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STS-61 SPACE SHUTTLE MISSION REPORT

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ABS: The STS-61 Space Shuttle Program Mission Report summarizes the Hubble Space Telescope (HST) servicing mission as well as the Orbiter, External Tank (ET), Solid Rocket Booster (SRB), Redesigned Solid Rocket Motor (RSRM), and the Space Shuttle main engine (SSME) systems performance during the fifty-ninth flight of the Space Shuttle Program and fifth flight of the Orbiter vehicle Endeavour (OV-105). In addition to the

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SPACE SHUTTLE

MISSION REPORT

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INTRODUCTION

The STS-61 Space Shuttle Program Mission Report summarizes the Hubble Space Telescope (HST) servicing mission as well as the Orbiter, External Tank (ET), Solid Rocket Booster (SRB), Redesigned Solid Rocket Motor (RSRM), and the Space Shuttle main engine (SSME) systems performance during the fifty-ninth flight of the Space Shuttle Program and fifth flight of the Orbiter vehicle Endeavour (OV-105). In addition to the Orbiter, the flight vehicle consisted of an ET designated at ET-60; three SSME's which were designated as serial numbers 2019, 2033, and 2017 in positions 1, 2, and 3, respectively; and two SRB's which were designated BI-063. The RSRMs that were installed in each SRB were designated as 360L023A (lightweight) for the left SRB, and 360L023B (lightweight) for the right SRB.

This STS-61 Space Shuttle Program Mission Report fulfills the Space Shuttle Program requirement as documented in NSTS 07700, Volume VIII, Appendix E. That document requires that each major organizational element supporting the Program report the results of their hardware evaluation and mission performance plus identify all related in-flight anomalies.

The primary objective of the STS-61 mission was to perform the first on-orbit servicing of the Hubble Space Telescope. The servicing tasks included the installation of new solar arrays, replacement of the Wide Field/Planetary Camera I (WF/PC I) with WF/PC II, replacement of the High Speed Photometer (HSP) with the Corrective Optics Space Telescope Axial Replacement (COSTAR), replacement of rate sensing units (RSUs) and electronic control units (ECUs), installation of new magnetic sensing systems and fuse plugs, and the repair of the Goddard High Resolution Spectrometer (GHRS). Secondary objectives were to perform the requirements of the IMAX Cargo Bay Camera (ICBC), the IMAX Camera, and the Air Force Maui Optical Site (AMOS) Calibration Test.

The STS-61 mission was planned as a nominal 11-day mission with two contingency days available should Orbiter contingency operations or weather avoidance be required. The sequence of events for the STS-61 mission is shown in Table I. The official Orbiter Project Office Problem Tracking List is shown in Table II, and the official Government Furnished Equipment (GFE) Problem Tracking List is shown in Table III. In addition, the Integration and Payload in-flight anomalies are referenced in the applicable sections of the report. Appendix A lists the sources of data, both formal and informal, that were used in the preparation of this document. Appendix B provides the definition of acronyms and abbreviations used in this document. All times are given in Greenwich mean time (G.m.t.) as well as mission elapsed time (MET).

The seven-person crew for this fifty-ninth flight of the Space Shuttle Program consisted of Richard O. Covey, Col., U. S. Air Force, Commander; Kenneth Bowersox, Cdr., U. S. Navy, Pilot; Kathryn C. Thornton, Civilian, Mission Specialist 1; Claude Nicollier, Civilian, Mission Specialist 2; Jeffrey A. Hoffman, Civilian, Mission Specialist 3; F. Story Musgrave, M.D., Ph.D., Civilian, Payload Commander and Mission Specialist 4; and Thomas D. Akers, Lt. Col., U. S. Air Force, Mission Specialist 5. STS-61 was the fifth space flight for Mission Specialist 4 (Payload Commander), the fourth space flight for the

Commander and Mission Specialist 3; the third space flight for Mission Specialist 1 and Mission Specialist 5; and the second space flight for the Pilot and Mission Specialist 2.

