119.7	128.3	Port	11-12	1009-J3	1.0	3.3	+	+	+	+	P	P
76.1	84.7	Stbd	16-17	1029-J2	1.3	3.6	+	+	+	+	U	P
100.2	108.8	Stbd	6-7	1047-J3	1.3	4.8	+	+	+	+	P	P
104.1	112.7	Stbd	7	1049-J3	1.4	6.1	+	+	+	+	P	P
207.2	215.8	Stbd	15-16	1056-J1	1.0	2.6	+	+	-	-	P	P
137.4	146.0	Stbd	7-8	1044-J1	0.2	0.6	+	+	-	-	U	P
170.4	179.0	Stbd	7-8	1057-J1	0.2	0.6	+	+	-	-	U	P
190.9	199.5	Stbd	19-20	1054-J3	0.1	0.4	+	+	-	-	U	P

[†] P=probable, Q=questionable, N=no, U=unfound

not have completed processing prior to main engine ignition. During the flight, data from this unit was manually shifted to align it with the other units. The small errors between the other units allowed analysis to proceed without additional synchronization. Mission Elapsed Time was set to 8.6 seconds behind Data Elapsed Time (MET=DET-8.6 seconds).

Automatic scanning of post-flight data acquired from MET 10~500 seconds revealed a total of 85 probable ascent debris impacts on the wing leading edge (38 port and 47 starboard) ranging from 0.1 Grms to 1.6 Grms.

IMPACT ANALYSIS - MMOD IMPACTS

No valid triggers were recorded by the WLE IDS system so no analysis for possible MM/OD impacts was performed.

Anomalies

No major system anomalies were reported. A single transient data anomaly (data spike) was found during flight. Automatic scanning of post-flight data revealed three additional data transient anomalies, totaling four as shown in the table below. All were found on the starboard wing. Because they were of relatively low magnitude, and so

few in number, these data anomalies did not significantly affect data analysis during the mission.

Supplemental Data Collected

To capture the Auxiliary Power Unit (APU) prelaunch startup, time-only data were taken with units 1031 and 1043 from L-7.5 min to L-0.5 min, followed by the return-to-trigger mode for launch. The test captured responses to APU startup at approximately L-5 min, slew checks, and engine gimbaling at approximately L-4 minutes to assess if these events posed a risk to early triggering. Review of the data indicated that responses to these events posed no early trigger risk.

To capture the WLE response to docking events, 20 min of time-only data were taken from unit 1034 beginning at approximately 15 min prior to docking to determine vehicle responses to docking events. No responses of significant magnitude above the system noise-level were detected for this data take.

To characterize the on-orbit quiescent environment, five sec of time-only data were collected from all 44 units during crew sleep on Flight Night 3 to establish the quiescent background for these units prior to beginning MMOD monitoring.

To characterize the WLE IDS battery performance, 10 ½-sec ascent g-time history downloads were made from units near 0 °F, and the units were subsequently placed into on-orbit monitoring until reset to assess how downlinking of data at temperature affects remaining battery life. The first part of the test was completed for unit 1015, and full tests completed for units 1049, 1041, 1056, and 1060. These data were collected for and assessed by the WLE IDS hardware provider, not the WLE MER data analysis team.

CONCLUSIONS

The WLE IDS system performed extremely well for ascent impact monitoring, allowing the ascent report to be published at 18 hr MET. The reported impacts were all close to the 1.0 Grms reporting threshold. The report findings were considered by the Thermal Protection System Damage Assessment Team (TPS DAT) when recommendations for focused inspections were made to Flight Control. Because the Flight Day 2 wing survey had clear imagery for these locations, a Flight Day 4 focused inspection of the WLE IDS impact probable panel locations was not recommended by the DAT.

The MMOD monitoring capability was limited for this flight, because of the lack of continuous wing coverage associated with battery/thermal considerations, gaps in coverage due to lack of Ku-band communications, the time required to request units be brought out of and placed into MMOD monitoring mode, and excessive invalid triggering of the units. Substantial resources were required for this flight to downlink and evaluate recorded raw data windows to determine trigger validity. No valid triggers were detected.

GOVERNMENT FURNISHED EQUIPMENT/FLIGHT CREW EQUIPMENT

The Government Furnished Equipment/Flight Crew Equipment (GFE/CFE) performed nominally throughout the mission. Some minor problems surfaced and these are discussed along with other GFE/FCE that operated properly in the following paragraphs.

On Flight Day (FD) 1, the crew reported a leak in the Personal Hygiene Hose (PHH) (IFA STS-116-V-02). The leak was at the dispenser end of the hose, but water was not leaking out the end of the dispenser. As a workaround, the PHH was replaced with the Red-Red Hose and Contingency Water Dispenser. Leakage of the hose was confirmed during postflight testing.

During rendezvous tools checkout on FD2, the crew found that one of the Hand-Held Lidar (HHL) cables would not work (IFA STS-116-V-03). It was replaced with a spare, which functioned nominally. Postflight testing was performed on the unit using the actual flight computer and HHL, and no anomaly was discovered. The cable functioned as required; it appears to be an unexplained anomaly.

During on-orbit monitoring of the Micro Meteoroid Orbital Debris (MMOD) data from the Wing Leading Edge (WLE) Impact Detection System (IDS), Sensor 1009 failed to communicate via RF with the WLE System Payload General Support Computer (PGSC) (IFA STS-116-V-06). The WLES PGSC indicated a "local timeout" indicating that it stopped trying to communicate (via RF) with the unit after a specified time and number of attempts. Troubleshooting efforts were undertaken to re-establish the RF communication, but without success. During postflight troubleshooting, the battery was changed, the unit began to respond normally and all data was downloaded.

A magenta hue was noticeable on Closed Circuit Television (CCTV) camera (IFA STS-116-V-07). The camera was still usable for mission operations, and other cameras were available for use. The camera was shipped to the vendor for inspection/repair.

During the WLEIDS performance of on-orbit MMOD monitoring, S/N 1021 failed to communicate and process up-linked commands (IFA STS-116-V-16). This caused a shutdown of the WLE Graphical User Interface (GUI). S/N 1021 had been in on-orbit mode for approximately 14 hours and had successfully processed several commands before this issue. The crew was able to reboot the laptop and restart the WLE GUI software.

POSTLAUNCH LAUNCH PAD INSPECTION

No flight hardware was found during the post launch inspection of the Main Launch Platform 1 (MLP-1), Launch Pad Fixed Service Structure (FSS), and Launch Pad B Apron, which was conducted on July 4, 2006. All areas of FSS, MLP, North/South Flame Trench, and Pad Apron were completed.

Inspection of the SRB holddown posts was performed, and the south holddown studs were visually assessed and verified as having no indication of hang-up. The erosion was typical for both the north and south posts. The North holddown post (HDP) blast-covers exhibited nominal erosion from the SRB exhaust plume damage; however, HDP 4 exhibited more erosion than the other three HDPs with blast covers due to lack of red colorization from the room temperature vulcanizing (RTV) laminate system. A piece of red laminate approx 4 in by 4 in was found on the east Pad apron. HDP 5 exhibited an approximately 2 in diameter of lifted/missing EPON shim material. Both SRB aft skirt GN₂ purge lines were intact and still standing straight up. The protective tape layering was mostly eroded from both lines. The braiding for both lines appeared to be completely intact without any fraying evident. Approx 6 to 10 in of eroded NASA Standard Initiator (NSI) firing line was protruding from HDP 6. The left and right SRB T-0 Ground Umbilical Carrier Assemblies (GUCAs) also appeared to be in nominal condition.

The LO₂ and LH₂ Tail Service Masts (TSM) appeared undamaged and both bonnets appeared to have closed properly. The MLP deck was generally in excellent shape. Typical blast erosion was observed in and around the SRB flame holes.

