

STS-113 SPACE SHUTTLE MISSION REPORT

February 2003



**National Aeronautics and
Space Administration**

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

NOTE

The STS-113 Space Shuttle Mission Report was prepared from inputs received from the responsible Space Shuttle Program offices as well as other organizations. The following personnel may be contacted should questions arise concerning the technical content of this document.

Kenneth L. Brown
281-483-3891

Orbiter and Subsystems

James Yeager, MSFC
256-544-3963

MSFC Elements (SRB,
RSRM, SSME, ET,
SRSS, and MPS)

Tandy N. Bruce
281-483-1142

Payloads/Experiments

Nanette F. Cerna
281-483-9045

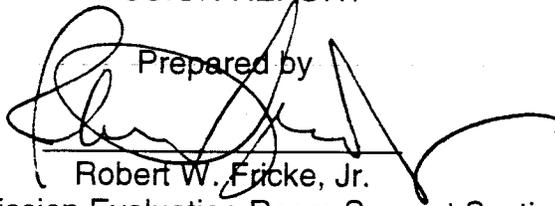
FCE and GFE

STS-113

SPACE SHUTTLE

MISSION REPORT

Prepared by



Robert W. Fricke, Jr.

LMSO/Mission Evaluation Room Support Section

Approved by



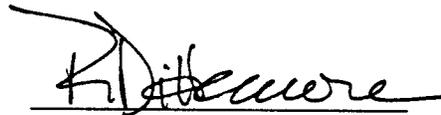
Kenneth L. Brown

STS-113 Lead Mission Evaluation Room Manager
Space Shuttle Vehicle Engineering Office



Ralph R. Roe, Jr.

Manager, Space Shuttle Vehicle Engineering Office



Ronald D. Dittmore

Space Shuttle Program Manager

Prepared by

Lockheed Martin Space Operations

for the

Space Shuttle Vehicle Engineering Office

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
LYNDON B. JOHNSON SPACE CENTER
HOUSTON, TEXAS 77058

February 2003

STS-113 Table of Contents

<u>Title</u>	<u>Page</u>
<u>INTRODUCTION</u>	1
<u>MISSION SUMMARY</u>	3
<u>PAYLOADS AND EXPERIMENTS</u>	10
<u>SUMMARY</u>	10
ISS OPERATIONS.....	10
CREW ACTIVITIES.....	11
MEMS-BASED PICOSAT INSPECTOR SATELLITE DEPLOYMENT.....	13
ISS PROBLEMS.....	13
<u>VEHICLE PERFORMANCE</u>	14
LAUNCH DELAY.....	14
SOLID ROCKET BOOSTERS.....	14
REUSABLE SOLID ROCKET MOTORS.....	14
EXTERNAL TANK.....	16
SPACE SHUTTLE MAIN ENGINES.....	17
SHUTTLE RANGE SAFETY SYSTEM.....	17
ORBITER SUBSYSTEMS PERFORMANCE.....	18
<u>Main Propulsion Subsystem</u>	18
<u>Reaction Control Subsystem</u>	18
<u>Orbital Maneuvering Subsystem</u>	21
<u>Power Reactant Storage and Distribution Subsystem</u>	22
<u>Fuel Cell Powerplant Subsystem</u>	23
<u>Auxiliary Power Unit Subsystem</u>	24
<u>Hydraulics/Water Spray Boiler Subsystem</u>	24
<u>Electrical Power Distribution and Control Subsystem</u>	25
<u>Orbiter Docking System</u>	25
<u>Atmospheric Revitalization Pressure Control Subsystem</u>	25
<u>Atmospheric Revitalization Subsystem</u>	26
<u>Active Thermal Control Subsystem</u>	28
<u>Supply and Waste Water Subsystem</u>	29
<u>Waste Collection Subsystem</u>	30
<u>Smoke Detection and Fire Suppression Subsystem</u> ..	30
<u>Flight Data Subsystem</u>	30
<u>Flight Control Subsystem</u>	31
<u>Flight Software</u>	31
<u>Displays and Controls Subsystem</u>	31
<u>Communications and Tracking Subsystem</u>	31
<u>Operational Instrumentation/Modular Auxiliary Data System</u>	32
<u>Structures and Mechanical Subsystems</u>	32
<u>Integrated Aerodynamics, Heating and Thermal Interfaces</u>	34
<u>Thermal Control Subsystem</u>	34
<u>Aerothermodynamics</u>	34

STS-112 Table of Contents

<u>Title</u>	<u>Page</u>
<u>Thermal Protection Subsystem and Windows</u>	35
<u>Gas Sample Analysis</u>	36
<u>EXTRAVEHICULAR ACTIVITY</u>	37
FIRST EXTRAVEHICULAR ACTIVITY.....	37
SECOND EXTRAVEHICULAR ACTIVITY	37
THIRD EXTRAVEHICULAR ACTIVITY	37
<u>REMOTE MANIPULATOR SYSTEM</u>	38
<u>GOVERNMENT FURNISHED EQUIPMENT/FLIGHT CREW</u>	
<u>EQUIPMENT</u>	39
<u>POSTLAUNCH PAD INSPECTION</u>	40
<u>DEVELOPMENT TEST OBJECTIVES/DETAILED SUPPLEMENTARY</u>	
<u>OBJECTIVES</u>	41
DEVELOPMENT TEST OBJECTIVES.....	41
DETAILED SUPPLEMENTARY OBJECTIVES	41
<u>PHOTOGRAPHY AND TELEVISION ANALYSIS</u>	43

List of Tables and Appendixes

<u>TABLE I - STS-113 SEQUENCE OF EVENTS</u>	44
<u>TABLE II - SPACE SHUTTLE VEHICLE ENGINEERING OFFICE</u>	
<u>IN-FLIGHT ANOMALY LIST</u>	47
<u>A - DOCUMENT SOURCES</u>	A-1
<u>B - ACRONYMS AND ABBREVIATIONS</u>	B-1

INTRODUCTION

The Space Transportation System (STS) -113 Space Shuttle Program Mission Report presents a discussion of the Orbiter activities of the mission, as well as presenting a summary of the External Tank (ET), Solid Rocket Booster (SRB), Reusable Solid Rocket Motor (RSRM), and Space Shuttle main engine (SSME) performance during this one-hundred and twelfth mission of the Space Shuttle Program. The STS-113 flight was the sixteenth flight to the International Space Station (ISS). STS-113 was the eighty-seventh mission since the return to flight, and the nineteenth flight of the Orbiter vehicle (OV) -105 (Endeavour) vehicle.

The flight vehicle consisted of the OV -105 Orbiter; an ET, which was the sixteenth Super Lightweight Tank (SLWT), and it was designated ET-116; three Block II SSMEs that were designated as S/Ns 2050, 2044 and 2045 in positions 1, 2 and 3 respectively, and two SRBs that were designated B1114. The two RSRMs were designated RSRM-86 with one installed in each SRB. The individual RSRM serial numbers were 360W086A for the left SRB and 360W086B for the right SRB.

The primary objective of the STS-113 mission was to launch the ISS 11A cargo element (CE) Integrated Truss Segment (ITS) - Port 1 (P1), install that truss on the ISS Stage 9A and perform an ISS Expedition 6 crewmember rotation with the three Expedition 5 crewmembers. The CE consisted of the ITS P1 pre-integrated with ultra high frequency (UHF) communication equipment, thermal radiator rotary joint (TRRJ), three external active thermal control system (EATCS) radiators, DC-to-DC converter unit (DDCU), remote power controller module (RPCM), and crew equipment translation aid (CETA) cart. Additionally, The Shuttle crew performed three extravehicular activities (EVAs) using the ISS airlock. Middeck items consisting of extravehicular activity (EVA) tools and equipment, camera lights, external television (ETV) camera, ISS Utilization payloads, portable computer system (PCS) items, photographic/TV equipment and water transfer equipment for on-orbit use and transfer were included.

The secondary objective was to deploy the MEMS-based PICOSAT Inspector (MEPSI) satellite. This scientific experiment consisted of two miniature satellites connected by a 50-foot tether.

The STS-113 flight was an 11 day, plus 1-day plus 2-contingency-day flight, of which seven days were to be docked to the ISS. The one additional day was provided, should and additional docked day be required. The two contingency days were available for landing weather avoidance or other Orbiter contingency operations. The sequence of mission events is shown in Table I, and the Orbiter In-Flight Anomaly List is shown in Table II.

All times during the flight are given in Greenwich mean time (G.m.t.) and mission elapsed time (MET). Appendix A lists the sources of data, both formal and informal, that were used in the preparation of this report. Appendix B provides the definition of acronyms and abbreviations used throughout this report.

The ten crewmembers that were on the STS-113 mission consisted of James D. Wetherbee, Captain, U. S. Navy, Commander; Paul S. Lockhart, Lt. Col., USAF, Pilot; Michael E. Lopez-Alegria, Captain, U. S. Navy, Mission Specialist 1; John B. Herrington, CDR, U. S. Navy, Mission Specialist 2; Kenneth D. Bowersox, Captain, U. S. Navy, Expedition 6 Commander; Nikolai M. Budarin, Cosmonaut, RSC Energia, Expedition 6

Soyuz Pilot, Donald R. Pettit, Ph.D., Civilian, Expedition 6 Flight Engineer. The Expedition 5 returning crewmembers are Valery G. Korzun, Colonel, Russian Air force Expedition 5 Commander and Soyuz Pilot; Sergei Y. Treshcev, Cosmonaut, RSC Energia, Flight Engineer; and Peggy A. Whitson, Ph.D., Civilian.

STS-113 was the sixth Space Shuttle flight for the Commander, the third space flight for Mission Specialist 1, the second space flight for the Pilot, and the first space flight for Mission Specialist 2.

This flight to the ISS was the fifth Space Shuttle space flight for the Expedition 6 Commander and the beginning of his first long-duration flight. This flight to the ISS was the second Space Shuttle flight for the Soyuz Pilot and the beginning of his second long-duration space flight. This flight was the first Space Shuttle flight for the Science Astronaut and the beginning of his first long-duration flight. The Expedition 5 Commander completed his second long-duration flight as well as his second Space Shuttle flight. The returning Expedition 5 Flight Engineer completed his first long-duration flight and his second Space Shuttle flight. The Expedition 5 Science Astronaut completed her first long-duration space flight and her second Space Shuttle flight.

MISSION SUMMARY

The vehicle subsystems performed satisfactorily, and all of the planned objectives of the STS-113 mission were accomplished.

The STS-113 mission was originally scheduled to launch on November 10, 2002. During the launch countdown, a high oxygen concentration in the payload bay led to the decision to scrub the launch (Flight Problem STS-113-V-01). The launch was tentatively rescheduled for November 17, 2002. The leaking flexible oxygen hose was replaced; however, during the repair activities, a work platform came in contact with the remote manipulator system (RMS) and caused some visible damage to the RMS. As a result, the launch was rescheduled for November 22, 2002, so that the Canadian RMS manufacturer could perform structural tests of the RMS. These tests proved that the structural integrity was not decreased and the RMS was declared ready for flight.

The launch countdown on November 22, 2002, was stopped during the T-9 minute hold because of adverse weather at the transatlantic abort landing (TAL) site and a 24-hour delay of the launch was declared.

During the countdown and the first six minutes after powering up the Global Positioning System (GPS) and commanding to navigation, the miniature air-to-ground receiver (MAGR) was expected to acquire and track satellites; however, the MAGR did not track any satellites. All channels reset and normal satellite acquisition and tracking began within 15 seconds. This problem did not impact the mission. The problem also was not expected. An investigation into the cause this anomaly has begun.

The STS-113 mission was launched at 328:00:49:47.021 G.m.t. on November 23, 2002, on the sixteenth mission to the International Space Station (ISS). This mission was an assembly and crew-exchange mission to the ISS. All Orbiter subsystems performed satisfactorily during ascent.

An orbital maneuvering subsystem (OMS) assist maneuver was performed following Solid Rocket Booster (SRB) separation. The maneuver was initiated at 328:00:52:01 G.m.t. (00:00:02:14 MET) and was 82.2 seconds in duration. At the end of the maneuver, the right-OMS ball-valve-2 continued to indicate open (Flight Problem STS-113-V-02). The indication dropped only 0.5 percent so that the current reading was 95.8 percent and should have been 0 percent. In accordance with the flight rules, the right OMS was to be used only for the deorbit maneuver. The remaining OMS rendezvous maneuvers were performed in the single-engine mode using only the left OMS engine.

The auxiliary power unit (APU) -2 injector temperature was biased higher than normal as seen during the last four flights of this APU (STS-97, -100, -108 and -111). The cause is believed to be the in-family failure of the spring clip retainer losing its spring properties. The loss of spring properties of the retainer, which holds this sensor and the heater controlling bed temperature sensor firmly to the gas generator (GG) injector well wall, has allowed the sensors to shift position. A design change to correct this problem is a double-walled spring clip, which is in final stages of approval. All three APUs will be removed during postflight turnaround activities for their standard 4-year maintenance plan refurbishment during which the spring clip modification will be made to APU 2.

The OMS 2 maneuver was performed using the left engine at 328:01:27:36 G.m.t. (00:00:37:49 MET) and was 339.8 seconds in duration. The differential velocity (ΔV) was 253.4 ft/sec, and the orbit was 125.8 by 170.0 nautical miles (nmi) following the maneuver. The OMS performed satisfactorily throughout the maneuver.

The payload bay doors were opened as planned at 328:02:34:37 G.m.t. (00:01:44:50 MET). All voltages were nominal and the motors opened the doors in nominal dual-motor time.

The Johnson Space Center (JSC) Image Science and Analysis Group noted no potentially anomalous events during the screening of the STS-113 launch videos.

Checkouts of the RMS, extravehicular mobility units (EMUs), the Orbiter space vision system (OSVS), and rendezvous tools were successfully completed and the docking ring was extended.

During the RMS checkout of the wrist-roll joint direct-drive, tachometer data showed rate spikes of approximately 2 radians/second in the negative direction (Flight Problem STS-113-V-03). At the start of the payload bay survey following the RMS checkout, a payload deployment retrieval system control point of resolution (PDRS CNTL POR) fault message was annunciated. A quick test of the wrist roll joint was successfully performed and the survey was continued with no further occurrences of the fault message. A second direct-drive test of the wrist roll joint was performed prior to cradling to confirm the health of the joint. This was the first flight of RMS S/N 201. It is thought that dry gear lube may have contributed to the spikes and caused the temporary sluggish joint.

The Orbiter docking system (ODS) was powered up at 329:00:21 G.m.t. (00:23:31 MET). The ring extension was completed nominally, and the system was powered down at 329:00:42 G.m.t. (00:23:52 MET). The ODS was ready for rendezvous and docking operations.

The first on-orbit fuel cell purge was a manual purge that was performed at 329:00:40 G.m.t. (00:23:51 MET). The approximate performance decay for fuel cells 1, 2, and 3 was 0.1 Vdc.

The trajectory control sensor (TCS) was initialized for the rendezvous tools checkout at 329:02:11:00 G.m.t. (01:01:21:13 MET). The TCS performed nominally during the checkout and is ready to support rendezvous and docking operations.

During the rendezvous with the ISS, the crew reported that the backup rendezvous proximity operations program (RPOP) was not working. This problem was not a constraint to rendezvous. A troubleshooting plan was sent to the crew and it was performed successfully. During the process, a bad cable was found and it was replaced, and the RPOP was available for undocking.

The ODS was powered up for docking operations at 329:21:05:55 G.m.t. (01:20:16:08 MET) and the ISS was captured at 329:21:58:40 G.m.t. (01:21:08:53 MET). Ring retraction and hook closure were completed nominally. No high-energy damper anomalies were observed. Elapsed time from contact to hook closure was 12 minutes 8 seconds. The ODS was powered off at 329:22:18:23 G.m.t. (01:21:28:36 MET).

The table on the following page shows the maneuvers that were performed to complete the rendezvous with the ISS.