MISSION SUMMARY

The countdown for the first launch attempt of STS-61 on December 1, 1993, was scrubbed because the crosswind at the Shuttle Landing Facility (SLF) exceeded the 15-knot limit. The countdown proceeded smoothly up to the T-9 minute hold; however, this hold was continued because of the crosswind condition. Approximately 45 minutes into the hold, the countdown was resumed until the T-5 minute point was reached, after which the hold was reinstated through the end of the launch window. During the extended hold, cloud cover developed over the launch area that violated the 8,000-ft minimum required by Range Operations. The launch was rescheduled for December 2, 1993.

The December 2, 1993, countdown for the second launch attempt proceeded nominally with no unplanned holds. The STS-61 launch occurred at the planned time of 336:09:26:59.983 G.m.t. (04:27 a.m. e.s.t.) on December 2, 1993. There were no significant anomalies during ascent.

Flight evaluation results indicate that all SSME and RSRM start sequences occurred as predicted, and the launch phase performance of the SSMEs, ET, and main propulsion system (MPS) was satisfactory in all respects. SRB separation, entry, deceleration, and water impact occurred as predicted. Both SRBs were successfully recovered and are being refurbished.

The determination of vehicle propulsive performance during ascent was made using vehicle acceleration, and preflight-predicted propulsion data. From these data, the average flight-derived engine specific impulse (Isp), as determined for the time period between SRB separation and start of 3-g throttling, was 452.0 seconds as compared with the tag value of 452.77 seconds.

No orbital maneuvering subsystem (OMS) 1 maneuver was required. The OMS-2 maneuver was initiated at 336:10:10:29.8 G.m.t [00:00:43:29.8 mission elapsed time (MET)]. The 201.5-second maneuver provided a differential velocity (ΔV) of 324.5 ft/sec, and the resulting orbit was 308.4 by 214.9 nmi. During the early part of the firing, the left OMS total quantity indication dropped suddenly to 44.6 percent. Later in the mission during the rendezvous coelliptic maneuver (NSR) at 337:13:11 G.m.t. (01:03:41 MET), the quantity indication returned to proper operation. The indication remained nominal for the remainder of the mission.

The payload bay door opening was completed satisfactorily at 336:10:56:32 G.m.t. (00:01:29:32 MET).

During the first rendezvous phasing maneuver (NC) 1 at 336:14:54:28.9 G.m.t. (00:05:27:28.9 MET), the right OMS helium tank pressure indication (V43P5122C) failed low. This tank has a redundant sensor for this measurement, and data from that measurement were good. At 338:03:21 G.m.t. (01:17:51 MET), just prior to the OMS-6 rendezvous phasing maneuver (NC3), the indication was restored when the right OMS helium isolation valves were opened. The measurement continued to operate properly.

Rendezvous with the HST was completed, and the HST was grappled at 338:08:46:56 G.m.t. (01:23:19:56 MET). Berthing of the HST in the flight service structure (FSS) was completed at 338:09:24:30 G.m.t. (01:23:57:30 MET).

Reaction control subsystem (RCS) thruster L2U was deselected by the redundancy management (RM) at 338:02:34:20 G.m.t. (01:17:07:20 MET). Injector temperatures showed both oxidizer and fuel flow, but no chamber pressure. Due to the telemetry format load (TFL) being used at the time, thruster L2U was in a group of thrusters that had a downlist data rate of one sample/second; therefore, data did not capture the actual pressure.

The first extravehicular activity (EVA) of 7 hours 53 minutes 58 seconds ended with all planned tasks completed. These tasks included replacement of HST RSUs 2 and 3, changeout of the RSU ECUs 1 and 3, replacement of fuse plugs, and preparations for solar array changeout.

The second EVA of 6 hours 35 minutes 30 seconds was successfully completed as planned. The HST solar arrays were replaced and an aliveness test of the new arrays was successfully completed. One of the original solar arrays did not stow properly (partially retracted), and it had to be jettisoned, and the other original solar array was stowed and returned to Earth.

At approximately 340:15:10 G.m.t. (04:05:43 MET), the APU 2 fuel line, fuel pump, and gas generator valve module (GGVM) system A heaters did not turn on at the expected cycle-on temperature of approximately 83°F. The bypass line temperature dropped from 83°F to 66°F over a 6-hour period and reached a steady decay rate of 1°F/hour. The lower fault detection annunciation (FDA) limit for this measurement is 60°F. The crew switched to the B heater at 341:00:06 G.m.t. (04:14:39 MET) prior to reaching the lower limit, and proper operation was observed. Postflight troubleshooting isolated the anomaly to the thermostat.