The GH₂ vent line latched on the eighth tooth (of eight) on the latching mechanism. The vent line was located right of the center position in the latching mechanism. The forks of the latching mechanism were found to be straddling the left-tube support, but no witness marks were obvious on the left tube that would indicate hard contact had occurred. The ET GUCA 7-inch GH₂ Quick-Disconnect (QD) probe was accessible for inspection and appeared to be undamaged. Both the QD probe sealing surface and the poppet valve assembly were in good condition. The deceleration cable was in nominal configuration; however, the GH₂ vent line blanket was mostly torn away by plume impingement.

The Orbiter Access Arm (OAA) appeared to be intact with no evidence of plume impingement. All slidewire baskets were secured with no evidence of damage.

The gaseous oxygen (GOX) vent arm (GVA), vent hood, ducts and structure appeared to be in nominal condition; however, the GVA hood -Y window (when extended over ET) was broken and missing a large triangular piece approximately 9 in long by 4 in wide. This piece was found intact on the Southwest corner of the Pad apron. The top of the GVA hood plenum exhibited two or three areas of missing TPS material. The GOX vent seals were not inspected due to access limitation.

Although many items were found, the Pad facility was found to be in excellent condition from a debris/damage standpoint as compared to previous flows, including STS-114. The most notable debris items using the new debris collection criteria are included below:

1. Several pieces of Pad facility rust/scale was found at 195 ft Level. A 2.5-in by 1.5-in piece and 1-in by 1.5-in piece found near Slidewire Basket 4. A 4-in by 2-in piece and 2-in diameter piece were found on the North grating near the emergency shower. A 1.5-in diameter piece was found on the East grating at the stairwell;
2. A 1-in by 1.5-in piece of facility rust/scale found at 235 ft Level on the north grating;
3. A 2-in bolt, a 3-in bolt, and a tube clamp were found in the SSME flame Trench;
4. Three dog tags were found loose – one on MLP in Southwest gutter; one on the Pad apron below the Southwest corner of MLP; one on the MLP deck North of RSRM flame hole by camera pedestal. Another dog tag was found hanging unsecured at one end (requirement is that both ends secured) on pipe/conduit on West side of LH₂ Tail Service Mast (TSM).
5. Numerous pieces of SRB throat plug material were found on the Pad Apron; and
6. Two large pieces of concrete/fondue fyre material (1-ft by 4-in each) and several smaller pieces (approx 3-in diameter (maximum each) along with a 6-in by 4-in access control sign were found at the bottom of the SSME flame-trench.

DEVELOPMENT TEST OBJECTIVES

DTO 702 – MODULAR AUXILIARY DATA SYSTEM PULSE CODE MODULATION TO SHUTTLE SYSTEM RECORDER TELEMETRY

This DTO was the initial flight to demonstrate the capability to downlink Solid State Recorder MADS PCM data from the vehicle. MADS ascent data was downlinked while on orbit early in the mission. Two MADS telemetry issues were identified and evaluated real-time. The MADS entry data were downlinked following landing while the vehicle was on the runway. One MADS telemetry issue was identified. None of the MADS issues affected the mission.

DTO 805 – CROSSWIND LANDING PERFORMANCE

This DTO of opportunity was not performed during landing because of insufficient wind at the KSC landing site.

DTO 848 – THERMAL PROTECTION SYSTEM REPAIR TECHNIQUES

Reinforced Carbon Carbon (RCC) samples were flown in a TPS sample box. During the third EVA, the crew set-up the sample box to allow the EVA crewmembers to perform RCC sample repairs using Non-Oxide Adhesive Experimental material. The DTO was completed and returned to Earth for evaluation. All planned activities required by this DTO were completed satisfactorily.

DTO 849 – ORBITER BOOM SENSOR SYSTEM/SHUTTLE REMOTE MANIPULATOR SYSTEM LOADS CHARACTERIZATION WITH EVA CREWMEMBERS

During the first EVA, the two EVA crewmembers conducted activities on the Orbiter Boom Sensor System (OBSS) that was attached to the Remote Manipulator System (RMS). The purpose of the DTO was to evaluate use as a contingency vehicle inspection platform as well as a vehicle repair platform.

All planned activities in support of this DTO were performed satisfactorily.

DTO 850 – WATER SPRAY BOILER COOLING WITH WATER/PROPYLENE GLYCOL MONOMETHYL ETHER ANTIFREEZE

For the second consecutive flight, DTO 850 successfully demonstrated the capability to perform a Water Spray Boiler (WSB) hot restart with PGME/water as soon as 3 hr 50 min after launch. This further demon

strates the capability to support an early return from orbit in the event of a mission contingency.

This DTO was performed satisfactorily post-ascent on flight day 1. APU 3 was started with an injector temperature of approximately 372 °F (below 382 °F required to perform APU restart) with a Gas Generator bed temperature of 364 °F (below required maximum of 401 °F). APU 3 ran for 8 min 14 sec. Steady state cooling of the lubrication oil was maintained at approximately 258 °F for 5 min 4 sec.

DTO 851 – EVA INFRARED CAMERA

The EVA Infrared Camera provided the capability to image the Wing Leading Edge (WLE) and Reinforced Carbon Carbon (RCC) using Infrared thermography. The purpose of this DTO was to test the application of infrared thermography on the RCC during on-orbit inspection.

The EVA Infrared Camera performed very well during the third EVA, and provided imagery that clearly revealed underlying RCC sample delamination. The first objective, imagery of the RCC WLE, was accomplished while the crew was translating to the Shuttle payload bay and back to the ISS airlock. The second objective, damaged sample imagery, was accomplished by imaging RCC samples with known damage in the Sample Box Assembly.

DTO 852 – SHUTTLE REMOTE MANIPULATOR SYSTEM ON-ORBIT LOADS, HEAVY PAYLOADS

The objective of this DTO was to characterize the loads – the weight and force exerted on the structure – that are induced into the SRMS during non-typical loaded SRMS operations and to correlate these loads to math models. Non-typical loads include heavy payload maneuvering and interaction with the vehicle motion control system. Activities in support of this DTO were performed during the first EVA.

LAUNCH PHOTOGRAPHY AND TELEVISION ANALYSIS

Numerous cameras provided usable photography of the launch pad during the launch as well as ascent photography through Solid Rocket Booster (SRB) separation. No off-nominal conditions were noted in the launch operations photography; one off-nominal condition was noted about 13 seconds after launch when Instafoam was ejected from the right-hand SRB aft skirt. This condition was noted on several different cameras. Also, the cameras showed aft-skirt foam exiting the vehicle several times during the launch.

The following paragraphs discuss nominal conditions that were observed during the launch and ascent operations.

1. Ice particles were noted falling from the External Tank (ET)/Orbiter umbilical from Space Shuttle Main Engine (SSME) ignition through liftoff. Ice particles were also noted falling from the Liquid Oxygen (LO₂) Tail Service Mast (TSM) prior to liftoff. Also, TSM purge barrier material tore or came loose during SRB ignition.
2. Numerous pieces of SRB throat plug material were noted exiting the SRBs at ignition. None of the cameras showed any stud hang-up. The SRB holddown post blast covers closed normally.
3. The Orbiter aft Reaction Control System (RCS) and ET butcher paper were observed exiting the vehicle. Also, the Tyvek covers on the Forward RCS (FRCS) were noted leaving the vehicle.
4. The Orbital Maneuvering System (OMS) Assist maneuver was noted as well as SRB separation.