Maneuver	Time, G.m.t./MET	ΔV , ft/sec	Firing time, Sec	Orbit, nmi.
NC1 (OMS-3 (Left OMS))	328:03:42:05 00:02:52:18	107.3	145.8	170.2 by 186.7
NC2 OMS 4 (Left OMS)	328:17:55:37 00:17:05:50	65.9	83.3	181.1 by 211.6
NC3 (RCS)	329:01:39:49 01:00:50:02	1.8	6.3	181.0 by 212.8
NC4 (OMS-5) (Left OMS)	329:17:27 01:16:37	31.7	40.0	198.2 by 214.5
Ti (OMS-6 (Left OMS))	329:19:05 01:18:15	8.1	10.2	
MC1 (RCS)	329:19:25 01:18:35	0.9	4.0	202.7 by 215.1
MC-2 (RCS)	329:20:00 01:19:10	1.5	6.5	202.8 by 215.1
Out of Plane Null (multi-axis RCS)	329:20:13 01:19:23	-	-	202.8 by 215.1
MC-3 (not required)	-	-	-	202.8 by 215.1
MC-4 (RCS)	329:20:27 01:19:37	1.0	4.0	203.3 by 215.5

The ISS experienced attitude control problems that required Shuttle resuming control of the ISS-Orbiter stack attitude. This occurred over a period of three orbits and approximately 22 lbm of propellant were consumed from the forward and 25 lbm from the aft reaction control subsystem (RCS) tanks. In addition, 2000 ft of orbital altitude were lost during these three orbits.

The ISS audio anomaly that occurred during the STS-112 mission recurred after docking. The ISS communications community developed troubleshooting procedures in an attempt to resolve the problem. A non-invasive troubleshooting plan was implemented but with the same results as STS-112. The non-invasive troubleshooting plan was not implemented because of the lack of sufficient time during docked operations.

The Shuttle RMS was used to unberth the ISS P1 truss segment and position the segment over the Orbiter port wing for handoff to the Space Station RMS (SSRMS). The SSRMS was used to perform the mating of the P1 truss to the ISS S0 truss. The Shuttle RMS was subsequently used to support EVA activities and was cradled, latched and powered down at 331:02:21 G.m.t. (03:01:31 MET). The Shuttle RMS performed nominally for all operations. No further occurrences of the wrist-roll control problem reported earlier in the mission were observed.

The first EVA was successfully completed with a total EVA time of 6 hours and 45 minutes. The EVA was conducted from the ISS airlock, and it officially began when the EMUs were placed on internal battery power at 330:19:48 G.m.t. (02:18:58 MET). The EVA concluded when repressurization of the airlock was initiated at 331:02:33 G.m.t. (03:01:43 MET).

The wireless video system (WVS) operated intermittently and was mostly off from the extravehicular 1 (EV1) crewmember. The TV from the EV2 crewmember experienced

breakups that were downlinked and the picture was smudged and torn. The cause of this condition is being evaluated.

The first reboost maneuver was started at 331:17:10:47 G.m.t. (03:16:21 MET) when all of the down-firing vernier thrusters were fired. The maneuver lasted 45 minutes. The performance of the RCS was nominal throughout the operation. The reboost imparted a ΔV of 2.4 ft/sec resulting in an overall average altitude increase of 2.4 nmi for a final orbit of 216 by 207 nmi.

At 331:18:46 G.m.t. (03:17:56 MET), the S-band power amplifier (PA) 2 forward output power dropped from 117 watts to an estimated power of 50 watts or less (Flight Problem STS-113-V-04). The power drop resulted in general purpose computer (GPC) 4 issuing a fault summary message "S-BD PA 2 PWR OUTPUT LOW". Instantaneously, the PA 2 reflected power dropped from 6 watts to 2 watts on the lower left aft (LLA) antenna. There was no change in the PA 2 reflected power when moving from the LLA antenna to the lower left forward (LLF) antenna. Data review also revealed a PA 2 temperature increase from 152 to 159 ° F at the time of initial drop in power. Although there was a significant drop in output power, the S-band return link remained locked up and no data were lost. The flight controllers commanded PA 1 on and PA 2 off at 331:19:03 G.m.t. (03:18:13 MET). The flight rules for STS-113 state that the failure of one or both the S-band power amplifiers results in a nominal end of mission.

This was the second time that this power amplifier (S/N 306) has caused the annunciation of a "S-BD PA 2 PWR OUTPUT LOW" fault summary message. The first occurrence was observed on STS-108 (OV-105, flight 17).

Additional checkout of S-Band Power Amplifier (PA) 2, which experienced a low output power problem earlier in the flight, was performed after separation from the ISS. The signature observed was consistent with that observed on the day of the initial problem. PA2 had a steady low-output power of approximately 56 watts (specification minimum is 100 watts) and was unaffected by changing S-Band transponders and pre-amplifiers. Despite the low output power, S-Band communications functioned nominally throughout the approximately 30-minute duration of the checkout. The S-Band system was returned to PA-1 operation at the end of the test. Although weaker than nominal, PA2 was a viable backup to PA1 for the remainder of the flight.

The second EVA was successfully completed with a total EVA time of 6 hours and 10 minutes. The EVA was conducted from the ISS airlock and officially started when the EMUs were placed on internal battery power at 332:18:36 G.m.t. (04:17:46 MET). The EVA was very successful in that all tasks were completed. The EVA concluded when repressurization of the airlock was initiated at 333:00:47 G.m.t. (04:23:57 MET).

The second reboost maneuver was started at 333:16:50:59 G.m.t. (05:16:01:12 MET). The session lasted the scheduled 55 minutes. The primary thruster pulse widths were 160 ms, and firings of the L1A and R1A thrusters were staggered with a cycle time of 24 seconds. In this cycle, each primary thruster was fired for a single 160 ms pulse. There were six breaks for attitude maintenance that limited the total number of pulses to 125 pulses. The aft down-firing vernier thrusters were used for attitude maintenance and these thrusters had an average duty cycle of 8.08 seconds on and 15.92 seconds off. The performance of the RCS was nominal throughout the operation. The reboost maneuver imparted a ΔV of 2.56 ft/sec resulting in an overall average altitude increase of 0.7 nmi for a final orbit of 216 by 209 nmi.

The crew supported troubleshooting of two problems observed earlier in the mission. In response to the lack of video coming through the WVS transceiver 2, the audiovisual interface unit (AVIU) was reconfigured and verified as operational. To troubleshoot the flight day 3 post-docking communications problem between Shuttle-to-ISS, a series of various communications checks were performed to characterize the scope of the communications problem.

The third EVA was successfully completed with a total EVA time of 7 hours and 0 minutes. The EVA was conducted from the ISS airlock and officially started when the EMUs were placed on internal battery power at 334:19:24 G.m.t. (06:18:34 MET). The EVA was very successful in that all tasks were completed. The EVA concluded when repressurization of the airlock was initiated at 335:02:24 G.m.t. (07:01:34 MET). The total EVA time for the mission was 19 hours 55 minutes (39 hours 50 minutes man-hours in space).

During the EVA, nominal video was successfully transmitted via the WVS from both extravehicular crewmembers (EV1 and EV2).

The crew was unable to install 2 of the 8 bolts that hold the Plant Generic-Bioprocessing Apparatus (PGBA) to the middeck locker interface. The payload hazard report certified the PGBA for return with 4 of 8 bolts provided all 4 outer corner bolts were installed. Further analysis was conducted to confirm that the PGBA was in a safe entry configuration with only 6 of 8 bolts fastened to the payload mounting panels.

The third and final planned reboost maneuver of the flight was successfully completed. The maneuver was started at 335:16:38:47 G.m.t. (07:15:49:00 MET) and lasted approximately 45 minutes. RCS performance was nominal throughout the maneuver. The reboost imparted a differential velocity (ΔV) of 8.6 ft/sec, which resulted in an overall average 2.4-nmi altitude increase for a final orbit of 216.6 by 211.4 nmi.

At 335:04:05 G.m.t. (07:03:15 MET), when changing the hardware caution and warning system for the 14.7-psia repressurization, the crew reported the tens place on the panel R13U caution/warning-parameter-select down-plunger did not work. The crew reported that the up pushbutton was used to obtain the proper values. Also, the crew reported that while attempting to change the panel R13U caution/warning-limit set-value, the ones-place up-plunger initially did not work. After several attempts, the plunger did start to work, but the operation of the pushbutton felt sticky. The sticky operation of this switch did not impact the mission.

During a FES water dump on the primary B controller, the flash evaporator system (FES) shut down at 335:23:45 G.m.t. (07:22:55 MET) (Flight Problem STS-113-V-05). After several unsuccessful attempts to restart the FES on the primary B controller and then on the primary A controller were both, ice formation was suspected and the core flush procedure was performed. The core flush was successful in removing the ice and the system operated nominally on the primary A controller. The primary A controller was used for the remainder of the flight and performed satisfactorily.

The ODS was powered up for undocking operations at 336:19:41:45 G.m.t. (08:18:51:58 MET). Hooks group 1 opened at 336:20:04:40 G.m.t. (08:19:14:53 MET); group 2 opened 10 seconds later, and undocking was successfully completed. The ODS was powered off at 336:21:15:07 G.m.t. (08:20:25:20 MET).

Following undocking, the initial Orbiter separation maneuver began with a +Z-axis pulse of primary RCS thrusters L1U, R1U, and F2U at 336:20:05:09 G.m.t. (08:19:15:22 MET). The ISS flyaround operations were not performed. Final separation from the ISS was accomplished with a 12.0-second +X-axis pulse of primary RCS thrusters L1A and R1A at 336:20:01:17 G.m.t. (08:19:11:30 MET). The ΔV delivered was 3.2 ft/sec and the resulting orbit was 215.0 by 211.5 nmi.

The flight control subsystem (FCS) checkout was performed satisfactorily using APU 1 to support the checkout with a start time of 337:14:58:33 G.m.t. (09:14:08:46 MET). The run time was 5 minutes and 45 seconds, and 17 pounds of fuel were used during the APU 1 operation. The total run time was too short to require spray cooling from the water spray boiler (WSB). FCS, APU, and hydraulics performance was nominal.

Following FCS checkout, the RCS hot-fire was performed nominally. The hot-fire began at 337:15:58:15 G.m.t. (09:15:08:28 MET) and ended at 337:16:04:23 G.m.t. (09:15:14:36 MET). All thrusters were fired at least once for a minimum duration of at least 240-milliseconds. A review of thruster chamber-pressure data confirmed that all of the thruster firings were satisfactory.

The Ku-band antenna was stowed for entry at 338:01:09:36 G.m.t. (10:00:19:41 MET).

The payload bay doors (PLBDs) were closed for the planned landing day opportunities at KSC. Both landing opportunities on the planned landing day were waved off at Kennedy Space Center (KSC) because of unacceptable landing conditions (cloud coverage).

Following the wave off to the second opportunity, the PLBDs were unlatched and reopened at 338:21:18:24 G.m.t. (10:20:28:37 MET). All PLBD unlatch and open operations were nominal and occurred in dual motor time.

The PLBDs were not closed for the first contingency day opportunities at KSC because of the forecasted unsatisfactory weather conditions. Both landing opportunities on the first contingency day were waved off as a result of the unacceptable weather conditions.

The PLBDs were closed and latched for the first KSC landing opportunity on the second contingency landing day at 340:16:53:55 G.m.t. (12:16:04:08 MET). All PLBD close and latch operations were nominal and occurred in dual motor time. However, both KSC landing opportunities were waved off and the PLBDs were reopened at 340:18:32:51 G.m.t. (12:17:43:04 MET). The doors operated satisfactorily during both the opening and closing operations. However, during the opening the starboard forward latch release indication 2 (B microswitch) failed to come on. The motor ran for approximately 68 seconds until the software removed the command at the single-motor run-time limit. The A microswitch came on within the nominal dual motor run time. The B microswitch transferred to the on position approximately 12 minutes after the bulkheads latches were released. An evaluation will be performed to determine the cause of the slow change of state.

The PLBDs were closed at 341:15:49:48 G.m.t. (13:15:00:01 MET) for the first landing opportunity at KSC on the third contingency day. The doors operation was nominal.

During the vent door repositioning prior to the deorbit maneuver, the left vent door 5 closed indication 1 failed to transfer on. This caused the motor to run for 10 seconds until the command timed out. The operation of indication 2 was normal. Indication 1

transferred on approximately 14 ½ minutes later. Postflight checks will be performed to determine if a problem exists.

The deorbit maneuver for the first KSC landing opportunity on the third contingency day, a dual-engine straight-feed firing, was performed on orbit 215 at 341:18:31:33.126 G.m.t. (13:17:41:46.105 MET). The maneuver was 178.2 seconds in duration with a ΔV of 333:1 ft/sec. The orbit after the deorbit maneuver was 25.2 by 213.6 nmi. Based on the satisfactory operation of the right OMS engine, the ball valve 2 open indication following the OMS assist maneuver was an indication problem rather than a problem with the engine.

Entry interface occurred at 341:19:05:41 G.m.t. (13:18:15:14 MET) and entry was completed satisfactorily. Main landing gear touchdown occurred on KSC concrete runway 33 at approximately 341:19:37:13 G.m.t. (13:18:57:26 MET) on December 7, 2002. The nose gear touchdown occurred at approximately 341:19:37:23 G.m.t. The drag chute was deployed at 341:19:37:24 G.m.t. The drag chute was jettisoned at 341:19:38:00 G.m.t. Wheels stop occurred at 341:19:38:28 G.m.t. The rollout was normal in all respects. The flight duration was 13 days 18 hours 57 minutes 26 seconds. The APU were shut down approximately 21 minutes and 57 seconds after landing.

PAYLOADS AND EXPERIMENTS

SUMMARY

The STS-113 mission was a crew rotation mission, the 16th U. S. mission to the International Space Station (ISS) and consisted of a four-member Orbiter crew. During the ascent phase, the ISS-11A Expedition 6 crewmembers were carried to the ISS. On the entry phase of the mission, the three-crewmember ISS-10A Expedition 5 crew was returned to Earth.

The cargo for the ISS mission consisted of the port 1 (P1) Integrated Truss Segment (ITS). Integrated on to the P1 ITS was ultrahigh frequency (UHF) communications equipment, three external active thermal control system (EATCS) radiators, thermal radiator rotary joint (TRRJ), direct-current (DC)-to-DC converter unit (DDCU), remote power controller module (RPCM), nitrogen tank assembly, ammonia tank assembly, pump module assembly and a crew equipment translation aide (CETA) cart.

Following undocking the MEMS-Based PICOSAT Inspector (MEPSI), a secondary payload sponsored by the Department of Defense (DoD), was deployed from cargo bay 3. This scientific experiment consisted of 2 miniature satellites connected by a 50-foot tether. Its purpose was to demonstrate the use of micro-sized electromechanical systems to support future satellite operations.

During the seven docked days, the Shuttle remote manipulator system (RMS) removed the P1 ITS from the cargo bay and performed the first arm-to-arm handover. The Space Station remote manipulator system (SSRMS) attached the P1 ITS to the port side of the S0 segment. Three extravehicular activities (EVAs) were performed to install the P1 ITS lines and cables. On non-EVA days, the flight crew performed middeck hardware transfer, water transfer, utilization experiment operations/transfers, and three ISS reboost maneuvers. The three reboost maneuvers lasted a combined 145 minutes and increased the ISS altitude 5.5 nautical miles (nmi). The final ISS orbit after the third reboost was 216.6 by 211.4 nmi. Following the successful completion of all ISS mission objectives, Endeavor undocked from the ISS on December 2, 2002 at 1:40 pm c.s.t. [336:19:41 G. m.t. (08:18:51 MET)].

ISS OPERATIONS

All of the ISS 11A mission and ISS on-orbit science objectives were successfully accomplished, and there were no impacts to ISS on-orbit operations.

The crew successfully transferred 31,404 lb (14245 kilograms of payload and logistics) from the Orbiter to the ISS, and 2250 lb (1021 kg) from the ISS to the Orbiter for return to Earth. These transfers to the ISS included the 28572 lb (12960 kg) P1 ITS, 2160 lb (980 kg) of science and logistics from the Shuttle middeck, 672 lb (306 kg) of water transferred in seven contingency water containers (CWCs). In addition, 32 lb (15 kg) of Orbiter oxygen was used during the three EVA prebreathe operations and six lithium hydroxide (LiOH) canisters were transfer to increase the ISS stockpile to 31 canisters.