Upon egress from the airlock by EV3 (Thornton) for the second EVA, EV3 could no longer receive transmissions from in-cabin crewmembers on the 296.8 MHz receiver. However, EV3 could still receive communications from EV4 (Akers) in both communications modes (A and B). As a result, the EVA was continued with EV4 relaying messages to EV3. However, about 3 hours 15 minutes later, EV3 began receiving communications from the Orbiter with no action taken. Near the end of the EVA, Orbiter communications were again lost by EV3. When EV3 switched to hard-line communications in the airlock, EV3 was still unable to receive communications from the Orbiter.

All planned tasks for the third EVA, which was 6 hours 47 minutes 21 seconds in length, were completed. These tasks included installation of the WF/PC II and the replacement of magnetic sensing system (MSS) 1 and 2. In addition, some of the easier tasks planned for the fourth EVA were also completed.

The fourth EVA was 6 hours 50 minutes 52 seconds in duration, and all planned tasks were completed. These tasks included removal of the HSP, installation of the COSTAR and installation of the DF-224 coprocessor. Extravehicular crewmember 3 (EV3) continued to have intermittent communications problems during the fourth EVA, just as experienced in the second EVA. During the periods of intermittent communications, the EV4 crewmember could still communicate with EV3, and as a result, the EVA was continued using the same communications protocol as used during the second EVA.

The HST reboost maneuver was 61 seconds in duration and was performed with forward RCS thrusters F1F, F2F, F3D, and F4D at 343:02:26 G.m.t. (06:16:59 MET). A 321-nmi. circular orbit was achieved as a result of this maneuver.

The fifth EVA was 7 hours 21 minutes in duration, and all planned tasks were performed. Tasks performed during this final EVA included replacement of the Solar Array Drive Electronics (SADE), installation of the GHRS power supply redundancy kit, manual deployment of the primary deployment mechanisms (PDMs) of both solar arrays and installation of protective enclosures for both MSSs. The total EVA time for this mission was 35 hours 28 minutes 41 seconds. Following the EVA, the HST solar-array secondary drive mechanisms (SDMs) were deployed, battery charging was completed, and both high-gain antennas were deployed in preparation for HST release on flight day 9.

Following completion of all servicing tasks, the HST was grappled at 344:07:44:14 G.m.t. (07:22:17:14 MET) and released at 344:10:26:47 G.m.t. (08:00:59:47 MET), about 3 hours later than planned to obtain additional insight into a data interface unit failure in the HST.

Following HST release, two RCS separation maneuvers were performed. The first maneuver was initiated at 344:10:27:21 G.m.t. (08:01:00:21 MET) and had a ΔV of 0.45 ft/sec. The second maneuver was initiated at 344:10:57:23 G.m.t. (08:01:30:23 MET) and had a ΔV of 1.2 ft/sec.

Flight control system (FCS) checkout was performed with all systems operating nominally. APU 1 was started at 346:02:28:37 G.m.t. (09:17:01:38 MET) and operated for 4 minutes 40 seconds, consuming approximately 13 lb of fuel. Hydraulic system 1 performance was also nominal. WSB cooling was not required because of the short APU run time.

The payload bay doors were closed at 347:01:37:41 G.m.t. (10:16:10:41 MET). The deorbit maneuver was performed at 347:04:14:45 G.m.t. (10:18:47:45 MET). The maneuver was approximately 295.2 seconds in duration and the ΔV was 522.8 ft/sec. Entry interface occurred at 347:04:54:39 G.m.t. (10:19:27:39 MET).