APPENDIX A

STS-121 MISSION EVENTS

Event	Description	Actual, GMT
ASCENT		
APU activation	APU-1 GG chamber pressure APU-2 GG chamber pressure APU-3 GG chamber pressure	185:18:33:09.109 185:18:33:10.473 185:18:33:11.696
*SRB HPU activation	Left HPU System A start command Left HPU System B start command Right HPU System A start command Right HPU System B start command	185:18:37:26.877 185:18:37:27.047 185:18:37:27.197 185:18:37:27.357
*MPS main engine (ME) start	ME-3 Start command accepted ME-2 Start command accepted ME-1 Start command accepted	185:18:37:48.425 185:18:37:48.573 185:18:37:48.679
*SRB ignition command (liftoff)	SRB Ignition command	185:18:37:54.987
Throttle to 104.5 percent	ME-3 Command Accepted ME-1 Command Accepted ME-2 Command Accepted	185:18:37:58.745 185:18:37:58.759 185:18:37:58.774
*Throttle to 67 percent	ME-1 command accepted ME-2 command accepted ME-3 command accepted	185:18:38:22.760 185:18:38:22.774 185:18:38:22.785
Maximum dynamic pressure	Derived ascent dynamic pressure	185:18:38:45
*Throttle to 104.5 percent	ME-3 command accepted ME-1 command accepted ME-2 command accepted	185:18:38:54.226 185:18:38:54.426 185:18:38:54.455
RCS window protect	Ignition command	185:18:39:56.6
Both RSRMs chamber pressure < 50 psi	Left RSRM chamber pressure Right RSRM chamber pressure	185:18:39:51.627 185:18:39:52.947
*End RSRM action time	Left RSRM chamber pressure Right RSRM chamber pressure	185:18:39:57.187 185:18:39:57.187
SRB separation command	SRB Separation command flag	185:18:39:57
*SRB physical separation	Left APU A Turbine speed – LOS Left APU B Turbine speed – LOS Right APU A Turbine speed – LOS Right APU B Turbine speed - LOS	185:18:39:57.507 185:18:39:57.547 185:18:39:57.547 185:18:39:57.587
OMS assist ignition	Left engine bi-prop valve position Right engine bi-prop valve position	185:18:40:07.8 185:18:40:07.8
OMS assist cutoff	Left engine bi-prop valve position Right engine bi-prop valve position	185:18:42:37.2 185:18:42:37.3
Throttle down for 3G	ME-3 command accepted ME-1 command accepted ME-2 command accepted	185:18:45:24.190 185:18:45:24.208 185:18:45:24.222
3g acceleration	Total load factor (g)	185:18:46:15.9
Throttle down to 67% for cutoff	ME-3 command accepted ME-1 command accepted ME-2 command accepted	185:18:46:18.591 185:18:46:18.609 185:18:46:18.623

APPENDIX A (Continued)

Event	Description	Actual, GMT
ASCENT (Concluded)		
SSME shutdown	ME-3 command accepted ME-1 command accepted ME-2 command accepted	185:18:46:25.071 185:18:46:25.089 185:18:46:25.103
MECO	MECO command flag MECO confirmed flag	185:18:46:26 185:18:46:27
ET separation	ET separation command flag	185:18:46:47
APU deactivation	APU-1 GG chamber pressure APU-2 GG chamber pressure APU-3 GG chamber pressure	185:18:52:22.808 185:18:52:37.244 185:18:52:43.365
OMS-1 maneuver	Left engine bi-prop valve position Right engine bi-prop valve position	Not required
OMS-2 ignition	Right engine bi-prop valve position Left engine bi-prop valve position	185:19:15:55.1 185:19:15:55.1
OMS-2 cutoff	Left engine bi-prop valve position Right engine bi-prop valve position	185:19:16:59.9 185:19:16:59.9
PLBD open	Right PLBD open 1 Left PLBD open 1	185:20:14:42 185:20:16:00
ON ORBIT		
OMS-3 ignition	Left engine bi-prop valve position Right engine bi-prop valve position	186:10:53:31.0 186:10:53:31.0
OMS-3 cutoff	Left engine bi-prop valve position Right engine bi-prop valve position	186:10:53:55.1 186:10:53:55.2
OMS-4 ignition	Left engine bi-prop valve position Right engine bi-prop valve position	186:21:45:59.2 186:21:45:59.2
OMS-4 cutoff	Right engine bi-prop valve position Left engine bi-prop valve position	186:21:47.47.3 186:21:47.47.3
OMS-5 ignition	Left engine bi-prop valve position Right engine bi-prop valve position	187:10:32:59.6 187:10:32:59.6
OMS-5 cutoff	Right engine bi-prop valve position Left engine bi-prop valve position	187:10:33:44.8 187:10:33:44.8
OMS-6 ignition	Left engine bi-prop valve position Right engine bi-prop valve position	187:12:04:46.1
OMS-6 cutoff	Left engine bi-prop valve position Right engine bi-prop valve position	187:12:05:03.3
Docking	Capture	186:14:51:42
Undocking	Undocking complete	196:10:07:38
FCS cutoff, APU start	APU-1 GG chamber pressure	197:07:57:57.660
APU stop	APU-1 GG chamber pressure	197:08:02:43.097

APPENDIX A (Concluded)

Event	Description	Actual, GMT
ENTRY		
PLBD close	Left PLBD close 1 Right PLBD close 1	198:09:30:34 198:09:33:29
APU activation	APU-2 GG chamber pressure APU-1 GG chamber pressure APU-3 GG chamber pressure	198:12:02:02.179 198:12:30:06.254 198:12:30:07.898
Deorbit burn ignition	Left engine bi-prop valve position Right engine bi-prop valve position	198:12:06:55:2 198:12:06:55:3
Deorbit burn cutoff	Left engine bi-prop valve position Right engine bi-prop valve position	198:12:09:58:2 198:12:09:58:3
Entry interface	Orbiter alternate/reference ellipsoid	198:12:42:49
Blackout end	Data locked (high signal rate)	No blackout
TAEM	Major mode code (305)	198:13:08:22
Main landing gear contact	MLG left tire press 2 MLG right tire press 1	198:13:14:42 198:13:14:42
MLG weight on wheels	MLG left weight on wheels MLG right weight on wheels	198:13:14:43 198:13:14:44
Drag chute deploy	Drag chute deploy No. 1 CP Volts	198:13:13:45.3
Nose landing gear contact	NLG left tire press 2	198:13:14:53
NLG weight on wheels	NLG weight on wheels	198:13:14:53
Drag chute jettison	Drag chute jettison No. 2 CP Volts	198:13:15:18.1
Wheels stop	Velocity WRT runway (F/S)	198:13:15:56
APU deactivation	APU-1 GG chamber pressure APU-2 GG chamber pressure APU-3 GG chamber pressure	198:13:33:16.397 198:13:33:24.397 198:13:33:30.239

APPENDIX B IN-FLIGHT ANOMALIES INTRODUCTION

This appendix contains listings and discussions of each of the In-Flight Anomalies (IFAs) that were identified for the STS-121 mission.