CREW ACTIVITIES

The following list provides:

1. Rotate Expedition 5 and 6 crews;

2. Install and safe the ITS P1 to ITS SO truss port side;
3. Fill and transfer technical water contingency water containers (CWCs) to ISS;
4. Transfer critical items;
5. Perform mandatory crew activities;
6. Perform minimum crew handover of 12 hours;
7. Complete ITS P1 activation and checkout;
8. Transfer remaining items;
9. Install two wireless video system (WVS) external transceiver assemblies;
10. Perform Space Station power distribution unit (SPDU) installation;
11. Configure mobile transporter/crew and equipment translation assembly (MT/CETA);
12. Release P1/P3 utility line clamps;
13. Check out the P1/P3 segment-to-segment attach system (SSAS);
14. Check out P1 MT worksites (7);
15. Activate and checkout P1 and S1 DC-DC converter units (DDCUs);
16. Install SPD on external active thermal control system (EATCS) loop B dry quick disconnects;
17. Remove design loads analysis launch pins;
18. Connect SO to P1 ammonia lines;
19. Install SPD on S1 ammonia tank assembly (ATA)/pump module;
20. Connect ammonia tank assembly N₂ and NH₃ lines;
21. Perform an additional 4-hour handover per crewmember;
22. If gases available, transfer O₂/N₂ to ISS airlock;
23. Empty and fill portable water reservoirs (PWRs);
24. Perform MEPSI deploy activity;
25. Perform ISS reboost maneuvers (3);
26. Perform Station Development Test Objective (SDTO) 13005-U ground support items only;
27. Perform on-orbit checkout activities;
28. Open radiator beam valve module (RVBM) thermal cover flaps;
29. Perform extravehicular activity radiation monitoring (EVARM) experiment activities;
30. Perform internal thermal control system (ITCS) sampling;
31. Release and stow P1 radiator beam launch locks;
32. Deploy P1 UHF antenna and verify operation;
33. Remove flexible hose rotary coupler (FHRC) launch restraint bolt;
34. Perform SDTO 13005-U during EVA using Station data management system (SDMS); and
35. Perform Shuttle Development Test Objectives (DTOs) and Detailed Secondary Objectives (DSOs).

In addition, a black ink cartridge, color ink cartridge and color printer paper were transferred to the ISS. Additional items transferred to the Shuttle for return were as follows:

1. Advanced thermoelectric refrigerator/freezer (ARCTIC);
2. Plant generic bioprocessing apparatus (PGBA) seed plugs;
3. Power supply to middeck active control experiment (MACE) II;
4. Power cable assembly;
5. Microgravity sciences glovebox (MSG) power and distribution control box;
6. Utility outlet panels;

7. Solidification using a baffle in sealed ampoules (SUBSA) sample box assembly;
8. Combustion synthesis under microgravity conditions (COSMIC) samples container;
9. Carbon dioxide removal assembly air selector valve;
10. Active rack isolation system push rods;
11. Pore formation and mobility investigation (PFMI) high-8 tapes;
12. CETA cart launch restraint assembly;
13. Frame standoff assembly;
14. Brake handle;
15. Lanyard assembly;
16. Launch lock assembly;
17. Fluid connector caps;
18. PGBA silencer kit;
19. Hand toys kit;
20. Hand string toys kit;
21. Spinning toys kit;
22. Lacrosse kit;
23. Hockey kit;
24. Human Research Facility (HRF) mouthpiece;
25. Portable computer memory card international adapter (PCMCIA) card;
26. Tissue equivalent proportional counter (TEPC) counter;
27. TEPC spectrometer;
28. Detector cable;
29. Power/data cable assembly;
30. Headset extension cable;
31. 10 to 50 in-lb torque wrench;
32. 5 to 35 in-lb torque driver;
33. 150 to 1000 in-lb torque wrench;
34. 30 to 200 in-lb torque wrench;
35. 40 to 200 in-lb torque wrench;
36. Connector cover;
37. Quick disconnect serial parallel digital assembly (1.0 inch);
38. Fluid gaseous nitrogen (GN₂) tank caps;
39. Fluid ammonia tank assembly (ATA) tank caps;
40. Digital video camera (DVCAM) video cassettes;
41. Kit with AK-1M samplers;
42. Beta camera video cassettes;
43. B (Russian Front) 1-1 fuse;
44. MSG exchangeable standard electronics module (ESEM) 3;
45. Sample tube kit;
46. 9A emergency books;
47. 9A warning books;
48. 9A medical checklists;

In addition to the transfer list, six unscheduled tasks were accomplished during the EVAs. These are as follows:

1. Removed radiator beam launch lock;
2. Reconfigured squib firing unit;
3. Deployed P1 UHF antenna;
4. Installed DDCU thermal cover;

5. Connected S0/node 1 wireless external television antenna (WETA) cable; and
6. Secured SSRMS Lee-B camera thermal cover.

The deletion of two tasks following the EVAs was required. These were:

1. Shuttle flyaround following undocking; and
2. SDTO 13005U (IWIS) during undocking.

One task was deferred and that was the mobile transporter/mobile base system/ Space Station remote manipulator system (MT/MBS/SSRMS) checkout at worksite 7 and translation to worksite 4.

The crew was unable to install 2 of the 8 bolts that hold the PGBA to the middeck locker interface. The payload hazard report certified the PGBA for return with 4 of the 8 bolts provided all 4 outer corner bolts were installed. Further analysis was conducted to confirm that the PGBA was in a safe entry configuration with only 6 of 8 bolts fastened to the payload mounting panels.

MEMS-BASED PICOSAT INSPECTOR SATELLITE DEPLOYMENT

The MEMS-based PICOSAT Inspector Satellite (MEPSI) was deployed at 336:22:04:47 G.m.t. (08:21:15:00 MET). The video clearly showed the PICOSAT deployments and the tether between the two satellites. On the first pass over the Menlo Park ground site, approximately two hours after deployment, four beacons were received from PICOSAT 2. Subsequent attempts to make contact with the PICOSAT satellites were unsuccessful until a pass on December 4 when 13 beacons were received from PICOSAT 1. These two passes constitute the only contacts with the satellites on this mission. Operations at Menlo Park have concluded, as the PICOSAT batteries are depleted. Data from the beacons is being analyzed, and a discussion of the results will be presented in separate documentation.

ISS PROBLEMS

The MT stalled during translation from worksite (WS) 4 to WS 7 during the second EVA. Inspection of the pathway identified the cause, which was contact between the MT integrated umbilical assembly (IUA) and the UHF antenna. The crew deployed the UHF antenna (planned for the stage 11A EVA) to clear the path and the MT was taken to WS 7. However, insufficient time remained to perform a checkout of the SSRMS and move the MT back to WS 4, so the MT was left at WS 7. The MT will be translated to WS 4 just before the stage EVA.

The MSG was inoperative because of suspected electronics box failures. Extensive troubleshooting performed before and during this mission resulted in the return of the MSGs power distribution controller (PDC) and ESEM 3 on this flight. A spare ESEM and PDC will be manifested on one of the next two logistics missions to the ISS. Both refrigerator/freezers (ARCTICs) are failed. ARCTIC 1 was returned on this flight; ARCTIC 2 remains on orbit for additional troubleshooting. ARCTIC 1 is planned to be returned to the ISS on Utilization Logistics Flight (ULF) -1.

The TEPC was declared failed and returned on this flight. It is planned to be returned to the ISS on ULF-1.

VEHICLE PERFORMANCE

LAUNCH DELAY

The STS-113 mission was originally scheduled to launch on November 10, 2002. During the launch countdown, a high oxygen concentration in the payload bay led to the decision to scrub the launch. During tanking, the midbody oxygen concentration was unusually high, reading 125 ppm instead of the nominal 10 to 20 ppm. The Launch Commit Criteria (LCC) for the concentration in this area states that any increase above the background level requires evaluation. Because of a procedural problem, the environmental control and life support system (ECLSS) load check was performed before the background concentration could be measured. As tanking continued, a decision was made to perform pre-planned contingency tests during liquid oxygen (LO₂) replenish and a leak in the ECLSS was found.

The launch was tentatively rescheduled for November 17, 2002. The leaking flexible oxygen hose was replaced; however, during the repair activities, a work platform came in contact with the remote manipulator system (RMS) and caused some visible damage to the RMS. As a result, the launch was rescheduled for November 22, 2002, so that the Canadian RMS manufacturer could perform structural tests of the RMS. These tests proved that the structural integrity was not decreased and the RMS was declared ready for flight.

The launch countdown on November 22, 2002, was stopped during the T-9 minute hold because of adverse weather at the transatlantic abort landing (TAL) site and a 24-hour delay of the launch was declared. Following a 24-hour delay, the vehicle was successfully launched on November 23, 2002.

SOLID ROCKET BOOSTERS

Analysis of the Solid Rocket Booster (SRB) systems data indicated nominal performance of all SRB subsystems. The prelaunch countdown was normal and no SRB Launch Commit Criteria (LCC) or Operations and Maintenance Requirements And Specifications Document (OMBSD) violations occurred. Likewise, no in-flight anomalies were identified in the evaluation of the data.

Both SRBs were recovered and returned to KSC for inspection, disassembly and refurbishment. The inspection revealed that both SRBs were in excellent condition. No anomalous SRB conditions were noted during the postflight operations.

REUSABLE SOLID ROCKET MOTORS

Data analysis of the flight performance of both reusable solid rocket motors (RSRMs) showed all parameters to be within the contract end item (CEI) specification limits, and the performance was typical of that observed on previous flights. The prelaunch countdown was normal and no RSRM LCC or OMRSD violations noted nor have any in-flight anomalies been identified in the data.

The maximum in-flight trace shape variation of pressure versus time during the 62- to 80-second time frame was calculated to be 0.6 percent at 69 seconds and 0.6 percent at 80.0 seconds for the left and right motors, respectively. These values were well within the 3.2-percent allowable limits.

Power application and operation of all field-joint heaters was accomplished routinely. Field-joint heaters operated for 12 hours 42 minutes during the launch countdown. Power was applied to the heating elements an average of 62 percent of the time during the LCC time frame. The right-hand-center field-joint sensor, located at the 15-degree position read 5 to 7 °F low during all pretests and countdowns. Because of the low sensor reading, in conjunction with a high solar radiation heating condition, the sensor at the 195-degree position on the same joint attained a temperature of 121 °F. At that time, heater operations were performed manually to maintain all sensors on the field-joint within the LCC limits. This manual operation continued until the peak solar radiation heating subsided.

Power application and operation of all igniter-joint heaters was accomplished routinely. The igniter-joint heaters operated for 17 hours 47 minutes during the launch countdown. Power was applied to the heating elements 75 percent of the time during the LCC time frame.

The heated, ground-supplied, aft skirt purges maintained the case/nozzle joint and flex bearing temperatures within the required LCC ranges. The purge was activated three times for a total of 11 hours 42 minutes during the time of recorded data for the countdown. It was necessary to activate the aft-skirt purge to maintain the nozzle-case joint temperatures at or above the minimum LCC temperature. During the LCC time frame, the nozzle/case joint temperatures were nominal and ranged from 77 °F to 85 °F and 77 and 86 °F for the left-hand and right-hand motors, respectively. The final flex bearing mean bulk temperature (FBMBT) was determined to be 82 °F.

All ground environmental instrumentation (GEI) and operational flight instrumentation (OFI) performed within established requirements. All available data were recorded, transmitted and analyzed. The right-hand-motor center field-joint sensor at the 15-degree position read low and the left-hand flex bearing aft end ring sensor at the 130-degree position was non-functional. All other sensors operated as expected.

Reconstructed motor performance parameters adjusted to a 60 °F propellant mean bulk temperature (PMBT) are shown in the following table. The calculated PMBT at launch was calculated to be 72°F.

MOTOR PERFORMANCE PARAMETERS

Parameter	CEI Specification Limit (60 °F)	Left Motor Delivered	Right Motor Delivered
Web time, seconds	105.4 – 116.7	110.2	110.5
Action time, seconds	115.2 – 131.2	123.5	124.2
Head end pressure, psia	847.9 – 965.7	909.1	910.3
Maximum sea level thrust, MLbf	2.88 – 3.26	3.06	3.07
Web time average pressure, psia	629.9 – 700.5	666.3	665.5
Web time average vacuum thrust, MLbf	2.46 – 2.74	2.61	2.61
Web time total impulse, MLbf sec	285.8 – 291.6	287.4	287.7
Action time impulse, MLbf seconds	293.7 – 299.7	296.4	296.2
ISP average delivered, Lbf sec/Lbm	266.5 – 270.3	268.2	268.2
Loaded propellant weight, Lbm	>1103750	1105817	1104891

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

The left-hand motor flex-bearing temperature sensor at the 130-degree location was non-functional prior to flight. Only two of four sensors are required to meet the OMRSD requirement for backup measurements to determine flex-mean bulk temperature prior to flight.

The predicted and actual propulsion systems performance is shown in the following RSRM Propulsion Performance table on this page. The final propellant mean bulk temperature calculation was made postflight with reconstructed data that showed a nominal temperature of 72 °F.

RSRM PROPULSION PERFORMANCE

Parameter	Left motor, 72 °F		Right motor, 72 °F	
	Predicted	Actual	Predicted	Actual
Impulse gates				
I-20, 10 ⁶ lbf-sec	64.79	65.19	64.73	65.46
I-60, 10 ⁶ lbf-sec	173.75	174.84	173.60	174.85
I-AT, 10 ⁶ lbf-sec	296.96	296.73	296.71	296.50
Vacuum Isp, lbf-sec/lbm	268.5	268.3	268.5	268.3
Burn rate, in/sec @ 60 °F At 625 psia	0.3665	0.3685	0.3666	0.3689
Event times, seconds ^a				
Ignition interval	0.232	N/A	0.232	N/A
Web time ^b	110.2	108.8	110.2	109.0
50 psia cue time	120.3	119.6	120.3	110.6
Action time ^b	122.5	121.9	122.5	122.7
Separation command	124.7	-	124.7	-
PMBT, °F	72	72	72	72
Maximum ignition rise rate, psia/10 ms	90.8	N/A	90.8	N/A
Decay time, seconds (59.4 psia to 85 K)	3.1	3.3	3.1	4.1
Tailoff Imbalance Impulse Differential	Predicted N/A		Actual 359.4	

Impulse Imbalance = Integral of the absolute value of the left motor thrust minus right motor thrust from web time to action time.

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

^bReferenced to liftoff time (ignition interval).

The postflight inspection of the external hardware thermal condition was performed with all thermal protection system (TPS) found to be in very good condition in all areas. The condition of both motors was similar to previous flight history.

EXTERNAL TANK

All External Tank (ET) objectives and requirements were met during the propellant loading and flight operations. No significant oxygen or hydrogen leakage concentrations were detected in the intertank. All ET electrical equipment and instrumentation operated satisfactorily. Purge and heater operations were also nominal. No ET LCC or OMRSD violations occurred.

The pressurization systems functioned properly throughout engine start and flight. The minimum liquid oxygen (LO₂) ullage pressure experienced during the ullage pressure slump was 13.5 psid.

Several intertank stringers that were in process were identified as being below the minimum thickness tolerance. An analysis was performed to ensure that the thinner stringers met the minimum margin-of-safety requirements. The stringers met the minimum margin-of-safety with some conservatism still left in the model.

During pad validation testing, both the primary and secondary Helium bubbling differential pressure (ΔP) transducers failed to meet the OMRSD File IV requirement of 1.0 psid (corresponds to a mass flow rate of about 0.009 lbm/sec). The actual readings were 0.97 psid on the primary leg and 0.99 on the secondary leg. Subsequent analysis showed that the mass flow rate could be met with a ΔP of less than 1.0 psid. The actual requirement was dependent on ambient temperature and determined before tanking. Based on an agreement on the maximum predicted temperature during tanking, the new ΔP requirement at that temperature was found to be 0.91 psid.

The ice/frost team reported the following conditions existed on the ET;

1. Typical -Y strut crack approximately 4 inches in length with no offset;
2. Hairline crack and four frost balls on the -Y longeron. The crack was approximately 5 inches in length with no offset and no frost;
3. Intertank thermal protection subsystem (TPS) stress relief had a crack that was nine inches in the -Y, -Z quadrant and one inch in the -Y +Z quadrant. This crack was within family and was acceptable for flight.

ET separation was confirmed. The postflight analysis of the impact point showed the ET impact to be 42 nautical miles uprange from the preflight predicted impact point.

SPACE SHUTTLE MAIN ENGINES

Prelaunch operations of the Space Shuttle main engines (SSMEs) were smooth with no LCC or OMSRD violations noted. The ignition confirm limits and mainstage redline margins were satisfactory. All Interface Control Document (ICD) start and shutdown transient requirements were met. Engine performance during start, mainstage, and shutdown was nominal and as predicted. Engine cutoff times were within the nominal limits for SSME 1, 2 and 3, respectively. Controller and software performance was satisfactory with no SSME in-flight anomalies identified from the review of the data.