1. Orbiter
2. Solid Rocket Booster (SRB)
3. Reusable Solid Rocket Motor (RSRM)
4. External Tank (ET) (None)
5. Space Shuttle Main Engine (SSME)
6. Systems Engineering and Integration (SE&I)

No FO&I In-Flight Anomalies were identified for the STS-121 Missio

APPENDIX B STS-121 IN-FLIGHT ANOMALIES

ORBITER ANOMALIES

IFA Number	Title	Comments
STS-121-V-01	L5L Heater Failed Off	<p>During the first launch countdown attempt after start of ET loading, the Reaction Control System (RCS) vernier thruster L5L heater was found to be failed off. The thruster temperatures were cool and not responding to the environment. All other vernier thruster heater temperatures increased indicating nominal heater operation. The heater switch was cycled at in an attempt to clear the problem. Injector temperatures on the affected thruster did not change. Temperatures appeared to remain at ambient (approximately 80 °F) while the remaining vernier thrusters were at approximately 110 °F or above.</p> <p>The minimum equipment list required all six vernier thrusters be operational for launch and flight rules require all six thrusters operational for vernier control while docked to the International Space Station (ISS); however, primary thrusters can be used for control as required for rendezvous or mated operations. The remaining five vernier thrusters are sufficient for Orbiter-alone control operations. The thruster was reselected during ISS rendezvous with nominal firings. The thruster temperatures increased with subsequent firings. After docking, temperature dropped below 90 °F, and the thruster was deselected.</p> <p>Vehicle troubleshooting and depot-level testing isolated the failure to the thruster temperature controller. Thruster L5L was replaced and passed all ATP requirements.</p>
STS-121-V-02	Personal Hygiene Hose Leak	<p>At approximately 000/05:17 MET, the crew reported a leak in the Personal Hygiene Hose (PHH). The leak was reported at the dispenser end of the hose, but water was not leaking out the end of the dispenser. As a workaround, the PHH was replaced with the Red-Red Hose and Contingency Water Dispenser.</p> <p>Leakage of the hose was confirmed during postflight testing. No damage was detected in the hose, and the nut torque was satisfactory. The leak appears to be a Teflon tape application issue or an original test error. This unit was tested 2 years prior to actually being flown on STS-121. For STS-115, the STS-121 hose will not be used. The STS-115 hose-fluid connectors were physically inspected and pressure-decay tested approximately a month prior to STS-115 planned launch and no issues were found.</p>

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IFA Number	Title	Comments
STS-121-V-03	Hand-Held LIDAR Cable Failure	<p>During rendezvous tools checkout on FD2, the crew found that one of the hand-held Lidar (HHL) cables would not work. It was replaced with a spare, which functioned nominally.</p> <p>Postflight testing was performed on the unit using the actual flight computer and HHL, and no anomaly was discovered. The cable functioned as required; it appears to be an unexplained anomaly. For STS-115, a system integration test was performed with the flight cable, HHL and laptop and the system worked properly. Redundant rendezvous tools are stowed in the STS-115 vehicle.</p>
STS-121-V-04	Protruding Gap Fillers	<p>Three protruding gap fillers were discovered on the lower fuselage. One was discovered during the Laser Dynamic Range Imager (LDRI) inspection of the port wing. This was identified as 4-ply Ames gap filler protruding on the port wing between tiles V070-191021-025 and -026 with a protrusion height of 0.5 in. The other two were discovered during the R-Bar Pitch Maneuver (RPM). One was identified as a single-ply gap filler protruding forward of the starboard External Tank door between tiles V070-395051-141 and -150 with a protrusion height of 1.04 in. The third gap filler was identified as a “tadpole” gap filler protruding on the lower, forward fuselage between the Reinforced Carbon Carbon (RCC) arrowhead plate and tile V070-391045-205 with a protrusion height of 0.02 in. All protruding gap filler sites were cleared for entry. The postflight inspection identified 15 gap fillers protruding and 0 gap fillers missing.</p>
STS-121-V-05	TPS Blanket Damage	<p>Two blanket patches were identified as lifted on the upper, forward crew cabin during the RPM. These patches were on blankets V070-391134-046 and V070-391138-071. Debris generation was not considered an entry concern based on static testing of flown patches on the ground. Postlanding inspections showed the patches were still attached as predicted. All patches on all vehicles are being reworked or eliminated. On-orbit imagery also identified two defects on Advanced Flexible Reusable Surface Insulation (AFRSI) blankets on the port side of the crew cabin at the crew hatch. The blanket on the crew hatch appeared “puffy” and a second blanket appeared to have a dark spot possibly indicating a piece of fabric was lifted. Both of these blankets were cleared for entry. The postflight inspection showed that the “puffy” condition of the crew hatch blanket was no longer present and a small tear was identified on the second blanket. No additional work was required for these two blankets.</p>

APPENDIX B STS-121 IN-FLIGHT ANOMALIES

IFA Number	Title	Comments
STS-121-V-06	WLE IDS Port Sensor Communication Failure	During on-orbit monitoring of the Micro Meteoroid Orbital Debris (MMOD) data from the Wing Leading Edge (WLE) Impact Detection System (IDS), Sensor 1009 failed to communicate via RF with the WLE System Payload General Support Computer (PGSC). The WLES PGSC indicated a "local timeout" which means that it stopped trying to communicate (via RF) with the unit after a specified time and number of attempts. Troubleshooting efforts were undertaken to re-establish the RF communication, but without success. During postflight troubleshooting, the battery was changed, the unit began to respond normally and all data was downloaded.
STS-121-V-07	CCTV Camera D Magenta Hue	A magenta hue was noticeable on Closed Circuit Television (CCTV) camera. The camera was still usable for mission operations, and other cameras were available for use. The camera was shipped to the vendor for inspection/repair.
STS-121-V-08	APU 1 Fuel Tank Unexplained Pressure Decay	Over the course of the flight, a pressure decay of 22 psi was noted on the APU 1 fuel tank. The other two tanks decayed only by 6 psi during the flight. Flight Control predicted a decay of no more than 12 psi. Data were reviewed from eight previous flights (4 of OV-103 and 4 from other vehicles) and the highest decay that was noted was 8 psi. The 22-psi drop was noted on both the tank inlet pressure and the tank outlet pressure measurements, exonerating instrumentation. The postlanding toxic vapor check and inspections under the fuel-line insulation did not reveal any evidence of any fuel in the aft compartment. All evidence pointed to a GN ₂ leak and not a fuel leak. During turnaround operations, both GN ₂ Quick Disconnect (QD) seals were removed as this was the most probable cause of the pressure decay. The flight-cap leak tests at the Hypergolic Maintenance Facility (HMF) revealed no leak; however, the seal inspection revealed significant damage. This anomaly has been closed as an unexplained anomaly.

APPENDIX B STS-121 IN-FLIGHT ANOMALIES

IFA Number	Title	Comments
STS-121-V-09	APU 3 GG Fuel Line/ Pump/Valve Temperature Not Controlling on Primary Thermostat	The APU 3 Gas Generator Fuel Pump (GGFP) heater failed-on temporarily. The APU 3 GGFP thermostat appeared to stick and the heater was then controlled by the over-temperature thermostat. The temperatures decreased. However, the heater spiked again and the APU was switched to the "A" heater. Each APU 3 GG/FP heater circuit involves three separate heater elements, which are line heater A, fuel pump heater A and Gas Generator Valve Module (GGVM) Heater A. Troubleshooting was performed. The GGVM heater was isolated from the A system and resistance checks showed that a direct short existed at the GGVM heater. A jumper was installed and all APU 3 GG/FP heater positions were tested. The heater functioned as expected. These test results exonerated the line and fuel pump heaters.
STS-121-V-10	MADS Forward Fuselage Overhead Pressure Off- Scale High	The Modular Auxiliary Data System (MADS) forward-fuselage vent-door pressure reading was anomalous. The signature was off-scale high (OSH) during all of ascent. Sensor troubleshooting is planned for during this turnaround flow. The current plan is to defer the removal and replacement of this sensor until the next turnaround flow.
STS-121-V-11	MADS 376 Bulkhead Delta Pressure Excursion	The MADS measurement of the 376 Bulkhead differential pressure (ΔP) shows a higher ΔP across the Xo376 bulkhead during ascent when compared to historical and predicted pressures. The ΔP observed would result in loads beyond certification, but in-flight assessment confirmed that the excessive load would not cause hardware damage or deformation. During postflight inspection, it was discovered that two 376 bulkhead blankets near the vent port were incorrectly installed and blocked the port. The blankets were reconfigured without removing the Forward Reaction Control System (FRCS) module.
STS-121-V-12	MPS Engine 3 LH ₂ Inlet Pressure Transducer Failure	During ascent, the Main Propulsion System (MPS) engine 3 inlet pressure showed erratic performance and a pressure drift of 4 psi. The shift began at the end of the thrust bucket and lasted until Main Engine Cutoff (MECO). Since no other system measurements indicated a corresponding pressure signature, the instrumentation was the most probable cause of this behavior. At that point in the mission, the main engine inlet pressure transducers did not serve a critical function. The measurement transducer was removed and replaced.

APPENDIX B STS-121 IN-FLIGHT ANOMALIES

IFA Number	Title	Comments
STS-121-V-13	Airlock/Vestibule Delta Pressure Transducer Drifting Low	<p>The External Airlock/Vestibule ΔP pressure transducer was reading 13.1 psi and should have been between 14.8-15.0 psi. This sensor is used for the vestibule leak check and was not used again during the flight. The Airlock-to-Vestibule ΔP reading drifted low over the course of mission. On Flight Day (FD) 1, the initial bias was 0.2 psi and it increased to approximately 2.3 psi later in the mission. All other pressure sensors (cabin, airlock and airlock-to-overboard) showed no indication of leakage. During turnaround operations, the airlock diaphragm was pressurized and a short-duration vacuum test was completed with no evidence of the anomaly. Post-flight testing was unable to reproduce the anomaly; however, the transducer was removed and replaced. The IFA was declared and unexplained anomaly.</p>
STS-121-V-14	FES Full-Up Primary B Shutdown	<p>At 185/20:27 GMT (000/01:49 MET), the Flash Evaporator System (FES) shut down in the Primary B Controller full-up mode (high load and topper cores being operated). Prior to this event, the FES had been switched from Primary A full-up to Primary B full-up as a part of the configuration required for supply water accumulation to support water transfers to the International Space Station (ISS). Both Freon loops were in the radiator-flow configuration and the Payload Bay Doors (PLB's) were doors open. Prior to the shutdown, three anomalous temperature excursions occurred. Two minutes after the shutdown, the FES was switched to the Primary B topping mode, which provided stable control of the system. About 3 ½ hours after the shutdown, the FES core-flush procedure was initiated beginning with the flushing of the topping core and followed by flushing of the high-load core. No indications of ice were observed during the flushing. The FES was left in Primary A until docking at which time the FES was shutdown until undocking.</p> <p>Postflight troubleshooting resulted in Primary B controller box output being verified as satisfactory. The borescope inspection showed the cores to be in satisfactory condition. The valves showed no features of concern. The ramp test verified that the secondary midpoint sensor was lagging. It also verified no lagging in the Primary B midpoint sensor and the Primary B controller-outlet and shutdown-outlet sensors.</p>

APPENDIX B

STS-121 IN-FLIGHT ANOMALIES

IFA Number	Title	Comments
STS-121-V-15	Right Air Data Probe Initial Failure to Deploy	<p>During air data probe deployment, the right-hand (RH) probe initially failed to deploy. After 53 sec of drive time, power was removed for 1.5 sec, then both motors continued to drive in the deploy direction for an additional 26.5 sec. At that point, the crew moved the switch to the “stow” position and allowed the motors to drive for 19 sec in the stow direction, and no limit switches transferred. The switch was then moved to the “deploy/heat” position. The motors drove for an additional 2 min 27sec in the deploy direction until both “deployed” limit switches were obtained. Because ac current draw was observed for both motors, a probe jam in an intermediate position was indicated.</p> <p>The post-landing visual inspections showed damage to tiles forward and aft of the probe. The probe was left deployed while the Orbiter was moved to the Orbiter Processing Facility (OPF). The probe was moved to a 90-deg position to allow visual and borescope inspection. There was a small area of raised metal (approximately 0.018 in long and 0.0009 in tall) found on the upper corner of the trunnion box, and the aft tile showed a line of damage corresponding to the raised metal. The raised metal caused a large chip in the Outer Mold Line (OML). The aft thermal barrier also had a corresponding visible contact line or crease. The jam was caused by interference between raised metal on the trunnion box and forward tile. The cause of the raised metal is unknown, but is most likely contact with external foreign object during ground processing late in the previous flow.</p>
STS-121-V-16	WLE IDS Inadvertent Software Shutdown	<p>During the Wing Leading Edge Impact Detection System (WLEIDS) performance of on-orbit Micro-Meteoroid Orbital Debris (MMOD) monitoring, S/N 1021 failed to communicate and process up-linked commands. This caused a shutdown of the WLE Graphical User Interface (GUI). S/N 1021 had been in on-orbit mode for approximately 14 hours and had successfully processed several commands before this issue. The crew was able to reboot the laptop and restart the WLE GUI software.</p> <p>Based on the error message and responses of the unit, the most probable cause of the failure was an incorrect command sequence. It appears that the restart command was executed prior to the unit receiving the cancel command. The unit was in on-orbit mode when a raw window download command was executed. The cancel and restart sequence is necessary to close the file first in order to download it.</p>

APPENDIX B

STS-121 IN-FLIGHT ANOMALIES

IFA Number	Title	Comments
STS-121-V-17	WSB 3 Exhaust Duct Blanket Stained	<p>During Water spray Boiler (WSB) exhaust duct plug installation following landing, the thermal blanket around the WSB 3 vent was wet. A strong Propylene Glycol Monomethyl Ether (PGME) odor was also present, and rust-colored staining of the TPS was also present. Flow direction of stains supports a post-landing event. Flight data reviews indicate that the boiler operated nominally during the initial stages of active hydraulic fluid cooling, but failed to secure spraying when the boiler core was full. Data review also showed the bypass valve failed to return to bypass mode when expected; this failure was reproduced during troubleshooting in the OPF. Vendor tests of the WSB 3 temperature and liquid level sensors did not indicate any further functional problems. Other WSB controller functional checks were all nominal. The OV-103 WSB was returned to the vendor for further troubleshooting. Meetings on hazard assessment resulted concluded that ignition was PGME/water vapor would not occur. Subsequent to STS-115, this overflow was determined to be an explained condition.</p>
STS-121-V-18	MADS Fuselage Left-hand Side Surface Pressure Off-Scale Low	<p>During entry, this measurement dropped to Off Scale Low (OSL) prior to reaching nominal pressure. The measurement provides housekeeping data and is used for trending purposes. The high and low data range is 15 to 0 psia, respectfully. The measurement is Criticality 3/3 with no impact entry.</p>
STS-121-V-19	TPS Missing Putty Repairs	<p>Following the STS-121 landing, a total of five TPS putty repairs were missing. Four of the five putty repairs were associated with corner repairs. The remaining one of the putty repairs was on a tile sidewall with a small gap (0.04 in). Failure analysis of the damage sites was conducted and it was determined that the failures occurred in the tile substrate below the putty repair/substrate interface. The largest mass liberated was 0.0016 lb. No downstream damage can be attributed to the loss of any of the putty repairs.</p>

APPENDIX B STS-121 IN-FLIGHT ANOMALIES

IFA Number	Title	Comments
STS-121-V-20	Left Hand Outboard Carrier Panel Koropon Discoloration	<p>During inspection of the left hand outboard carrier panel, a localized Koropon discoloration indicative of overheating was noticed post flights 31 (STS-114) and 32 (STS-116). The color change is characteristic of a Koropon coated aluminum substrate exposed to a temperature approximately 400-450 F. Overheating was first noticed on the carrier panel after flight 31. The discolored Koropon was repaired and fresh corrosion protection was reapplied. After flight 32, the panel was inspected and it appeared to have more overheating indications. Engineering evaluation of the installed condition indicated an interface non-conformance between the gap filler and the columbium seal. A thick gap filler tends to result in over-compression of the carrier panel/columbium seal interface which produces a gap on the primary seal panel/columbium seal interface. This gap can allow a flow to be introduced potentially resulting in overheating to structure.</p> <p>A leak check evaluation resulting from the 0.018" gap along the approximately 6" interface between the columbium seal and the primary seal panel is still well below the certification limit of 65 SCFM. Therefore, the 0.018" gap should not adversely affect the function of the elevon system. The oversize gap filler was replaced with one that has the minimum allowable thickness (0.130" thinner than previous gap filler). The compression on the columbium seal was also minimized by removing the laminated shim on the carrier panel. Stress analysis indicates that the carrier panel with localized overheated condition continues to maintain a positive margin.</p>