The preliminary reconstructed specific impulse (I_{sp}) was 452.9 seconds and the tag value was 451.6 seconds, so the flight-derived I_{sp} was 1.3 seconds higher than predicted. The Block II engines I_{sp} are typically approximately 0.8 to 1.3 seconds higher than that predicted from ground testing data.

Main engine cutoff (MECO) occurred 502.8 seconds after SRB ignition. The commanded maximum dynamic pressure (max Q_á) throttle-down was a two-step throttle-down to 72 percent.

SHUTTLE RANGE SAFETY SYSTEM

The Shuttle Range Safety System (SRSS) closed-loop testing was completed as scheduled during the launch countdown. All SRSS safe and arm (S&A) devices were armed and system inhibits were turned off at appropriate times. The system operated as

expected throughout the countdown and flight. As planned, the SRB S&A devices were safed and SRB system power was turned off prior to SRB separation.

ORBITER SUBSYSTEMS PERFORMANCE

Main Propulsion Subsystem

The main propulsion subsystem (MPS) performed satisfactorily. There were no LCC violations, and there were no in-flight anomalies identified from the analysis of the data. Tabulations for prelaunch, MECO, post-MECO and entry/landing events revealed no anomalous valve movements. All valve timings were within the required specification and within the current historical database. The peak hydrogen concentration during the final loading was 160 ppm, which compares favorably with previous data from this vehicle.

During the first loading of liquid oxygen (LO₂), approximately 1 hour 40 minutes into the fast-fill operations, the hazardous gas detection system (HGDS) indicated increased levels of LO₂ in the aft compartment. The LO₂ levels increased from approximately 13 parts per million (ppm) to a peak of 140 ppm and the level didn't drop below 100 ppm during the remainder of the first loading. During the LO₂ detanking operations, the ullage pressure was raised by 8 psi and the LO₂ concentration dropped to 0 ppm. The LO₂ concentration during the second loading were 165 ppm peak and steady state, a level that has been observed on many previous missions of this vehicle.

Another item of interest was noted during the second tanking of the MPS when Space Shuttle main engine (SSME) 3 LO₂ inlet-pressure transducer was biased by approximately 15 psia. The previous flight showed a transducer bias of approximately 4 psia. The transducer was replaced during the postflight turnaround operations.

The overall gaseous hydrogen (GH₂) system in-flight performance was nominal. All three flow control valves performed nominally. Likewise, helium system performance for the SSME and pneumatic helium systems was nominal. Entry helium usage was 61 lbm, which is within the requirements.

After the review of the STS-113 data, a momentary violation of the ± 0.8 -psi requirement was observed during throttle-up coming out of the throttle bucket. During dynamic transients, parameters such as SSME outlet temperatures and External Tank (ET) nose-cap pressures can lag other parameters used in the reconstruction, thus causing flow calculations to be in error. After the transients have passed, these errors diminish and the model correlates well with flight data.

No action is required for the OV-105 hardware prior to STS-115. Steady-state model data indicates that the gaseous oxygen (GO₂) pressurization system performed nominally, verifying that the flow control valve orifices are free from both blockage and erosion. This requirement will be reviewed to evaluate modifying either the criteria for transients or the time period that is in effect.

Reaction Control Subsystem

The reaction control subsystem (RCS) performed nominally with no in-flight anomalies identified during the mission.

A total of 12 maneuvers, which included two 45-minute reboost maneuvers and one 55-minute maneuver that raised the altitude of the International Space Station (ISS) approximately 5.8 nautical miles (nmi). The three reboost periods were completed satisfactorily.

A total of 7157 lbm propellants (4393.6 lbm - oxidizer, 2763.4 lbm - fuel) were used from the RCS during the mission. A total of 1524 lbm of orbital maneuvering subsystem (OMS) propellants were also used by the RCS during the mission. The primary RCS thrusters had 6622 firings and a total firing time of approximately 870.69 seconds. The vernier RCS thrusters had 5380 firings and a total firing time of 32,175.37 seconds.

During the vernier thruster pulse data review, the observed chamber pressures (Pc) data were characterized as a non-smooth drop in pressure lasting approximately two seconds during a long, otherwise nominal, firing with a subsequent return to nominal pressure. It was observed in the data from the first reboost maneuver, second reboost maneuver, the maneuver to the required attitude for the ISS separation maneuver, as well as after the ISS separation maneuver. The first occurrence was observed during the first reboost maneuver on thruster R5D, which was being fed propellants from the left orbital maneuvering subsystem (OMS). Present theories indicate the bubbles formed prior to the reboost maneuver while the crossfeed line was dead-ended and experiencing thermal cycles. Prior to opening the crossfeed line isolation valves, the crossfeed line pressure was low enough for helium gas to come out of solution. Subsequently, during the 45-minute maneuver, a helium bubble in the crossfeed line would have been swept slowly to the right-side propellant system, and eventually the bubble was expelled through the vernier thruster.

The Pc data signature recurred during the second reboost maneuver on thrusters R5D and L5D. This reboost maneuver was also fed from the left OMS, thus explaining the repeated data signature on thruster R5D. The thruster L5D Pc signature was the same as R5D, but, since the second reboost maneuver was fed from the left OMS, there must have been helium closer to the left-side crossfeed valves that did not get swept into the right RCS during the first reboost maneuver, but instead migrated to the left RCS. There were no uneven pulses observed during the third reboost maneuver that was fed from the right OMS. The final occurrence of uncharacteristic Pc data was during the maneuver to the ISS final separation maneuver attitude and for a short period after the maneuver. Only thruster R5D Pc data were uneven during the maneuver to the ISS separation attitude while thrusters R5D, L5D, and then R5R were observed to have uneven Pc during the period after the separation maneuver.

The severity of the uncharacteristic data decreased with usage. During the first reboost, maneuver, the thruster R5D Pc dropped to 20 psia for at least one pressure measurement sample (sampled once every 40 ms). The redundancy RM fail-off limit is less than 26 psia; however, the thruster was never deselected as failed off because the software requires the Pc to be less than 26 psia for three RM samples. Because the RM samples the pressure once every 80 ms, the Pc would have to be less than 26 for more than 320 ms before being declared failed. During the second reboost maneuver, the Pc dropped to about 80 psia with nominal pressure around 110 psia. During the ISS separation period, the Pc only dropped to 93 psia.

Overall, helium bubbles did not impact the mission, and this signature has been seen on past flights. Because of the design of the vernier thruster injector, it has only one oxidizer and one fuel injector; it is more sensitive to helium bubbles. In contrast, primary thrusters have 84 injector doubles, which have been Stability Tested to ensure safe

operation with helium ingestion. During this flight, no primary thruster firings were observed to be off nominal in any way.

The crew indicated the forward manifold-5 isolation valve switch felt different during the circuit-breaker test following the RCS hot-fire checkout. The switch was cycled to open, then the test was repeated followed by a cycle to the closed position. The switch, remote power controller (RPC) and circuit breaker performance were nominal. During the postflight debriefing, the crew described the switch as feeling like a three-position switch (in which the switch locks into place at the different positions except that this switch did return to the GPC position as it should) and that it did feel different than the other two manifold 5 isolation valve switches. The same characteristic was noted during the retest and again during the postflight valve test. With respect to OMS/RCS, this is considered a switch characteristic and not a problem. The crew also noted that in general, the OV-105 vehicle switches felt different than the rest of the fleet, describing them as having more friction or slightly stiffer.

The RCS window protect maneuver was performed satisfactorily. This maneuver provided a method of protecting the windows of the Orbiter from booster separation motor exhaust products. This maneuver results in improved window clarity during the mission and a reduction in the turnaround effort following the mission.

SIGNIFICANT RCS MANEUVERS

Maneuver	Time, G.m.t./MET	ΔV , ft/sec	Firing time, sec	Orbit, nmi.
Window Protect	328:00:51:50.3 00:00:02:03:3	-	2.08	-
NC3	329:01:39:49 01:00:50:02	1.8	7.8	181.0 by 212.8
MC1	329:19:25:48.2 01:18:35:05.2	0.9	4.0	202.7 by 215.1
MC-2	329:20:00:10.5 01:19:10:27.5	1.5	6.5	202.8 by 215.1
Out of Plane Null (multi-axis)	329:20:13:48.4 01:19:24:06.4	-	-	202.8 by 215.1
MC-3 (not required)	-	-	-	202.8 by 215.1
MC-4	329:20:27:08.6 01:19:38:26.6	1.0	4.0	203.3 by 215.5
First Reboost Maneuver	331:17:10:47 03:16:21:00	2.4	45 minutes	216 by 207.6
Second Reboost Maneuver	333:16:51:00 05:16:01:12	2.56	55 minutes	216 by 211.4
Third Reboost Maneuver	335:16:38:48 07:15:49:00	8.7	45 minutes	216.6 by 211.4
ISS Separation	336:20:01:17 08:19:11:30	3.2	12	215.0 by 211.5

The first and third planned reboost maneuvers was successfully completed, and each was 45 minutes in length. RCS performance was nominal throughout the maneuvers.

The second reboost session lasted the scheduled 55 minutes. The primary thruster pulse widths were 160 ms, and firings of the L1A and R1A thrusters were staggered with

a cycle time of 24 seconds. In this cycle, each primary thruster was fired for a single 160 ms pulse. There were six breaks for attitude maintenance that limited the total number of pulses to 125 pulses. The aft down-firing vernier thrusters were used for attitude maintenance and these thrusters had an average duty cycle of 8.08 seconds on and 15.92 seconds off. The performance of the RCS was nominal throughout both maneuvers.

The ISS experienced attitude control problems that required Shuttle to resume control of the ISS-Orbiter stack attitude. This occurred over a period of three orbits and approximately 22 lbm of propellant were consumed from the forward and 25 lbm from the aft RCS tanks. In addition, 2000 ft of orbital altitude were lost during these three orbits.

The following table shows how the attitude control of the combined ISS and Orbiter were shared during the docked operations.

ATTITUDE CONTROL OF THE ISS/ORBITER DURING DOCKED OPERATIONS

Control Responsibility	Start, G.m.t.	End, G.m.t.	Elapsed Time, D:H:M:S	Comments
Shuttle	329:21:58:40	330:03:08:27	00:05:09:47	Problem with handover to ISS
ISS	330:03:08:27	331:16:00:08	01:12:51:41	Initial handoff to ISS
Shuttle	331:16:00:08	331:18:30:22	00:02:30:14	Reboost maneuver 1
ISS	331:18:30:22	333:15:58:00	01:21:27:38	
Shuttle	333:15:58:00	333:18:13:35	00:02:15:35	Reboost maneuver 2
ISS	333:18:13:35	333:22:37:31	00:04:23:56	
Shuttle	333:22:37:31	334:00:34:59	00:01:57:28	Simultaneous water dump
ISS	334:00:34:59	335:15:37:03	01:15:02:04	
Shuttle	335:15:37:03	335:17:55:55	00:02:18:52	Reboost maneuver 3
ISS	335:17:55:55	336:19:23:48	01:01:27:53	ISS control until undocking phase
Shuttle	336:19:23:48	336:20:05:09	00:00:41:21	Undocking

Following undocking, the initial Orbiter separation maneuver began with a +Z-axis pulse of primary RCS thrusters L1U, R1U, and F2U. The ISS flyaround operations were not performed. Final separation from ISS was accomplished satisfactorily, and the RCS performed satisfactorily.

Following FCS checkout, the RCS hot-fire was performed nominally. The hot-fire began at 337:15:58:15 G.m.t. (09:15:08:28 MET) and ended at 337:16:04:23 G.m.t. (09:15:14:36 MET). All thrusters were fired at least once for a minimum duration of at least 240-milliseconds. A review of thruster chamber-pressure data confirmed that all of the thruster firings were satisfactory.

Orbital Maneuvering Subsystem

The orbital maneuvering subsystem (OMS) performed satisfactorily throughout the mission. One in-flight anomaly was identified during the review and analysis of the data.

A total of 23,538 lbm (14,623 lbm - oxidizer and 8915 lbm - fuel) of OMS propellants were consumed during the mission. A total of 1524 lbm of OMS propellants were provided during interconnect operations to the RCS.

At the shutdown of the OMS assist maneuver following Solid Rocket Booster (SRB) separation, the right-engine ball valve no. 2 went from 96.6 percent to 96.1 percent (open), while ball valve no. 1 showed a nominal closed reading (Flight Problem STS-113-V-02). The indication was a failed-open ball valve for which the flight rules state the engine will only be used for the deorbit maneuver. This resulted in all of the remaining OMS maneuvers, with the exception of the deorbit maneuver, being performed with the single left engine. The left-engine ball valve performance was nominal throughout the flight. During the 13 days between launch and the deorbit maneuver, the linear voltage differential transformer (LVDT) reading slowly decreased at the rate of one data bit every four days. Because of this steady downward progression, and with no other visibility into the valve, it was believed that the valve was indeed failed open. During and after the deorbit maneuver, the LVDT reading was a constant 95.1 percent, but during entry the reading increased to 95.8 percent. This led to the conclusion that the indication represented an LVDT failure, namely, that the magnet had become lodged inside the bore of the LVDT. During the postflight ball-valve-cavity drain, it was confirmed that the valve was indeed closed; thus, the problem was with the LVDT. To date, all previous ball-valve failures have been LVDT failures.

The following table lists the OMS maneuvers that were performed during the mission.

OMS MANEUVERS

Maneuver	Time, G.m.t./MET	ΔV , ft/sec	Firing time, sec	Orbit, nmi.
OMS assist (Dual engine)	328:00:52:02 00:00:02:15	N/A	82.2	N/A
OMS-2 (Left engine)	328:01:27:36 00:00:37:49	253.4	339.8	125.81 by 170.0
OMS-3 (Left engine)	328:03:42:05 00:02:52:18	107.3	145.8	170.2 by 186.7
OMS-4 (Left engine)	328:17:55:37 00:17:05:50	65.9	83.8	181.1 by 211.6
NC4 (OMS-5) (left OMS)	329:17:26:43 01:16:34:56	31.7	40.0	198.2 by 214.5
Ti (OMS-6) (left OMS)	329:19:05:47 01:18:17:58	8.1	10.2	
Deorbit Maneuver (Dual Engine)	341:18:31:33.126 13:17:41:46.105	333.1	178.2	25.2 by 213.6

The deorbit maneuver for the first KSC landing opportunity on the third contingency day, a dual-engine straight-feed firing, was performed on orbit 215. Both OMS engines performed satisfactorily

Power Reactant Storage and Distribution

The power reactant storage and distribution (PRSD) subsystem performance was nominal throughout the STS-113 mission. No LCC or OMRSD violations occurred during

the countdown and mission, and no in-flight anomalies were noted during the analysis of the data. All File IX requirements were satisfied during the mission.

The PRSD subsystem supplied the fuel cells with 2954 lbm of oxygen and 372 lbm of hydrogen for the production of 4316 kWh of electrical energy. In addition, the environmental control and life support system (ECLSS) was supplied 203 lbm of oxygen for life support. In addition, 32 lbm of oxygen were transferred to the ISS for use during the prebreathe activities prior to each extravehicular activity (EVA). A 51-hour mission extension was possible at the average power level with the reactants remaining at landing. At an extension day power level of 13.3 kW, a 50-hour mission extension was possible.

PRSD tanks 4 and 5 were depleted to residual quantities during the mission. The Orbiter landed with 744 lbm of oxygen and 75 pounds of hydrogen remaining.

Cryogenic samples were taken after the cryogenic loading during the prelaunch period, and tests indicated a 413-ppm Helium contamination, which exceeds the 110-ppm allowable in the specification. This condition was waived as acceptable for flight because there was sufficient cryogenics existed for the anticipated increase in fuel cell purges.

Fuel Cell Powerplant Subsystem

The overall performance of the fuel cell powerplant (FCP) subsystem was nominal during the mission. There were no OMRSD or LCC violations, nor were any in-flight anomalies found during the analysis of the data. The average power level and load was 13.0 kW and 424 amperes. The fuel cells produced 3326 lbm of potable water and 4316 kWh of electrical energy while using 2954 lbm of oxygen and 372 lbm of hydrogen.

Seven purges of the fuel cells were performed, all of which achieved nominal results. The fuel cell reactant purge system operated nominally in both the automatic and manual modes.

The actual fuel cell voltages at the end of the mission were 0.15 Vdc above the predicted for fuel cell 1, 0.15 Vdc above predicted for fuel cell 2, and 0.10 Vdc above the predicted for fuel cell 3. The voltage margin above the minimum performance curve at 200 amperes at the end of the mission was 0.9 Vdc for fuel cell 1, 0.9 Vdc for fuel cell 2, and 1.1 Vdc for fuel cell 3.