APPENDIX B
STS-121 IN-FLIGHT ANOMALIES

SOLID ROCKET BOOSTER ANOMALIES

IFA Number	Title	Comments
STS-121-B-001	Enhanced Data Acquisition System (EDAS) Failure	Data was not obtained from one of two RH Enhanced Data Acquisition System (EDAS) units. EDAS S/N 2000002 was configured to record four channels of ET Liquid Hydrogen (LH2) PAL ramp data. The failure was isolated to drained memory keeper battery. The root cause was identified as no process for tracking battery installation time. The EDAS memory functioned properly after replacing drained keeper battery.
STS-121-B-002	Missing Paper Based Phenolic Shim Material from LH Aft Skirt Holddown Post (HDP) Shoe #5	HDP 5 exhibited approximately 2 in diameter of lifted/missing EPON shim material.

**APPENDIX B
STS-121 IN-FLIGHT ANOMALIES**

REUSABLE SOLID ROCKET MOTOR ANOMALIES

IFA Number	Title	Comments
STS-121-M-001	Gas Penetrations through Nozzle Joint 2 RTV with Soot to the Primary O-ring, RSRM-93A&B	<p>The RSRM-93B occurrence was identified as non-distinct intermittent gas penetrations through the dogleg from 305 to 0 to 85 degrees and from 126 to 215 degrees of the circumference. A small area of heat-affected virgin CCP was found on the nose cap at 165 degrees. No other heat affects to the adhesive, paint, metal, or O-rings were noted. Soot to the primary O-ring was observed at 158 degrees, but no soot was observed past the primary O-ring.</p> <p>The RSRM-93A occurrence was identified as non-distinct intermittent gas penetrations around the full circumference through the dogleg. No heat affects to phenolics, adhesive, paint, metal, or O-rings were found. Soot to the primary O-ring was observed intermittent from 45 degrees to 315 degrees. No soot was observed past the primary O-ring. These gas penetrations were through the Nozzle-Joint-2 RTV material with soot to the primary O-ring of both RSRM-93A and RSRM-93B. The RTV did not function as designed, thus resulting in an unsatisfactory condition.</p> <p>It should be noted that both gas penetrations on RSRM-93A and RSRM-93B are understood and are within the previous envelope of experience for joint 2.</p>

APPENDIX B STS-121 IN-FLIGHT ANOMALIES

EXTERNAL TANK

IFA Number	Title	Comments
STS-121-T-001	Bipod Heater Web Temperature Sensor	During the STS-121/ET-119 pre-launch power-on “perform/verify” checkout of the ET bipod heaters, the left-hand web temperatures continued to decrease almost to the LCC ET-14 15-minute minimum temperature limit of 8 °F and manual set-point control was initiated. The cause of the anomaly was the build-tolerances stacked of the redesigned bipod fitting, copper plate, phenolics isolator and the tolerance associated with the location of the web temperature sensor and wire bonding affected the overall heat transfer of the system.
STS-121-T-002	ET LH ₂ 5-Percent Liquid-Level Sensor Failed to Wet State During ET Liquid-Level Sensor Checkout	During ET liquid-level sensor replenish checkout, the LH ₂ 5-percent liquid-level sensor failed to the “wet” state. The sensor read “wet” after the sensor actually went dry during the draining of the LH ₂ . The sensor then transitioned spontaneously to the “dry” state two hours later.
STS-121-T-003	Photography from Camera 154 Showed the LO ₂ Brackets at Locations STA-1129, 1377, and 1632 Had Foam Damage	The bracket TPS damage at the three locations was noted by the Final Inspection Team (FIT) during the first launch attempt on July 1, 2006. The damage was described as: <ol style="list-style-type: none"> 1. Chafing between the LO₂ feedline bracket foam and the LO₂ feedline foam at STA’s 1129 and 1377; 2. Chafing plus small chips or slight damage, that had less than 0.5 in maximum Dimension. The most probable cause has been documented as a foam loss and chafing that resulted from LO ₂ feedline and LH ₂ tank movement as well as thermal effects of tanking. Acceptance criteria have been put into place for all future ETs.
STS-121-T-004	Crack in PDL Foam on the Inboard Strut of the LO ₂ Feed-line Bracket	Following the initial launch scrub, ice was observed at the Station 1129 feedline bracket strut at the strut/feedline interface. During the inspection following the second launch scrub, a crack in the PDL foam was observed during detanking, and subsequently, the cracked foam fell off and was found on level zero of the Mobile Launch Platform. The foam loss had a mass of 0.0057 lbm. Boroscope photographs showed no other anomalies and the assured that there were TPS integrity was not compromised. A use-as-is disposition was given, and a subsequent tanking and launch occurred on July 4, 2006. No additional non-conformances were identified in the numerous tests as well the documentation review.
STS-121-T-005	TPS Tear at Fairing and ET –Y SRB Tray Gap Noted after Tanking Complete	On July 4, 2006, after ET fill was complete, the FIT noted a TPS tear at the gap between the fairing and the ET/Y SRB cable tray. The dimensions of the tear were 2 in by 0.5 in wide by 0.5 in deep. This condition violated the Launch Commit Criteria. The most probable cause was determined to be that the TPS crack/tear resulted from LH ₂ movement and thermal effects of tanking. NSTS documentation has been updated to reflect the acceptance criteria for this condition.

APPENDIX B
STS-121 IN-FLIGHT ANOMALIES

SPACE SHUTTLE MAIN ENGINE ANOMALIES

IFA Number	Title	Comments
STS-121-E-01	Purge Pressure anomaly.	During ascent, MPS E-3 LH ₂ inlet pressure showed an erratic performance and a pressure drift of 4 psi. The drift only occurred during this flight when compared to the previous 6 flights. The shift began at the end of the thrust bucket and lasted until MECO.

**APPENDIX B
STS-121 IN-FLIGHT ANOMALIES**

SYSTEM ENGINEERING AND INTEGRATION ANOMALIES

IFA Number	Title	Comments
STS-121-I-001	SRB HDP #5 Shoe Shim Blister	Reference STS-121-B-002
STS-121-I-002	MLP-1, SRB Thermal Control System Primary system failed during S0007	LH and RH Igniter and joint heater primary power system "A" failed. Switched to redundant system "B".
STS-121-I-003	HDP#2 Range Safety Cable missing post-launch	Cable separated from SRB, but HDP piece was missing.
STS-121-I-004	Missing Orbiter putty repairs	Reference STS-121-V-19
STS-121-I-005	Orbiter TPS Blanket Repair Damage	Reference STS-121-V-05
STS-121-I-006	LH2 5% Sensor Channel Fail Wet	During each of the loading attempts, the External Tank (ET) liquid hydrogen 5-percent fill-point sensor failed wet when commanded to the dry state during the prelaunch simulation commands. During the two detanking operations, this sensor was slow to transition to dry. A failed wet condition of this sensor is acceptable for flight, as it is used during loading, detanking and for post-flight reconstruction, and has a backup timer for use during ascent.
STS-121-I-007	Orbiter Tile Shim Stock Debris Release	Reference STS-121-K-061
STS-121-I-008	Lift-Off Pad Facility Debris, including items from Shuttle Processing Special "K" list, post-launch pad walk-down reports, and imagery observations	Reference STS-121-K-014, 015, 016, 027, 028, 030 - 045, 057, 058, 060, 064,
STS-121-I-009	FIREX System Water Flow Reduction - Post STS-121 Orbiter heat shield spray test showed significant loss of water flow due to clogged strainer baskets from rust and scale in the MLP supply piping	Reference STS-121-K-012
STS-121-I-010	DOLILU ops anomaly - PLOAD LOX estimate high by ~ 600 pounds	Reference STS-121-D-005

APPENDIX B

STS-121 IN-FLIGHT ANOMALIES

IFA Number	Title	Comments
STS-121-I-011	Shuttle KU masks did not protect 5 degree buffer around SSRMS	During postflight data review, the Ku-Band personnel discovered that the Ku-Band had radiated slightly inside the built-in 5-degree buffer in the Radio Frequency (RF) Protect Box. The event was the result of a command error. The hardware and software operated nominally. Reference STS-121-D-004.
STS-121-I-012	Suspect Mystic Tape on Orbiter Right Inboard Elevon Cove Tiles - used in OPF processing	During STS-121 on-orbit imagery review, suspect Mystic tape was seen in two locations on the Right Inboard Elevon Cove Tiles. The STS-121 Pre-Flight Baseline Configuration Imagery (BCI) photos were reviewed, but the results were inconclusive because the elevons were tilted down which obscured the area in question. BCI photos for OV-104/STS-115 determined conclusively (due to the elevon position) that this condition did not exist on OV-104 for STS-115.
STS-121-I-013	Hydrogen Burn-Off Igniter (HBOI) ejected particles that impacted SSME 1 at HBOI startup	Hydrogen Burn-Off Igniter (HBOI) ejected debris impacted SSME #1 nozzle and left OMS nozzle during HBOI startup (T-9.9 seconds). SSME performance during ascent was nominal. This is a nozzle re-use issue, and the nozzle will be inspected post-flight to determine if rework is required.
STS-121-I-014	RH RSRM - Red Tape on Forward Dome Factory Joint Weatherseal Adjacent to Systems Tunnel at 95°	Red "rocket" tape which was used to mask the EPDM from Acrymax paint was found between the cable close out and the systems tunnel on the Right Hand (RH) forward dome factory joint weather seal (at 95 degrees). The tape was left by Ground Ops after painting the cable close out.
STS-121-I-015	Auxiliary Power Unit (APU) 1 Fuel Tank Unexplained Pressure Decay - 22 psi pressure decay over the course of the STS-121 flight	Reference STS-121-V-08
STS-121-I-016	Anomalous Shift Noted in SSME 3 Pressures	Reference STS-121-E-01

APPENDIX C

DOCUMENT SOURCES

MER DAILY REPORTS

The following STS-121 MER Daily Reports by David S. Moyer, Lead MER Manager:

- Launch (Ascent Plus 2-Hour) Report, dated July 4, 2006
- First Daily Report, dated July 5, 2006
- Second Daily Report, dated July 6, 2006
- Third Daily Report, dated July 7, 2006
- Fourth Daily Report, dated July 8, 2006
- Fifth Daily Report, dated July 9, 2006
- Sixth Daily Report, dated July 10, 2006
- Seventh Daily Report, dated July 11, 2006
- Eighth Daily Report, dated July 12, 2006
- Ninth Daily Report, dated July 13, 2006
- Tenth Eleventh Daily Report, dated July 14, 2006
- Eleventh Daily Report, dated July 15, 2006
- Twelfth Daily Report, dated July 16, 2006
- Thirteenth Daily Report, dated July 17, 2006
- Landing Plus 2 Hour Report, dated July 18, 2006

ET/SRB/RSRM/SSME REPORTS

- STS-121 SRB, RSRM and ET Console Flash Report, David W. Moor, USA-Huntsville, received July 5, 2006.
- STS-121 Preliminary Event Times, David W. Moor, USA-Huntsville, received July 5, 2006.
- STS-121 RSRM Flash Report, Glen Ricks for ATK RSRM Chief Engineer, received July 4, 2006.
- STS-121 RSRM Executive Summary, Larry Manuel, ATK-Huntsville, received July 31, 2006.
- STS-121 MSFC Elements In-Flight Anomalies, David W. Moor, USA-Huntsville, received December 20, 2006.

ORBITER REPORTS

- STS-121 Communications and Tracking, Martha M. May, Boeing-Houston, received September 8, 2006
- STS-121 OMS Report, Erich L. Bass, Boeing-Houston, received August 25, 2006.
- STS-121 ADTA Report, Howard A. Damoff, Boeing—Houston, received August 21, 2006.
- STS-121 D & C Post Mission Summary, Quoc F. Ngo, Boeing-Houston, received August 3, 2006.
- STS-121 Landing and Deceleration Report, Chip C. Heinol, Boeing-Houston, received August 2, 2006.
- STS-121 Global Positioning System Report, Ray W. Nuss, NASA-JSC, received August 29, 2006.
- STS-121 Structures and Mechanical Report, Jeffrey A. Goodmark & Link J. Salvador, Boeing-Houston, received December 21, 2006.
- STS-121 Sample Bottle Data, Keith E. Van Tassel, NASA-JSC, received December 18, 2006.
- STS-121 TPS Post Landing Inspection and Debris Assessment, T. Ford, NASA-KSC, received December 17, 2006.
- STS-121 WLE IDS Post Flight Report, Jon Max Maynard, Boeing-Houston, received December 15, 2006.

STS-121 Flight Software Report, Stephen D. Jayne, Boeing-Houston, received December 1, 2006.
STS-121 ATCS Post-Flight Mission Report, Christopher Hoffman, Boeing-Houston, received November 8, 2006.
STS-121 DPS Hardware Report, James E. Cooley, Boeing-Houston, received September 25, 2006.
STS-121 Final Post-Flight Aeroheating Report, Dennis C. Chao, Boeing-Houston, received September 16, 2006.
STS-121 EPDC Mission Report, William D. Peterson, Boeing-Houston, received August 29, 2006.
STS-121 RCS Mission Report, James M. Garza, Boeing-Houston, received August 25, 2006.
STS-121 MPS Mission Report, Rusty L. Scheier, Boeing-Houston, received August 25, 2006.
STS-121 Orbiter Docking System, Chip C. Heinol, Boeing-Houston, received August 25, 2006.
STS-121 Flight Control Systems, Donald L. McCorvey, Boeing-Houston, received August 23, 2006.
STS-121 RCS Pulse Count Data, Donald E. Varanouski, Boeing-Houston, received August 22, 2006.
STS-121 DTO 851 Analysis Results, Russell E. Yates, NASA-JSC, received August 17, 2006.
STS-121 Life Support Systems Report (ARPCS and Airlock Systems, Supply Water and Waste Water Management, and Fire and Smoke Detection System), Isaac Andu, Boeing-Houston, received August 15, 2006.
STS-121 Thermal Control System Mission Summary, Kent K. Rowley, Boeing-Houston, received August 10, 2006.
STS-121 Windows Mission Summary, Orlando Torres, Boeing-KSC, received August 10, 2006.
STS-121 Fuel Cells and PRSD Mission Report, Johnny D. Wong, Boeing-Houston, received August 9, 2006.
STS-121 OI/MADS Mission Reports, Bruce S. Woods and Dwight A. Favors, Boeing-Houston, received August 7, 2006.
STS-121 Auxiliary Power Unit Mission Report, Christopher N. Adi, Boeing-Houston, received August 4, 2006.
STS-121 Hydraulics-WSB System, Jeffrey S. Goza, Boeing-Houston, received August 4, 2006.
STS-121 Multifunction Electronic Display System (MEDS), Mark D. Fugitt, Boeing-Houston, received July 31, 2006.
STS-121 In-Flight Anomaly Input, Luis A. Saucedo, NASA-JSC, received August 29, 2006.
STS-121 In-Flight Anomaly Input, Michael D. Wright, NASA-JSC, received August 31, 2006.
STS-121 Orbiter In-Flight Anomaly Input, Malise M. Fletcher, NASA-JSC, received November 29, 2006.