The overall thermal performance of the fuel cell, water line, and reactant purge heater systems was nominal. The fuel cell water relief nozzle temperature was cycling between 277 and 272 °F during prelaunch operations, and its normal cycling range is 157 to 235 °F. While troubleshooting, control bus AB1 was dropped and the temperature rose to 340 °F, thus narrowing the problem to temperature controller B that is contained in mid-power-control- assembly (PCA)-2 or in the associated temperature return wiring, which is also contained in the mid-PCA-2. A waiver was submitted that allowed this condition to be flown as is, and there was no impact to the flight.

The prelaunch cell performance monitor (CPM) data were documented during the prelaunch operations. The CPM value for fuel-cell-2 sub-stack CPM was observed to have changed to 78 mV from 64 mV. The 14-mV change was nearing the 18mV in the LCC. A review of the fuel cell monitoring system single cell data did not yield any crossover indications. Many of the cells on half of the sub-stack had gained 1 to 2 mV in

performance while the other half had remained the same. The fuel cell monitoring system (FCMS) was activated and provided full-rate data during on-orbit operations for 12 minutes. None of the fuel cell individual cell voltages indicated any problems and no pin sharing was indicated.

Auxiliary Power Unit Subsystem

The auxiliary power unit (APU) subsystem performance was nominal throughout the mission. No in-flight anomalies or significant problems were identified during the evaluation of the data. All in-flight checkout requirements were completed satisfactorily.

The auxiliary power unit (APU) 2 gas generator (GG) injector bed temperature was biased higher than normal as seen during the last four flights of this APU (STS-97, -100, -108 and -111). The cause is believed to be the in-family failure of the spring clip retainer losing its spring properties. The loss of spring properties of the retainer, which holds this sensor and the heater controlling bed temperature sensor firmly to the GG injector well wall, has allowed the sensors to shift position. A design change to correct this problem is a double-walled spring clip, which is in final stages of approval. All three APUs were removed during postflight turnaround activities for their standard 4-year maintenance plan refurbishment during which the spring clip modification will be made to APU 2.

The flight control subsystem (FCS) checkout was performed satisfactorily using auxiliary power unit (APU) 1 to support the checkout with a start time of 337:14:58:33 G.m.t. (09:14:08:46 MET). The run time was 5 minutes and 45 seconds, and 17 pounds of fuel were used during the APU 1 operation. The total run time was too short to require spray cooling from the water spray boiler (WSB). FCS, APU, and hydraulics performance was nominal.

The following table presents the APU run times and fuel consumption for the mission.

APU RUN TIMES AND FUEL CONSUMPTION

Flight phase	APU 1 (S/N 207)		APU 2 (S/N 203)		APU 3 (S/N 311)	
	Time, Min:sec	Fuel consumption, lb	Time, Min:sec	Fuel consumption, lb	Time, min:sec	Fuel consumption, lb
Ascent	19:34	51	19:47	56	20:00	55
FCS checkout	5.45	17				
Entry ^a	65:44	125	92:00	206	65:49	141
Total	91:03	193	111:47	262	85.49	196

^a APU's were shut down 26 minutes 20 seconds after landing.

During ascent, the APU 1 exhaust gas temperature (EGT) 1 transducer was erratic. The transducer was also erratic during entry, dropping 200 °F during a 15-minute period, and then recovered to normal operation soon after landing. The transducer will be removed and replaced before the next flight of this vehicle.

Hydraulics/Water Spray Boiler Subsystem

The hydraulics/WSB subsystem performed satisfactorily throughout the mission. The OV-105 vehicle used the water additive, Propylene Glycol Monomethyl Ether (PGME), in

all three WSBs. No overcooling or undercooling conditions were noted in the data. Spray cooling was noted at 32 seconds, 42 seconds and 1 minute 12 seconds after MECO on systems 1, 2 and 3 respectively.

The WSB system 3 GN₂ relief valve reseal pressure was approximately 27.3 psig. The reseal requirement for this valve reseal is 28 psig. However, similar performance was observed during the previous mission of this vehicle.

There were no unexpected decreases in reservoir quantity, indicating that the systems had no gross leakage. Priority valve checks at APU activation were all well below the 1-second specification.

The APU/HYD system 1 was selected for FCS checkout. Hydraulic system 1 operation was nominal.

Electrical Power Distribution and Control Subsystem

The electrical power distribution and control (EPDC) subsystem performed nominally during all mission phases. The data review and analysis did not identify any abnormal conditions. Also, all File IX requirements were satisfied.

Orbiter Docking System

The Orbiter docking system (ODS) was powered up at 329:00:21 G.m.t. (00:23:31 MET). The ring extension was completed nominally, and the system was powered down at 329:00:42 G.m.t. (00:23:52 MET). The ODS is ready for rendezvous and docking operations.

The ODS was powered up for docking operations at 329:21:05:55 G.m.t. (01:20:16:08 MET) and the ISS was captured at 329:21:58:40 G.m.t. (01:21:08:53 MET). Ring retraction and hook closure were completed nominally. No high-energy damper anomalies were observed. Elapsed time from contact-to-hook closure was 12 minutes 8 seconds. The ODS was powered off at 329:22:18:23 G.m.t. (01:21:28:36 MET).

The ODS valves were used during the docked operations. The Orbiter was docked to the ISS pressurized mating adapter (PMA) 2 and the vestibule was pressurized from the ISS. The post-undocking vestibule leak check was nominal.

The external airlock waterline heater reconfiguration from string-A heaters to string-B heaters was performed as part of the in-flight checkout. The string-C heaters were not required.

The active-system-monitor parameters indicated normal outputs throughout the duration of the flight.

Atmospheric Revitalization Pressure Control Subsystem

During the first launch countdown, a high oxygen concentration in the payload bay led to the decision to scrub the launch (Flight Problem STS-113-V-01). The levels measured from 15 parts per million (ppm) to 130 ppm and the level should be approximately zero. Troubleshooting isolated the leakage to the pressure control subsystem (PCS) system 2 between the valve panel and bulkhead 576. The inspection following the scrub of the

launch found a blowing leak (550 scim) on the upper side of the flexible hose braiding at the bulkhead 576 fitting.

The flexible hose braiding showed signs of bird-caging deformation, typically an indication that the flexible hose has been subjected to an applied external load. The oxygen flexible hose was removed and replaced and a failure analysis was performed on the failed hose. The findings from an inspection of the flexible hoses on the vehicles indicated the presence of cracks and fatigue striations in some flexible hoses, which are the result of relatively low-frequency reverse bending fatigue. All flexible hoses that have been examined that have exhibited fatigue cracking have had associated damage on the exterior of the line.

The atmospheric revitalization pressure control subsystem (ARPCS) performed normally throughout the duration of the flight. To minimize the use of consumables and maintain pressure for gas transfer to the ISS, the 14.7-psia cabin regulators were left off after orbital insertion. At 328:22:20 G.m.t. (00:21:31 MET), PCS 1 was placed in service, and taken out of service just prior to pressure equalization with ISS.

All 3 EVA's on this mission were performed from the ISS Airlock. Due to the large amount of oxygen (O₂) exhausted into the cabin atmosphere during the ISS prebreathe procedure, cabin pressure during the docked period was maintained by the introduction of the O₂ from the ISS prebreathe and the ISS pressure control system.

After the third EVA, the entire stack was repressurized to 14.7 psia using Orbiter O₂ at 336:03:24 G.m.t. (07:02:35 MET). Following this pressure operation, normal pressure-control was maintained by the Orbiter for the remainder of the docked phase of the flight.

After undocking, PCS system 2 was placed in service and a full switchover to PCS2 was observed. Full switchover was observed on both systems this flight. No nitrogen (N₂) or O₂ was transferred to the ISS tanks via the transfer lines this flight.

The active system monitor parameters indicated normal output throughout the duration of the flight.

Atmospheric Revitalization Subsystem

The atmospheric revitalization subsystem (ARS) performed nominally through the duration of the flight with the following mission highlights provided. Hardware checkout in accordance with the file IX requirements was completed satisfactorily.

The 77.0 °F indicated cabin air temperature at launch was 5 °F warmer than the ECLSS/Payload Thermal Compatibility Verification Analysis. The 77°F launch temperature was 3 °F below the flight rule prelaunch limit of 80°F cabin air temperature. The cabin air temperature climbed to 84.5° F at 3 hours and 23 minutes after launch and that was the peak cabin air temperature during the mission.

At launch, the cabin partial pressure carbon dioxide (ppCO₂) sensor indicated a value of 1.33 mmHg and it peaked at 1.88-mmHg ppCO₂ 2 hours and 38 minutes into the flight. During on-orbit operations, the Orbiter cabin ppCO₂ peak of 7.6 mmHg occurred approximately 17 minutes 32 seconds prior to docking with the ISS. While docked to the ISS, the Orbiter crew compartment ppCO₂ peaked at 7.4 mmHg at 332:00:00 G.m.t. (03:23:11 MET). The carbon dioxide removal assembly (CDRA) and Vozdukh (Russian carbon dioxide controller) were the primary ppCO₂ control devices during the docked

portion of the flight. The CDRA operation was intermittent and the Vozdukh remained fully functional in the manual mode with a 10-minute cycle time. The intermittent operation of the CDRA continued until flight day 5 when instrumentation indicated the unit was leaking from bed 2. Operation of the CDRA was suspended and the ISS crew performed the CDRA repair by removing the discrepant 103 and 104 selector valves and replacing these with new ones. Upon completion of the valve replacement, the CDRA was repowered and operated flawlessly through the end of the docked portion of the mission.

Preflight planning scheduled eight lithium hydroxide (LiOH) cartridges for ISS exchange, which involved exchanging fresh Orbiter manifested cartridges for older packed cartridges that had been placed aboard the ISS during previous flights. However, once on-orbit, one additional ISS LiOH cartridge was exchanged for an Orbiter- manifested cartridge, bringing the total to nine LiOH cartridges exchanged. In addition to the nine exchanged LiOH cartridges, the ISS Program requested six more LiOH cartridges for transfer and stowage aboard the ISS.

A total of 28 LiOH cartridges were spent during the mission. Nine of these spent cartridges had been in this vehicle and were transferred from the ISS and the remaining 19 cartridges had been manifested for Orbiter usage.

The floodlight cold plate temperature location on the 576 bulkhead indicated the temperature averaged approximately 70.0° F during the mission, decreasing to a minimum temperature of 65.43 °F at 340:24:02 G.m.t. (12:23:13 MET).

The ARS file IX requirements were satisfied. These requirements include the checkout of the secondary cabin temperature controller and the checkout of the primary water-cooling loop (WCL) 1 actuator and its response to temperature. This activity occurred during the cold-soak period of the first landing opportunity with WCL 1 actuator check out 331:23:09 G.m.t. (03:22:20 MET). The cabin temperature controller was switched from the primary to the secondary controller at 331:23:09 G.m.t. (03:22:20 MET).

At launch, the cabin humidity was 36.8 percent and peaked to 39.9 percent at 1 hour and 32 minutes after launch. The heat exchanger outlet air temperature at launch was 54.3 °F and peaked to 65.4 ° F at approximately 4 minutes 11 seconds into the flight.

During the on-orbit phase of the mission, the cabin temperature averaged 75.5 °F and during the docked portion of the mission the cabin temperature varied from a low of 74.4 ° F to temperature highs of 78.0 ° F, with an average temperature of 75.6 ° F.

The ppCO₂ peaked to an indicated ppCO₂ reading of 7.4 mmHg during the docked phase of the mission and 7.6-mmHg ppCO₂ during the non-docked phase of the mission.

Cabin humidity averaged 35 percent for the flight, peaking at more than 60 percent during the FES deicing procedures performed on flight day 9.

During the landing phase of the flight, the heat exchanger outlet temperature peaked to 59.7 ° F at 7 minutes and 41 seconds after wheel stop, with the cabin air temperature peaking to 73.7 °F at 55 minutes after wheel stop and prior to crew egress. The temperature at landing was 71.2 °F, below the 75-degree cabin air temperature limit. The cabin humidity peaked near 52 percent at approximately 10 minutes after wheel stop.

Active Thermal Control Subsystem

The active thermal control subsystem (ATCS) performed nominally during ascent. Pre-evaporative cooling was observed and it was within family historically. The flash evaporator subsystem (FES) outlet temperatures dropped from 85 to 62° F. Other ATCS hardware performed nominally with the exception of the FES in topping mode under primary B control.

One anomalous performance signature was observed in the transients in the FES outlet temperature. The transients began occurring at about 328:03:39 G.m.t. (00:02:50 MET) when the FES was already in the topping mode under primary B command control following completion of the post-orbital insertion procedures. Another anomaly, which may be closely tied to or be a part of the transient outlet temperature events, is the FES shutdown that occurred during a FES water dump using the primary B controller. At 335:19:52 G.m.t. (07:19:03 MET), a FES water dump using the primary B controller was initiated. A previous FES water dump was performed from 334:19:34 G.m.t. (06:18:45 MET) through 335:02:25 G.m.t. (07:01:36 MET) using the primary A controller. After filling the planned seven contingency water containers (CWCs) for transfer to the ISS, the supply and wastewater management subsystem (SWWMS) water tanks were configured to gang tanks B, C, and D together. At 335:23:04 G.m.t. (07:22:55 MET), the FES outlet temperature increased suddenly to 48° F, which is outside the control band of the FES primary controller. The outlet recovered quickly and returned to the control band. About 5 minutes later, a second temperature increase occurred, this time to 52° F, again outside of the control band. The controller tried to recover by bringing temperatures below the control band resulting in a under-temperature shutdown. The lowest FES outlet temperature observed was 34.5° F. At 335:23:16 G.m.t. (07:23:07 MET), the crew restarted the FES using the primary B controller. The controller shut down at 335:23:58:39 G.m.t. (07:23:08:48 MET). Approximately two minutes later, the crew attempted a restart using the primary A controller. The FES ran on the primary-A controller for 13 minutes before a rate shutdown occurred. At 329:00:21 G.m.t. (07:23:32 MET), the FES core flush procedure was performed on the topping core and completed 43 minutes later. During the flush, duct temperatures showed signatures of excess carryover and ice being removed from the topping core. The portion of the flush procedure that runs the secondary controller for an extended time was run for about 34 minutes. The first 3 minutes of the extended secondary controller operation saw the forward topping duct temperature drop from 231° F to 48° F, while the aft duct section dropped from about 260° F to about 60° F. These duct temperatures began to recover about 7 minutes after they bottomed out. After the flush procedure, the FES operated on the primary-A controller for the remainder of the mission. During this latter period, the FES exhibited no outlet temperature transients and performed nominally throughout the remainder of the mission.

Both the nominal end-of-mission (EOM) day and the on the first contingency day (December 6) landing opportunities were waived off. However, radiator bypass/FES checkouts were performed on both days. On flight day 15, the radiator coldsoak was initiated at 341:14:37 G.m.t. (13:13:48 MET) and ended 57 minutes later with the start of the radiator bypass/FES checkout. The radiator bypass/FES checkout was performed and ended with the configuring of the FES to the primary-A controller in the full-up mode. After the payload bay doors were closed, the FES was configured from primary A command to primary A general-purpose computer (GPC) control in preparation for entry. The radiators were configured for radiator flow about 11 minutes before touchdown. Shortly thereafter, the radiator flow control assemblies were switched from normal setpoint-control to high setpoint-control in preparation for the ammonia boiler system

(ABS) activation. Satisfactory cooling was maintained throughout the entry and postlanding activities before the crew exited the vehicle.

Supply and Waste Water Subsystem

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, water transfer to the ISS and the overboard nozzle dump system. The line heater maintained the supply water dump line temperature between 75.3 °F and 97.3°F throughout the mission. Four wastewater nozzle dumps from the wastewater tank, were made at an average rate of 1.97 percent/minute (3.25 lb/min). The Shuttle urine pre-treat assembly (SUPA) was manifested for STS-113, and condensate collection in the contingency water containers (CWCs) was implemented to minimize waste dumps while docked with the ISS. The Oxone Hose Section flown on STS-113 contained two-tablets and the change-outs occurred during the post-sleep time instead of pre-sleep time.

As a result of condensate separation/collection, two CWCs of Shuttle Condensate were filled and dumped overboard through the wastewater dump nozzle. The waste dump isolation valve was closed prior to connecting the CWC into the waste cross-tie quick disconnect to prevent back flow from the waste tank. The wastewater dump line temperature was maintained between 54.9 °F and 76.8 °F throughout the mission.

Vacuum vent line temperature was maintained between 57.2 °F and 79.8 °F.

Seven CWCs were filled with supply water and transferred to the ISS, for a total of 672 lb. All of the CWCs transferred were technical water. The calculated average fill rate was 109 lb/hr. In addition, one payload water reservoir (PWR) of iodinated water (approximately 18 lb) was filled and transferred to the ISS.

At 330:09:56:21 G.m.t. (02:09:06:34 MET), the supply water tank A quantity sensor exhibited a quantity dropout at a tank quantity of 99.3 percent. The tank quantity dropped to 54.7 percent for one second and recovered. In addition, the tank quantity sensor dropped a number of times to almost the same quantity level (99.9 and 99.4 percent) during the mission.

At 330:08:38:03 G.m.t. (05:07:48:16 MET), the supply water tank B quantity sensor showed quantity dropout at a tank quantity of 65.8 percent. The tank dropped to a negative 9.5 percent for one second and recovered. Also, other dropouts of the Tank B quantity were observed throughout the mission. Tank B dropouts were also noticed during previous flights of this vehicle (OV-105). At 333:02:49:00 G.m.t. (05:01:59:13 MET), the supply water tank D quantity sensor exhibited a quantity dropout at a tank quantity of 48.78 percent. The tank quantity dropped to 19 percent for one second and recovered. In addition, the tank quantity sensor dropped at the quantity level of 74 percent to zero percent. This was the first occurrence of the tank D quantity sensor to drop and this occurrence will be document for future reference. Such dropouts have been experienced in previous flights and the problem was caused by either contamination of the collector bar and/or a surface defect on the collector bar of the potentiometer, either of which causes an intermittent break in continuity. These dropouts are understood problems and the quantity sensor will be replaced during the Orbiter Major Modification (OMM) period.

Waste Collection Subsystem

The waste collection subsystem performed satisfactorily throughout the mission.

Smoke Detection and Fire Suppression Subsystem

The smoke detection system showed no indications of smoke generation during the entire duration of the flight. Use of the fire suppression system was not required.

Flight Data Subsystem

The flight data subsystem performed satisfactorily. No in-flight anomalies were identified in the data review and analysis.

STS-113 was the second flight of the MAGR, using three-string certified link 5-firmware that was previously flown as a Development Test Objective (DTO). The MAGR is now certified as a three-string replacement for the Tactical Air Navigation (TACAN) system; however, the MAGR will not totally replace the TACAN equipment until 2008. The MAGR is also being considered as a single-string system for concurrent operation with the TACAN. Although the MAGR state-vector solution was not incorporated into the navigation system for this flight, the available downlisted MAGR data were closely monitored and evaluated throughout the flight. A payload and general support computer (PGSC) was not available to this flight to record additional MAGR data.

During prelaunch operations, the MAGR did not acquire and track satellites for a six-minute period. All of the channels were reset and normal satellite acquisition and tracking commenced within 15 seconds. The problem did not recur during the mission. A problem resolution team is analyzing the data in an attempt to determine the cause of this condition.

At 335:04:05 G.m.t. (07:03:15 MET), when changing the hardware caution and warning system for the 14.7-psia repressurization, the crew reported the tens place on the panel R13U caution/warning-parameter-select down-plunger did not work. The crew reported that the up pushbutton was used to obtain the proper values. Also, the crew reported that while attempting to change the panel R13U caution/warning-limit-set-value, the ones-place up-plunger initially did not work. After several attempts, the plunger did start to work, but the operation of the pushbutton felt sticky. The sticky operation of this switch did not impact the mission. Postflight activity will include the replacement of the switch.

The performance of the star trackers was satisfactory. The -Y star tracker acquired stars 185 times during the mission. In addition, the star tracker also acquired a navigation star 84 times during the mission. Over 84 percent of the misses were isolated to two stars. The Orbiter attitude and bright objects in the field of view can cause these misses. The -Z star tracker acquired 24 stars during the mission and missed 8 stars. The data showed that most of these misses occurred while docked with the ISS when bright objects were in the field of view.

The inertial measurement units (IMUs) performed satisfactorily. While on-orbit, only one adjustment of the accelerometer compensations was required for IMUs 1 and 2. Also only one adjustment was required for the drift bias in IMU 1. All three IMUs have been declared acceptable for the next flight of this vehicle.

Flight Control Subsystem

The flight control subsystem (FCS) performed satisfactorily throughout the mission. No in-flight anomalies were identified in the data.

The FCS checkout was performed satisfactorily using APU 1 to support the checkout with a start time of 337:14:58:33 G.m.t. (09:14:08:46 MET). FCS performance was nominal.

Flight Software

STS-113 was the fourth flight of the OI-29 software. The flight software performed satisfactorily throughout the mission with no in-flight anomalies identified during the data review and analysis.

Displays and Controls Subsystem

The displays and controls subsystem performed nominally and no in-flight anomalies were identified from the data.

At 335:04:05 G.m.t. (07:03:15 MET), when changing the hardware caution and warning system for the 14.7-psia repressurization, the crew reported the tens place on the panel R13U caution/warning-parameter-select down-plunger did not work. The crew reported that the up pushbutton was used to obtain the proper values. Also, the crew reported that while attempting to change the panel R13U caution/warning-limit set-value, the ones-place up-plunger initially did not work. After several attempts, the plunger did start to work, but the operation of the pushbutton felt sticky. The sticky operation of this switch did not impact the mission. Postflight activity will include the replacement of the switch.

Communications and Tracking Subsystem

The communications and tracking subsystem performed nominally in support of the mission except for the three items discussed in the following paragraphs. No in-flight anomalies were noted in the data. All communications and tracking subsystem file IX requirements were fulfilled.

The ISS audio anomaly that occurred during the STS-112 mission recurred after docking. The ISS communications community developed troubleshooting procedures in an attempt to resolve the problem. A non-invasive troubleshooting plan was implemented but with the same results as STS-112. The non-invasive troubleshooting plan was not implemented because of the lack of sufficient time during docked operations.

At 331:18:46 G. m. (03:17:56 MET), the S-Band power amplifier (PA) 2 forward output power dropped from 117 watts to an estimated power of 50 watts or less. The power drop resulted in the GPC issuing a fault summary message S-BD PA 2 PWR OUTPUT LOW. Instantaneously, the PA 2 reflected power dropped from 6 watts to 2 watts on the lower left aft (LLA) antenna. There was no change in the PA 2 reflected power when moving from the LLA antenna to the lower left forward (LLF) antenna. Data review also revealed a PA 2 temperature increase from 152 to 159 °F at the time of the initial drop in power. Although there was a significant drop in output power, the S-Band return link remained locked up, and no data were lost. The flight controllers commanded PA 1 on and PA 2 off at 331:19:03 GMT (03:18:13 MET).

Additional checkout of S-Band PA 2 was performed after separation from the ISS. The signature observed was consistent with that observed on the day of the initial problem. PA 2 had a steady, low output power of approximately 56 watts (specification minimum is 100 watts) and was unaffected by changing S-Band transponders and preamplifiers. Despite the low output power, S-Band communications functioned nominally throughout the approximately 30-minute duration of the checkout. The S-Band system was returned to PA 1 operation at the end of the test. Although weaker than nominal, PA 2 remained a viable backup to PA 1 for the remainder of the flight.

This is the second time this PA (S/N 306) has caused the annunciation of a S-BD PA 2 PWR OUTPUT LOW fault summary message. The first occurrence was observed on STS-108, which was the seventeenth flight of the OV-105 vehicle.

During the latter part of the flight, the Mission Control Center (MCC) was unable to intermittently process an image from the digital television (DTV) system. On the first occurrence, the ground equipment was reset several times with no success. The data showed that data were getting to the ground; however, it was a full frame instead of an image. The onboard configuration was verified and the crew cycled the power to the vertical interval processor (VIP), and the image was recovered. The same conditions occurred later in the flight, and power cycling did not recover the image. The crew verified that there was a good image on the onboard monitor. After undocking, the crew played back the recording of the undocking. After this, the DTV downlink worked properly until the Ku-band antenna was stowed; however, the ground equipment had to be cycled several times to recover the downlink. Each time that the ground equipment was cycled, the cause of the problem was explained as being a ground problem.

Operational Instrumentation/Modular Auxiliary Data System

The operational instrumentation (OI) subsystem and modular auxiliary data system (MADS) performed satisfactorily throughout the STS-113 mission. No in-flight anomalies were identified during the review and analysis of the data.

Structures and Mechanical Subsystems

The structures and mechanical subsystems performed nominally throughout the mission. No in-flight anomalies or significant problems were identified during the review and analysis of the data.

The payload bay doors were opened as planned at 328:02:34:37 G.m.t. (00: 01:44:50 MET). All voltages were nominal and the motors opened the doors in nominal dual-motor time.

The payload bay doors (PLBDs) were closed for the planned landing day opportunities at KSC. Both landing opportunities on the planned landing day were waved off at Kennedy Space Center (KSC) because of unacceptable landing conditions (cloud coverage).

Following the wave off to the second opportunity, the PLBDs were unlatched and reopened at 338:21:18:24 G.m.t. (10:20:28:37 MET). All PLBD unlatch and open operations were nominal and occurred in dual motor time.

The PLBDs were not closed for the first contingency day opportunities at KSC because of the forecasted unsatisfactory weather conditions. Both landing opportunities on the first contingency day were waved off as a result of the unacceptable weather conditions.

The PLBDs were not closed for the first contingency day opportunities at KSC because of the forecasted unsatisfactory weather conditions. Both landing opportunities on the first contingency day were waved off as a result of the unacceptable weather conditions.

The PLBDs were closed and latched for the first KSC landing opportunity on the second contingency landing day at 340:16:53:55 G.m.t. (12:16:04:08 MET). All PLBD close and latch operations were nominal and occurred in dual motor time. However, both KSC landing opportunities were waved off and the PLBDs were reopened at 340:18:32:51 G.m.t. (12:17:43:04 MET). The doors operated satisfactorily during both the opening and closing operations. However, during the opening the starboard forward latch release indication 2 (B microswitch) failed to come on. The motor ran for approximately 68 seconds until the software removed the command at the single-motor run-time limit. The A microswitch came on within the nominal dual motor run time. The B microswitch transferred on approximately 12 minutes after the bulkheads latches were released. An evaluation will be performed to determine the cause of the slow change of state.

The landing parameters are shown in the following table

LANDING PARAMETERS

Parameter	From Threshold, ft	Speed, Keas	Sink rate, ft/sec	Pitch rate, deg/sec
Main gear touchdown	2903.9	196.4	-1.09	N/A
Nose gear touchdown	5809.4	159.2	N/A	-5.00
Brake initiation speed		85.3 keas		
Brake-on time		41.13 seconds		
Rollout distance		10600.0 feet		
Rollout time		75:13 seconds		
Runway		33 (Concrete) KSC		
Orbiter weight at landing		201714.7 lb		
Brake sensor Location	Peak Pressure, Psia	Brake assembly		Gross energy, million ft-lb
Left-hand inboard 1	599.3	Left-hand inboard		7.86
Left-hand inboard 3	599.3			
Left-hand outboard 2	625.7	Left-hand outboard		9.02
Left-hand outboard 4	625.7			
Right-hand inboard 1	816.8	Right-hand inboard		8.02
Right-hand inboard 3	816.8			
Right-hand outboard 2	622.9	Right-hand outboard		6.61
Right-hand outboard 4	622.9			

During the vent door repositioning prior to the deorbit maneuver, the left vent door 5 closed indication 1 failed to transfer on. This caused the motor to run for 10 seconds until the command timed out. The operation of indication 2 was normal. Indication 1 transferred on approximately 14 ½ minutes later. Postflight checks will be performed to determine if a problem exists.

The landing gear tires were in good condition. The External Tank/Orbiter (E/O) separation devices (EO-1, EO-2 and EO-3) functioned normally. No ordnance

fragments were found on the runway beneath the umbilicals. The EO-2 and EO-3 fitting retainer springs appeared to be in the nominal configuration. The EO-2 and EO-3 pyrotechnic debris shutters were fully closed and no other debris was found on the runway.

Integrated Aerodynamics, Heating and Thermal Interfaces

The surface thermal sensors indicated that an early boundary-layer transition occurred 1158.4 seconds after entry interface (EI) on the left-hand wing inboard lower surface near the trailing edge at Mach 9.3. However, it was brief, and decreased in 73.7 seconds. The final permanent transition started at both the left-hand and right-hand wing lower surfaces near the trailing edge, after which it moved from the outboard area toward inboard area and from the trailing edge toward the leading edge rapidly and simultaneously.

The transition onset times occurred at 1203.4 seconds after EI on the left-hand wing lower surface outboard trailing edges at Mach 8.1, and 1207.5 seconds after EI on the right-hand wing at Mach 8.0. The transition reached the left-hand wing lower-surface forward area at 1289.4 seconds after EI at Mach 6.2, and at 1285.3 seconds after EI on the right-hand wing at Mach 6.3. The transition also reached the aft fuselage lower-surface centerline area 1285.3 seconds after EI at Mach 6.3. Transition spread from the aft to the mid and forward fuselage in 4.1 seconds. The transition onset times on the lower surface mid fuselage centerline and forward fuselage centerline were the same at 1289.4 seconds from EI at Mach 6.2.

The acreage heating was nominal. The maximum structural temperature data are within the range expected for this type of mission and within the flight history of OV-105. The temperature-rise data on the port aft fuselage recorded the highest temperature rise for OV-105, but the rise was within fleet experience.

Structure temperature data did not indicate any local heating problems

Thermal Control Subsystem

The thermal-control subsystem performed satisfactorily throughout the STS-113 mission and no temperature violations to the vehicle or vehicle subsystems were noted.

Aerothermodynamics

Aileron deflection data and yaw thruster firings indicated that STS-113 experienced boundary layer transition at approximately Mach 10.5.

Wing structural thermocouple temperature data did not indicate an asymmetric transition; however, aileron deflection data, and yaw thruster firings indicated that asymmetric drag occurred on the left wing approximately Mach 10.5. The time of transition from laminar to turbulent flow will be defined from the MADS recording of the surface temperature data.

The acreage maximum structural heating data was within the range expected for this type of mission and within the flight history of this vehicle. The temperature rise data on the port aft fuselage side was the highest temperature rise recorded on the OV-105 vehicle, but the temperature rise was within the fleet experience.

Local heating was also normal. The preliminary evaluation does not indicate abnormal entry heating as the cause.

Thermal Protection Subsystem and Windows

The thermal protection subsystem (TPS) performed satisfactorily. The postlanding inspection of the Orbiter TPS identified a total of 113 damage sites of which 29 had a major dimension of 1-inch or larger. This total does not include the numerous damage sites on the base heat shield that are attributed to SSME vibration/acoustics, exhaust plume recirculation and the flame arrestment sparkler system. The distribution of these impacts on the vehicle is shown in the following table.

TPS DAMAGE SITES

Orbiter Surfaces	Hits > 1 Inch	Total Hits
Lower Surface	14	68
Upper Surface	2	5
Window Area	13	38
Right Side	0	0
Left Side	0	2
Right OMS Pod	0	0
Left OMS Pod	0	0
Total	29	113

The Orbiter lower surface sustained 68 damage sites of which 14 had a major dimension of 1-inch or larger; both numbers are well within family. The majority of the damage sites occurred between the nose landing gear and the main landing gear doors. This area sustained 43 hits with 6 greater than 1 inch. Most of these damage sites were shallow, indicative of damage from ET foam.

The largest lower surface tile damage site, located on the right-hand inboard elevon, measured 7 inches by 1 inch by ½ inch. This damage spanned two tiles and the cause of the damage has not been determined.

A comparison of lower surface damage sites for the previous 10 flights is shown in the following table.

COMPARISON OF LOWER SURFACE DAMAGE SITE DATA FROM LAST TEN FLIGHTS

Parameter	STS -102	STS -100	STS -104	STS -105	STS -108	STS -109	STS -110	STS -111	STS -112	STS -113
Lower surface, total hits	44	42	108	144	95	63	70	47	79	68
Lower surface, hits > 1 in.	10	4	4	25	22	14	18	21	22	14
Longest damage site, in.	1.0	2.5	4.5	5	8.0	3.5	3.5	3.0	3.5	7.0
Deepest damage site, in.	0.12	0.12	0.25	0.06	0.37	0.12	0.62	0.50	0.25	0.59

A total of 38 damage sites, with 13 having a major greater than one inch, were identified on the window perimeter tiles. Damage to the window perimeter tiles on the forward-facing windows is attributed to impacts made by the forward RCS paper covers with

room temperature vulcanizing (RTV) material adhesive on the back. The hazing and streaking was normal on the forward-facing windows.