OTHER REPORTS

STS-121 EVA Report, Aaron Mears, NASA-JSC, received August 3, 2006.
STS-121 Launch Photography and Television Analysis, Author Unknown, KSC, received December 20, 2006.
STS-121 Payload and Experiments Report, Michelle P. Lewis, NASA-JSC, received August 22, 2006.
STS-121 Remote Manipulator System and Orbiter Boom Sensor System, Leissa Smith, MDA Corporation, received August 17, 2006.
STS-121 Final Mission Events List, Vernon C. Hill, ESCG-Houston, received July 18, 2006.

APPENDIX D

ACRONYMS AND ABBREVIATIONS

Acronym	Definition
ADTA	Air Data Transducer Assembly
AFRSI	Advanced Flexible, Reusable, Surface Insulation
AGT	adaptive guidance throttling
APFR	Articulating Portable Foot Return
APU	Auxiliary power unit
ARC	Ames Research Center
ARPCS	Atmospheric Revitalization Pressure Control System
ARS	Atmospheric Revitalization System
ATCS	Active Thermal Control System
AVIU	Audio Visual Interface Unit
BGA	Beta Gimbal Assembly
BITE	built-in test equipment
BSM	Booster separation motor
C&T	Communications and Tracking
CDR	Commander
CMG	Control Moment Gyroscope
CST	comprehensive self-test
CWC	contingency water container
D&C	Displays and Controls
DDU	display driver unit
DPS	Data Processing System
DTN	Data Trend Notice
DTO	Development Test Objective
EAFB	Edwards Air Force Base
ECLSS	Environmental Control and Life Support System
ECO	engine cutoff
EDT	Eastern daylight time
EI	Entry Interface
EMU	extravehicular mobility unit
EOM	end of mission
EPDC	Electrical Power Distribution and Control
ESP	External Stowage Platform
ESPAD	External Stowage Platform Attachment Device
ET	External Tank
ETSD	EVA Tool Storage Device
EV1	designation for extravehicular crewmember 1
EV2	designation for extravehicular crewmember 2
EVA	extravehicular activity
EWA	Emittance Wash Applicator
FBMBT	flexible bearing mean bulk temperature
FCMS	Fuel Cell Monitoring System
FCS	Flight Control System
FES	Flash Evaporator System
FHRC	Flex Hose Rotary Cover

APPENDIX D

ACRONYMS AND ABBREVIATIONS

Acronym	Definition
FID	failure identifier
FPP	Floating Potential Probe
FRCS	Forward Reaction Control System
FSS	Flight Service Structure
GEI	ground environmental instrumentation
GMT	Greenwich mean time
GN&C	Guidance, Navigation, and Control
GPC	General Purpose Computer
GPS	Global Positioning System
GUCP	ground umbilical carrier plate
HPFTP	high-pressure fuel turbopump
HPOTP	high-pressure oxidizer turbopump
HRF	Human Research Facility
ICD	Interface Control Document
IDP	integrated display processor
IFA	In-flight anomaly
IPR	interim problem report
ISIS	Integrated Sensor Inspection System
ISS	International Space Station
ITVC	Intensified Television Camera
KSC	John F. Kennedy Space Center
l _{bm}	pounds mass
LCC	Launch Commit Criteria
LCG	liquid-cooling garment
LCS	Laser Camera System
LCVG	liquid cooling and ventilation garment
LDR1	Laser Dynamic Range Imager
LESS	Leading Edge Structural System
LH	left hand
LP	left pod
LRSI	low-temperature, reusable, surface insulation
LVLH	local vertical, local horizontal
LWT	lightweight tank
LWTSA	lightweight tool stowage assembly
MC	mid-course correction
MCC	Mission Control Center
MDD	mate/demate device
MDU	multifunction display unit
ME	main engine
MECO	main engine cutoff
MEDS	Multifunction Electronic Display System
MET	mission elapsed time
MISSE	Material International Space Station Experiment
Ml _{bf}	Million pounds force
MLI	multilayer insulation
MMOD	Micrometeoroid Orbital Debris

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ACRONYMS AND ABBREVIATIONS

Acronym	Definition
MMT	Mission Management Team
MMU	manned maneuvering unit
MPLM	multipurpose logistics module
MPM	manipulator positioning mechanism
MPS	Main Propulsion System
MRL	manipulator release latch
N/A	not applicable
NASA	National Aeronautics and Space Administration
NAVAID	Navigation Aid
NOAX	Non-Oxide Adhesive Experiment
NSI	NASA Standard Initiator
NSLD	NASA Shuttle Logistics Depot
NWS	nose wheel steering
OBSS	Orbiter Boom Sensor System
ODS	Orbiter Docking System
OFI	operational flight instrumentation
OME	Orbital Maneuvering Engine
OMRSD	Operational Maintenance Requirements and Specifications Document
OMS	Orbital Maneuvering System
OPS	Operational Sequence
ORGA	Orbiter rate gyro assembly
OV	Orbiter Vehicle
PASS	Primary Avionics Software System
PCMCIA	portable computer memory card international adapter
PCS	pressure control system
PEC	Payload Experiment Carrier
PGME	Propylene Glycol Monomethyl Ether
PGSC	payload general support computer
PGT	pistol-grip tool
PLBD	payload bay door
PMBT	propellant mean bulk temperature
ppm	parts per million
PRT	Problem Resolution Team
PTU	pan-and-tilt unit
PV&D	Purge, Vent, and Drain
PWR	payload water reservoir
RCC	reinforced carbon-carbon
RCS	Reaction Control System
RH	right hand
RHC	rotational hand controller
RIV	(Pogo) Recirculation Isolation Valve
RJD	reaction jet driver
RJMC	Rotary Joint Motor Controller
RM	Redundancy Management

APPENDIX D

ACRONYMS AND ABBREVIATIONS

Acronym	Definition
RMS	Remote Manipulator System
ROOBA	Recharge Oxygen Orifice Bypass Assembly
RP	right pod
RPC	Remote Power Controller
RPM	R-bar pitch maneuver
RSB PDU	Rudder/Speed Brake Power Drive Unit
RSC	RMS sideview camera
RSRM	Reusable Solid Rocket Motor
S&A	safe and arm
S/N	serial number
SAM	System Area Manager
scim	standard cubic inches per minute
SMRD	spin motor rotation detector
SODB	Shuttle Operational Data Book
SP	sensor package
SRB	Solid Rocket Booster
SRGA	station rate gyro assembly
SRMS	Shuttle Remote Manipulator System
SRSS	Shuttle Range Safety System
SSME	Space Shuttle Main Engine
SSP	Space Shuttle Program
SSRMS	Space Station Remote Manipulator System
STS	Space Transportation System
SWWMS	Supply and Waste Water Management System
TCS	Thermal Control System
TEA	torque-equilibrium attitude
THC	transitional hand controller
TIG	time of ignition
TPS	Thermal Protection System
TSA	Tool Stowage Assembly
TSM	Tail Service Mast
TVC	thrust vector controller
VRCS	Vernier Reaction Control System
VTR	Video Tape Recorder
WCL	water coolant loop
WCS	Waste Collection System
WIF	Worksite Interface Fixture
WLE	wing leading edge
WLEIDS	Wing Leading Edge Impact Detection System
WLES	Wing Leading Edge System
WSB	water spray boiler

APPENDIX D
ACRONYMS AND ABBREVIATIONS

Symbols:	Definition
ΔV	differential velocity
GH_2	gaseous hydrogen
GN_2	gaseous nitrogen
GO_2	gaseous oxygen
I_{sp}	specific impulse
LH_2	liquid hydrogen
$LiOH$	lithium hydroxide
LO_2	liquid oxygen
P_c	chamber pressure
SiC	silicon carbide