Typical amounts of tile damage occurred on the Orbiter base heat shield. The SSME dome heat shield closeout blankets were in good overall condition on SSMEs 1 and 3. The closeout blanket on SSME 2 was damaged /frayed from the 12 o'clock position to the 3 o'clock position. A portion of the outer mold line fabric was also missing.

During the post-landing walkdown of the runway, an 8-inch long piece of Ames Gap Filler material was found on the runway.

In summary, both the total number of Orbiter TPS damage sites and the number of sites that were 1-inch or larger were within the established family. However, the number of damage sites between the nose landing gear and the main landing gear wheel wells was slightly higher than normal. The potential identification of debris damage sources for this mission will be based on laboratory analysis of the Orbiter postlanding microchemical samples, inspection of the recovered SRB components, film analysis and aerodynamic debris particle trajectory analysis. The results will be published in the STS-113 Debris/Ice/TPS Assessment and Integrated Photographic Analysis report.

Gas Sample Analysis

The analysis of the gas samples contained in the six bottles showed the samples to be acceptable and within the nominal range for percentage of hydrogen. Constituents present in each bottle greater than 0.1 percent were determined. Back-pressure calculations of actual pressure assumed all bottles were a total volume of 250 cc.

The analysis was performed using an AeroVac Mass Spectrometer with a 0 to 1000 Torr capacitance manometer. The backup analysis was accomplished using a Finnegan 9001 Gas Chromatograph with Discharge Ionization Detection (DID). A backup analysis was made of all constituents with the exception of Helium.

Computations to determine the amount of hydrogen contributed by the pyrotechnic used to open and close the sampling bottle assumed that the composition would match that of experimental values obtained under controlled conditions. They indicated that the ratio of hydrogen to carbon monoxide is 0.54. Corrected hydrogen, therefore, is the value of carbon monoxide multiplied by 0.54 and that solution subtracted from the hydrogen detected.

The percent air and oxygen from the air was calculated from the amount of argon in the sample. The calculations assume normal air to be 78.08 percent nitrogen, 20.95 percent oxygen and 0.934 percent argon.

The table showing the data measured from the bottles is presented in the Shuttle Flight Data and In-Flight Anomaly List (JSC 19413). This document may be accessed on the Space Shuttle Vehicle Engineering Office home page under the MER heading.

EXTRAVEHICULAR ACTIVITY

The crew performed three extravehicular activities (EVAs) successfully with all planned tasks completed. The total EVA time was 19 hours 55 minutes for a total EVA man-hours was 39 hours 50 minutes.

FIRST EXTRAVEHICULAR ACTIVITY

The first EVA was successfully completed with a total EVA time of 6 hours and 45 minutes. The EVA, which was conducted from the ISS airlock, officially began when the EMUs were placed on internal battery power at 330:19:48 G.m.t. (02:18:58 MET). The EVA concluded when repressurization of the airlock was initiated at 331:02:33 G.m.t. (03:01:43 MET).

The ground monitoring personnel reported that biomedical data were not received from either crewmember during the EVA. Postflight testing of the biomedical data instrumentation will be performed to determine the cause of the failure.

SECOND EXTRAVEHICULAR ACTIVITY

The second EVA was successfully completed with a total EVA time of 6 hours and 10 minutes. The EVA was conducted from the ISS airlock and officially started when the EMUs were placed on internal battery power at 332:18:36 G.m.t. (04:17:46 MET). The EVA was very successful in that all tasks were completed. The EVA concluded when repressurization of the airlock was initiated at 333:00:47 G.m.t. (04:23:57 MET).

THIRD EXTRAVEHICULAR ACTIVITY

The third EVA was successfully completed with a total EVA time of 7 hours. The EVA was conducted from the ISS airlock and officially started when the EMUs were placed on internal battery power at 334:19:24 G.m.t. (06:18:34 MET). The EVA was very successful in that all tasks were completed. The EVA concluded when repressurization of the airlock was initiated at 335:02:24 G.m.t. (07:01:34 MET).

During the EVA, nominal video was successfully transmitted via the Wireless Video System (WVS) from both extravehicular crewmembers (EV1 and EV2).

REMOTE MANIPULATOR SYSTEM

The Shuttle remote manipulator system (RMS) performed satisfactorily on this sixty-eighth flight of the RMS. No in-flight anomalies or problems were noted during the mission. The RMS provided viewing support during the installation of the S1 truss.

During the repair activities, the leaking flexible oxygen hose was replaced; however, a work platform came in contact with the remote manipulator system (RMS) upper boom and caused some visible damage to the carbon composite boom. As a result, the launch was rescheduled for November 22, 2002, so that the Canadian RMS manufacturer could perform structural tests of the RMS. These tests proved that the structural integrity was not decreased and the RMS was declared ready for flight.

During the RMS checkout, the wrist-roll joint tachometer data showed rate spikes of approximately 2 radians/second in the negative direction while performing the direct drive test (Flight Problem STS-113-V-03). At the start of the payload bay survey following the RMS checkout, a payload deployment and retrieval system control point of resolution (PDRS CNTL POR) fault message was annunciated. An investigation determined that an attitude trajectory tracking error detection had occurred because the wrist roll joint was not tracking the command. The malfunction procedure for a sluggish joint was performed, and operating in the single-joint mode and at coarse rates cleared the stalled wrist-roll joint condition. The survey was completed with no further occurrences of the fault message. A second direct-drive test of the wrist roll joint was performed prior to cradling to confirm the good health of the joint. This was the first flight of the RMS S/N 201 arm since it was refurbished. Initial indications are that dry gear lube may have contributed to the spikes and caused the temporary sluggish joint.

The Shuttle RMS was used to unberth the ISS P1 truss segment and positioned the segment over the Orbiter port wing for handoff to the Space Station RMS (SSRMS). The SSRMS was used to perform the mating of the P1 truss to the ISS S0 truss. The Shuttle RMS was subsequently used to support EVA activities and was cradled, latched and powered down at 331:02:21 G.m.t. (03:01:31 MET). The Shuttle RMS performed nominally for all operations. No further occurrences of the wrist-roll control problem reported earlier in the mission were observed.

GOVERNMENT FURNISHED EQUIPMENT/FLIGHT CREW EQUIPMENT

The Government Furnished Equipment/Flight Crew Equipment (GFE/FCE) 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.

The crew experienced a number of problems while trying to access the rendezvous proximity operators program (RPOP) payload and general support computer (PGSC) from the onboard PGSC network. The RPOP PGSC is used as the backup laptop running the RPOP application during rendezvous and undocking as well as running the wireless video system software during the extravehicular activities (EVAs). The problems were noted on flight day (FD) 3, 4, 5, 7, and 9. The problem was isolated to the hard drive in the RPOP PGSC. The hard drive was replaced on FD 9 and the PGSC was successfully returned to the network.

The wireless video system (WVS) operated intermittently and was mostly off from the extravehicular 1 (EV1) crewmember during the first and second extravehicular activity (EVA). The TV from the EV2 crewmember experienced breakups that were downlinked and the picture was smudged and torn during the first EVA. The crew supported troubleshooting of two problems observed earlier in the mission: In response to the lack of video coming through the wireless video system transceiver 2, the audiovisual interface unit (AVIU) was reconfigured and verified as operational. Good images on the WVS were received from both crewmembers during the third EVA.

On flight day (FD) 7, the Mission Control Center (MCC) was unable to process an image from the digital television system (DTV). The ground equipment was reset several times and still no image could be processed. The DTV telemetry showed that data were getting to the ground, however, there was a fill frame rather than an image. The onboard configuration was verified, and the crew cycled the power to the vertical interval processor (VIP). The image was recovered with this power cycle.

About 13 hours later, the image was again lost when the DTV system was powered off. The image did not recover when the system was powered back on. The VIP was again power cycled, but the image was not recovered. The crew verified that there was a good image onboard.

About 19 hours later, the crew played back the recording of the undocking sequence on DTV. After this DTV downlink, the DTV continued to operate properly until the Ku-band antenna was stowed. However, during this time, the ground equipment had to be cycled a few times to recover the downlink image. There was never a loss of downlink during this period that could not be explained by the ground problem.

During installation of the plant generic Bioprocessing apparatus (PGBA) in preparation for its return to Earth, the crew was able to engage only six of eight of the attachment fasteners. The two starboard side lower fasteners could not be engaged. A second attempt was made to attach the fasteners by loosening the six engaged fasteners. All of the fasteners were initially engaged; however, the two fasteners that previously could not be fastened again disengaged.

POSTLAUNCH PAD INSPECTION

The postlaunch inspection of the mobile launch platform (MLP) -2, Launch Pad A and fixed service structure, north flame trench and Pad-A apron were performed. No flight hardware was found.

Orbiter lift-off lateral acceleration data that is used to predict stud hang-ups was not received from the Orbiter contractor because a data stream loss had occurred. An inspection was performed and the south holddown studs were visually assessed as having no indication of hang-up. Erosion was typical on both the north and south posts. The north holddown post blast covers and the T-0 umbilical exhibited minimal exhaust plume damage. Both SRB aft-skirt GN₂ purge lines were intact and erect; however, the protective tape layering was partially eroded and exhibited fraying on the right-hand side.

The LO₂ and LH₂ tail service masts (TSMs) appeared undamaged with both bonnets closed properly. The MLP deck was generally in good shape.

The GH₂ vent line latched on the seventh of eight teeth on the latching mechanism. The vent line was centered in the latching mechanism. The ground umbilical carrier plate (GUCP) 7-inch quick-disconnect (QD) probe appeared to be undamaged with the sealing surface in good shape. The deceleration cable was in its nominal configuration, and the vent-line blanket was sooted. A slight twist was found in the restraining collar fixture adjacent to the GUCP.

The Orbiter access arm (OAA) appeared to be intact with no evidence of plume impingement. All slide-wire baskets were secured with no evidence of damage.

The gaseous oxygen (GO₂) vent arm, ducts and structure appeared to be in nominal shape with no evidence of plume damage. The GO₂ vent seals were inspected and found to be in good shape with a small (3/8 inch by 1/4 inch) indication of ET paint residue present on the +Y seal lower center position.

Debris findings included:

- A. A bolt (3/16 inch by 1 1/8 inch) with nut attached was found adjacent to the left-hand water pipe between holddown post (HDP) 6 and 8;
- B. The operational television (OTV) camera 55 was found in the full-up position, indicating a pan and tilt mechanism failure;
- C. SRB plug material was found on the pad apron; and
- D. Nominal erosion was noted on the north flame trench deflector and it was attributed to the left and right SRBs.

Overall damage to the pad appeared to be normal.

DEVELOPMENT TEST OBJECTIVES/DETAILED SUPPLEMENTARY OBJECTIVES

DEVELOPMENT TEST OBJECTIVES

DTO 264 Space Station RMS Dynamic Validation During Shuttle and ISS Mated Flight - This detailed test objective (DTO) was performed during the installation of the S1 truss. No further activities were planned. Results of the data evaluation from this DTO will be reported in separate documentation.

DTO 700-14 Single String Global Positioning System - The miniature air to ground receiver (MAGR) Development Test Objective (DTO) for STS-113 was successfully completed. Engineering data were recorded onto the MAGR payload and general support computer (PGSC) for the entire planned time during the mission. The crew reported the daily MAGR status each day to assure ground personnel of proper data recording. During the final crew activity with the PGSC, the crew configured the MAGR PGSC for entry and stowed the computer in a modified middeck locker. The MAGR PGSC was programmed to record data during entry and landing and it performed nominally.

The MAGR receiver performed nominally most of the mission. An anomaly did occur on flight day (FD) 4 that had been previously documented in a program-approved Flight Software Waiver/Operations Note. The effect of this anomaly was a slightly degraded, but not out-of-tolerance receiver performance. A second anomaly that was also documented in a program-approved Flight Software Waiver/Operations Note appears to have occurred on FD6. This anomaly caused eventual loss of the MAGR function, but the conditions was corrected by performing the procedures documented in the Operations Notes. It is anticipated that the recorded MAGR PGSC data will confirm this second anomaly.

DTO 805 Crosswind Landing Performance (DTO of Opportunity) - Data were received on the heads-up-display tape and the slip angle indicated crosswinds gusting up to 7 knots, but not during the period just before touchdown and from touchdown through derotation. Final reconstruction of the data determined insignificant additional information to obtain lateral directional handling qualities at landing.

DETAILED SUPPLEMENTARY OBJECTIVES

DSO 490B - Bioavailability and Performance Effects on Promethazine During Space Flight - In-flight activities were accomplished as planned. The results of the postflight analysis will be reported in separate documentation.

DSO 493 - Monitoring Latent Virus Reactivation & Shedding - In-flight activities were accomplished as planned; results will be reported after post flight analysis is complete.

DSO 498 - Space Flight and Immune Function - Tests were performed with the crew preflight and postflight. The results for this process will be reported in separate documentation.

DSO 499 - Eye Movements and Motion Perception Induced by Off-Vertical Axis Rotation (OVAR) - Tests were performed with the crew preflight and postflight. The results for this process will be reported in separate documentation.

DSO 500 - Space Flight Induced Reactivation of Latent Epstein-Barr Virus - Preflight and postflight tests were performed with the crew. The results of this process will be reported in separate documentation.

DSO 503-S - Test of Midodrine as a Countermeasure Against Postflight Orthostatic Hypotension -Preflight and postflight tests were performed with the crew. The results of this process will be reported in separate documentation.

DSO 632 - Pharmacokinetics and Contributing Physiologic Changes During Space Flight - Preflight and postflight tests were performed with the crew. The results of this process will be reported in separate documentation.

DSO 634 - Sleep/Wake Actigraphy and Light Exposure During Space Flight - In-flight activities were accomplished as planned; results will be reported after postflight analysis is completed.

PHOTOGRAPHY AND TELEVISION ANALYSIS

The launch videos and films were reviewed and evaluated following the STS-113 launch and no anomalous events or conditions were noted.

In addition, films from the 35mm umbilical well camera, the 16mm umbilical camera as well as the hand-held 35mm cameras onboard the Orbiter provided good coverage of the ascent and ET after separation. No anomalous conditions were noted. However, in the 35mm hand-held photography of the ET, the ET was backlit by the Sun and analysis of the ET was not possible from that film.

No anomalous events were noted in the review of the landing videos. All aspects of the landing appeared to be normal.

TABLE 1. - STS-113 SEQUENCE OF EVENTS

EVENT	DESCRIPTION	ACTUAL
APU Activation	APU-1 GG chamber pressure APU-2 GG chamber pressure APU-3 GG chamber pressure	328:00:44:58.535 328:00:45:03.259 328:00:45:06.779
*SRB HPU Activation	LH HPU System A start command LH HPU System B start command RH HPU System A start command RH HPU System B start command	328:00:49:19.001 328:00:49:19.161 328:00:49:19.321 328:00:49:19.381
*Main Propulsion System Start	ME-3 Start command accepted ME-2 Start command accepted ME-1 Start command accepted	328:00:49:40.461 328:00:49:40.584 328:00:49:40.711
*SRB Ignition Command (Liftoff)	SRB Ignition command	328:00:49:47.021
*Throttle to 104.5 Percent	ME-3 Command accepted ME-1 Command accepted ME-2 Command accepted	328:00:49:50.841 328:00:49:50.850 328:00:49:50.863
*Throttle to 99 Percent	ME-3 Command accepted ME-1 Command accepted ME-2 Command accepted	328:00:50:04.921 328:00:50:04.931 328:00:50:04.944
*Throttle to 72 Percent	ME-3 Command accepted ME-1 Command accepted ME-2 Command accepted	328:00:50:20.122 328:00:50:20.131 328:00:50:20.144
*Throttle to 104.5 Percent	ME-2 Command accepted ME-3 Command accepted ME-1 Command accepted	328:00:50:33.242 328:00:50:33.251 328:00:50:33.264
Maximum Dynamic Pressure	Derived ascent dynamic performance	328:00:50:47
*Both RSRMs Chamber Pressure at 50 psi	LH RSRM chamber pressure RH RSRM chamber pressure	328:00:51:46.341 328:00:51:46.461
*End RSRM Action Time	LH RSRM chamber pressure RH RSRM chamber pressure	**
*SRB Physical Separation	LH APU B turbine speed - LOS	328:00:51:51.265
SRB Separation Command	SRB separation command flag	328:00:51:52
OMS Assist Maneuver ignition	Left engine bi-prop valve position Right engine bi-prop valve position	328:00:52:01.6 328:00:52:01.6
OMS Assist Maneuver Cutoff	Left engine bi-prop valve position Right engine bi-prop valve position	328:00:53:24.0 328:00:53:24.0
*Throttle Down for 3g Acceleration	ME-3 Command accepted ME-1 Command accepted ME-2 Command accepted	328:00:57:10.209 328:00:57:10.222 328:00:57:10.228
3g Acceleration	Total load factor	320:00:57:23.6
*Throttle Down to 67 Percent for Cutoff	ME-3 Command accepted ME-1 Command accepted ME-2 Command accepted	328:00:58:03.650 328:00:58:03.663 328:00:58:03.669
*SSME Shutdown	ME-3 Command accepted ME-1 Command accepted ME-2 Command accepted	328:00:58:09.930 328:00:58:09.943 328:00:58:09.949
MECO	MECO Command Flag MECO Confirmed Flag	328:00:58:11 328:00:58:11
ET Separation	ET separation command flag	328:00:58:32
APU activation	APU-2 GG chamber pressure APU-1 GG chamber pressure APU-3 GG chamber pressure	328:01:04:28.792 328:01:04:48.557 328:01:05:04.831

* Data supplied by Marshall Space Flight Center

** Data not available

TABLE 1. - STS-113 SEQUENCE OF EVENTS

EVENT	DESCRIPTION	ACTUAL
OMS 1 Ignition	Left engine bi-prop valve position Right engine bi-prop valve position	Not Performed – direct insertion trajectory flown
OMS 1 Cutoff	Left Engine bi-prop valve position Right engine bi-prop valve position	
OMS 2 Ignition	Left Engine bi-prop valve position Right engine bi-prop valve position	328:01:27:36.4 N/A
OMS 2 Cutoff	Left Engine bi-prop valve position Right engine bi-prop valve position	328:01:33:16.2 N/A
Payload Bay Doors	Right payload bay door open 1 Left payload bay door open 1	328:02:33:18 328:02:34:37
OMS 3 Ignition	Left Engine bi-prop valve position Right engine bi-prop valve position	328:03:42:06.1 N/A
OMS 3 Cutoff	Left Engine bi-prop valve position Right engine bi-prop valve position	328:03:44:31.1 N/A
OMS 4 Ignition	Left Engine bi-prop valve position Right engine bi-prop valve position	328:17:55:37.3 N/A
OMS 4 Cutoff	Left Engine bi-prop valve position Right engine bi-prop valve position	328:17:57:01.3 N/A
OMS 5 Ignition	Left Engine bi-prop valve position Right engine bi-prop valve position	329:17:26:43.1 N/A
OMS 5 Cutoff	Left Engine bi-prop valve position Right engine bi-prop valve position	329:17:27:23.5 N/A
OMS 6 Ignition	Left Engine bi-prop valve position Right engine bi-prop valve position	329:19:05:47.3 N/A
OMS 6 Cutoff	Left Engine bi-prop valve position Right engine bi-prop valve position	329:19:05:57.7 N/A
Docking Ring Capture	Capture	282:15:16:08
Docking with ISS	Docking ring final position	282:15:32:23
Integrated Truss Segment Grapple	As reported	330:14:59:32.126
Begin First Extravehicular Activity	As reported	330:19:48
End First Extravehicular Activity	As reported	331:02:33
First Reboost Maneuver (1 hr)	As determined in the MER (45 min.)	331:17:10:47
Begin Second Extravehicular Activity	As reported	332:18:36
End Second Extravehicular Activity	As reported	333:00:36
Second Reboost Maneuver (35 min)	As determined in the MER (55 min.)	333:16:50:59
Begin Third Extravehicular Activity	As reported	334:19:24
End Third Extravehicular Activity	As reported	335:02:24
Begin Third Reboost Maneuver	As determined in the MER (45 min.)	335:16:38:47
Undocking Completed	Undock Complete	336:20:04:50
Flight Control Subsystem Checkout		
APU 1 Start	APU-1 GG chamber pressure	337:14:58:30.553
APU 1 Stop	APU-1 GG chamber pressure	337:15:04:12.522
Start RCS Hot-Fire	As reported by the MER	337:15:58:15
End RCS Hot-Fire	As reported by the MER	337:16:04:23
Payload Bay Doors Closed	Left payload bay door closed Right payload bay door closed	338:16:57:14 338:16:59:55
Payload Bay Doors Reopen (1)	Left payload bay door closed Right payload bay door closed	338:21:17:05 338:21:18:25
Payload Bay Doors Reclosed (2)	Left payload bay door closed Right payload bay door closed	340:16:51:13 340:16:52:54

TABLE 1. - STS-113 SEQUENCE OF EVENTS

EVENT	DESCRIPTION	ACTUAL
Payload Bay Doors Opened (2)	Left payload bay door closed	340:18:30:14
	Right payload bay door closed	340:18:32:52
Payload Bay Doors Closed	Left payload bay door closed	341:15:48:14
	Right payload bay door closed	341:15:49:49
APU Activation	APU-2 GG chamber pressure	341:18:26:50.987
	APU-1 GG chamber pressure	341:18:52:58.826
	APU-3 GG chamber pressure	341:18:53:08.111
Deorbit Burn Ignition	Left Engine bi-prop valve position	341:18:31:33.2
	Right engine bi-prop valve position	341:18:31:33.2
Deorbit Burn Cutoff	Right Engine bi-prop valve position	341:18:34:31.3
	Left engine bi-prop valve position	341:18:34:31.4
Entry Interface	Current orbital altitude above ellipsoid	341:19:05:41
Blackout End	Data locked (High sample rate)	No blackout
TAEM	Major mode cold (305)	341:19:30:40
Main Landing Gear Contact	MLG Left-hand inboard tire pressure	341:19:37:13
	MLG right-hand inboard tire pressure	341:19:37:13
Main Landing Gear Weight on Wheels	MLG left-hand weight on wheels	341:19:37:13
	MLG right-hand weight on wheels	341:19:37:13
Nose Landing Gear Contact	NLG right-hand inboard tire pressure	341:19:37:23
Nose Landing Gear at Weight-on-Wheels	NLG weight-on-wheels	341:19:37:23
Drag Chute Deployment	Drag Chute Deployment	341:19:37:24.5
Drag chute jettison	Drag chute jettison	341:19:38:00.1
Wheel stop	Velocity with respect to runway	341:19:38:28
APU Deactivation	APU-1 GG chamber pressure	341:19:58:39.954
	APU-2 GG chamber pressure	341:19:58:49.598
	APU-3 GG chamber pressure	341:19:58:54.331

- * MSFC supplied data
- ** Data not available

TABLE II- STS-113 SPACE SHUTTLE VEHICLE ENGINEERING OFFICE IN-FLIGHT ANOMALY LIST

No.	Title	Reference	Comments
STS-113-V-04	S-Band PA 2 Power Output Low	331:18:46 G.m.t. 03:17:56 MET IPR 115V-0003 SPR 113RF06	<p>At 331:18:46 G.m.t. (03:17:56 MET), the S-band power amplifier (PA) 2 forward output power dropped from 117 watts to an estimated power of 50 watts or less. The power drop resulted in general purpose computer (GPC) 4 issuing a fault summary message (S-BD PA 2 PWR OUTPUT LOW. Instantaneously, the PA 2 reflected power dropped from 6 watts to 2 watts on the lower-left alt (LLA) antenna. There was no change in the PA 2 reflected power when moving from the LLA antenna to the lower left forward (LLF) antenna. Data review revealed a PA 2 temperature increase from 152 to 159 °F at the time of the initial drop in power. Although there was a significant drop in output power, the S-band return link remained locked up and no data were lost. The flight controllers commanded PA 1 on and PA 2 off at 331:19:03 G.m.t. (03:18:13 MET).</p> <p>Additional checkout of S-band PA 2 was performed after separation from the ISS. The signature observed was consistent with that observed on the day of the initial problem. PA 2 had a steady low -output power of approximately 56 watts (specification minimum is 100 watts) and was unaffected by changing S-band transponders and pre-amplifiers. Despite the low output power, S band communications functioned nominally throughout the approximately 30 minute duration of the checkout. The S-band system was returned to PA 1 operation at the end of the test. Although weaker than nominal, PA2 appeared to be a viable backup for the remainder of the flight. This was the second occurrence of the PA causing an annunciation of the fault summary message shown above. The first occurrence was observed on the STS-108 mission</p> <p>KSC: Postflight testing was performed at KSC.</p>
STS-113-V-05	FES Failure Using Primary B Controller	335:23:45 G.m.t. 07:22:55 MET 115V-0005 SPR 113RF05	<p>The flash evaporator system (FES) shutdown at 335:23:45 G.m.t. (07:22:55 MET) during a FES water dump on the primary B controller. After attempts to restart on primary B and then primary A controllers was unsuccessful, ice formation was suspected and the core flush procedure was performed. The core flush was unsuccessful and the system operated nominally on the primary A controller for the remainder of the flight.</p> <p>KSC: Troubleshooting was performed on the FES controller and associated wiring.</p>

DOCUMENT SOURCES

In an attempt to define the official as well as the unofficial sources of data for the STS-113 Mission Report, the following list is provided.

1. Flight Requirements Document
2. Public Affairs Press Kit
3. Customer Support Room (CSR) Daily Reports and Final CSR Report
4. MER Daily Reports
5. MER Mission Summary Report
6. SSVEO In-Flight Anomaly List
7. MER Funny/Problem Tracking List
8. MER Event Times
9. Subsystem Manager Reports/Inputs
10. MOD Systems Anomaly List
11. MSFC Flash and Executive Summary Reports
12. MSFC Event Times
13. MSFC Interim Report
14. Crew Debriefing comments
15. Shuttle Operational Data Book
16. STS-113 Summary of Significant Events
17. Contractor Reports of Subsystem Operation

ACRONYMS AND ABBREVIATIONS

The following is a list of the acronyms and abbreviations and their definitions as these items are used in this document.

ABS	Ammonia Boiler System
APU	auxiliary power unit
ARCTIC	advanced thermoelectric refrigerator/freezer
ARPCS	atmospheric revitalization pressure control system
ARS	atmospheric revitalization system
ATA	ammonia tank assembly
ATCS	active thermal control system
AVIU	audiovisual interface unit
cc	cubic centimeter
CDRA	carbon dioxide removal assembly
CE	cargo element
CEI	contract end item
CETA	crew and equipment translation aid
CO ₂	carbon dioxide
COSMIC	?
CPM	cell performance monitor
CWC	contingency water container
dc	direct current
DDCU	dc to dc control unit
DID	discharge ionization detection
DoD	Department of Defense
ΔP	differential pressure
DSO	Detailed Supplementary Objective
DTO	Developmental Test Objective
ΔV	differential velocity
DVCAM	digital video camera
EATCS	Early active thermal control system
ECLSS	Environmental control life support system
EGT	exhaust gas temperature
EMU	extravehicular mobility unit
EOM	end of mission
E/O	External Tank/Orbiter
EPDC	electrical power distribution and control
ESEM	exchangeable standard electronics module
ET	External Tank
ETV	external television system
EV	extravehicular (crewmember designation during EVA)
EVA	extravehicular activity
EVARM	extravehicular activity radiation monitoring
FBMBT	flexible bearing mean bulk temperature
FCE	flight crew equipment
FCMS	fuel cell monitoring system
FCP	fuel cell powerplant
FCS	flight control system/subsystem

FD	flight day
FES	flash evaporator system
FHRC	flex hose rotary coupler
ft/sec	feet per second
GEI	ground environment instrumentation
GFE	Government furnished equipment
GG	gas generator
G.m.t.	Greenwich mean time
GH ₂	gaseous hydrogen
GN ₂	gaseous nitrogen
GO ₂	gaseous oxygen
GPC	general-purpose computer
GPS	Global Positioning System
GSE	ground support equipment
GUCP	ground umbilical carrier plate
HDP	holddown post
HRF	Human Research Facility
ICD	Interface Control Document
IMU	inertial measurement unit
I _{sp}	specific impulse
ISSPDU	International Space Station power distribution unit
ISS	International Space Station
ITCS	Internal thermal control system
ITS	Integrated Truss Segment
IUA	integrated umbilical assembly
IVA	intravehicular activity
JSC	Johnson Space Center
keas	knots estimated air speed
kg	kilogram
KSC	Kennedy Space Center
kW	kilowatt
kWh	kilowatt/hour
lb	pound
lbm	pound mass
LCC	Launch Commit Criteria
LH ₂	liquid hydrogen
LiOH	lithium hydroxide
LLA	left lower aft (antenna)
LLF	left lower forward (antenna)
LMSO	Lockheed Martin Space Operations
LO ₂	liquid oxygen
LVDT	linear voltage differential transformer
MACE	middeck active control experiment
MADS	modular auxiliary data system
MAGR	miniature air-to-ground receiver
Max q _α	maximum dynamic pressure
MBS	Mobile Base System
MC	midcourse correction (rendezvous maneuver)
MCC	Mission Control Center
MEC	master events controller

MECO	main engine cutoff
MEMS	?
MEPSI	MEMS-based Picosat Inspector (Satellite)
MER	Mission Evaluation Room
MET	mission elapsed time
MILA	Merritt Island Launch Area
MLI	multilayer insulation
MLP	Mobile Launch Platform
Mlbf	million pounds force
MPS	main propulsion system
MSG	Micro-gravity Science Glovebox
MT	Mobile Transporter
mV	millivolts
N ₂	nitrogen
NASA	National Aeronautics and Space Administration
NC1, NC2	circularization maneuvers (rendezvous maneuver)
NC3, NC4	circularization maneuvers (rendezvous maneuver)
nmi	nautical mile
O ₂	oxygen
OAA	Orbiter Access Arm
ODS	Orbiter Docking System
OFI	operational flight instrumentation
OI	operational instrumentation
OMM	Orbiter Major Modification
OMRSD	Operations and Maintenance Requirements and Specifications Document
OMS	orbital maneuvering subsystem
OSVS	Orbiter Space Vision System
OTV	Operation television
OV	Orbiter Vehicle
P1	Port 1
PA	power amplifier
P _c	chamber pressure
PCMCIA	portable computer memory card international adapter
PCA	power controller assembly
PCS	pressure control system/portable computer system
PDC	power distribution controller
PFMI	?
PGBA	Plant Generic Bioprocessing Apparatus
PGME	Propylene Glycol Monomethyl Ether
PGSC	payload and general support computer
PLBD	payload bay door
PMBT	propellant mean bulk temperature
ppCO ₂	partial pressure carbon dioxide
ppm	parts per million
PRSD	power reactant storage and distribution/Prototype Synchrotron Radiation Detector
psia	pound per square inch absolute
PWR	payload water reservoir
QD	quick disconnect
RCS	reaction control subsystem

RMS	Remote Manipulator System
RPC	remote power controller
RPCM	remote power controller module
RPOP	rendezvous proximity operators program
RSRM	Reusable Solid Rocket Motor
RTV	room temperature vulcanizing (material)
RVBM	?
S&A	safe and arm
SDMS	Station Data Management System
SDTO	Station Development Test Objective
SLWT	super lightweight tank
S/N	serial number
SO	starboard zero (truss)
SRB	Solid Rocket Booster
SRSS	Shuttle range safety system
SSME	Space Shuttle main engine
SSRMS	Space Station Remote Manipulator System
SUBSA	?
STS	Space Transportation System
SUPA	Shuttle Urine Pretreat Assembly
SWWMS	Supply and wastewater management system
TAL	TransAtlantic Landing
T-	Time minus minutes to launch
TACAN	Tactical Air Navigation System
TCS	Trajectory control sensor
TEPC	Tissue Equivalent Proportional Counter
Ti	terminal initiation maneuver
TPS	thermal protection system/subsystem
TRRJ	thermal radiator rotary joint
TSM	tail service mast
UHF	Ultrahigh frequency
ULF	Utilization Logistics Flight
Vdc	Volts direct current
VIP	vertical-interval processor
VOX	voice operated
VOZDUKH	Russian carbon dioxide removal system
WCL	water coolant loop
WEDA	?
WRJ	wrist roll joint
WS	work site
WSB	water spray boiler
WVS	wireless video system