The 212,828-lb Orbiter touched down on the Shuttle Landing Facility concrete runway 33 at 347:05:25:37 G.m.t. (10:19:58:37 MET) on December 12, 1993. The Orbiter drag chute was deployed satisfactorily at 347:05:25:41.4 G.m.t., and nose landing gear touchdown occurred 4.6 seconds after drag chute deployment. The drag chute was jettisoned at 347:05:26:07.6 G.m.t. with wheels stop occurring at 347:05:26:26 G.m.t. The rollout was normal in all respects. The flight duration was 10 days 19 hours 58 minutes 37 seconds. All three APU's were powered down by 347:05:44:09 G.m.t. The crew completed the required postflight reconfigurations and departed the Orbiter landing area at 347:06:10 G.m.t.

During the shutdown of the APUs following the postlanding hydraulics load test, an load increase was noted in the APU 3 data, and the load was present until APU 3 was shut down. An increase in the SSME 3 return pressure was also noted during this period. Postflight testing has identified the cause of the conditions. At the time when these conditions were present, the SSMEs were being driven to the rain drain position. The SSME 1 thrust vector control (TVC) actuator was against its hardstop because of the presence of a +10° retraction commmand and the additional retraction of 0.8° caused by thermal gradients. When APU 1 was shut down, the actuator switched to hydraulic system 3 and went into the "chatter" mode. This mode occurs normally when an actuator is lightly into the hardstop. While operating in the "chatter" mode, the actuator power spool oscillates at approximately 50 Hertz, allowing hydraulic fluid to pass from the supply to return. The hydraulic flow rate can be increased as much as 18 gallons/minute in this mode.

The postflight inspection of the payload bay doors revealed a clip that retained the dogbone seal between port payload bay door panels 1 and 2 had broken away from the graphite/epoxy retaining angle.

PAYLOADS

HUBBLE SPACE TELESCOPE SERVICING

Results of the completed HST checkout indicate that all replacement hardware for the HST is operating properly.

The STS-61 payloads consisted of all the stowage hardware and HST hardware that were used in this first servicing mission to the HST, plus the IMAX camera located in the payload bay and the IMAX camera located in the cabin. In addition, more than 200 tools and crew aids were onboard for support of the servicing tasks.

The primary servicing tasks consisted of the following items which are listed in the order of priority:

a. Replace the solar arrays with the improved solar array II, which was designed to eliminate the "jitter" caused by the thermally induced flexing of the original solar arrays. Retraction of the solar arrays was to be completed between EVA 1 and EVA 2. The negative-axis solar array was retracted and stowed satisfactorily; however, the positive-axis solar array was bowed, and this array was only retracted about 30 percent because of the possibility of breakage of the bowed and twisted bistem creating a potential EVA hazard. This solar array replacement task was completed successfully during the second EVA. The unretracted positive-axis solar array was manually jettisoned by an extravehicular crewmember. This jettison provided some of the more dramatic video that was taken during the mission. The retracted solar array was stowed in the cargo bay for return and postflight analysis. The solar arrays were deployed during the fifth EVA with help from the crew in operating the primary deployment mechanisms (PDMs). After the assist from the crew, the solar arrays unfurled nominally, and functional testing of the arrays was completed with satisfactory results prior to release of the HST from the RMS.

b. Replace Rate Sensing Unit 2. This RSU replacement task was completed successfully during the first EVA. The crew experienced some difficulty closing the aft shroud doors after the RSU changeout was completed. However, the initial door latch misalignment was corrected and the doors were successfully closed, latched, and bolted.

c. Replace the WF/PC I with WF/PC II and install four new instrument fuse plugs. The WF/PC and fuse replacements were completed successfully during the third EVA. A satisfactory aliveness test was completed on flight day three, and the satisfactory functional testing of the camera was completed on flight day 6. The camera that was removed from the HST was stowed in the cargo bay for return and subsequent postflight analysis.

d. Replace the High Speed Photometer with the Corrective Optics Space Telescope Axial Replacement. This replacement task was completed successfully during the fourth EVA. Functional testing of the COSTAR was successfully completed prior to the fifth EVA. The HSP was stored in the cargo bay for return and postflight analysis.

e. Install new magnetic sensing system 1. This replacement task was completed successfully during the third EVA. Aliveness tests of the replaced hardware were satisfactory.

f. Replace Rate Sensing Unit 3 along with electronic control unit 3. This task was completed very satisfactorily during the first EVA. After completion of this task along with the RSU 2 replacement and the ECU 1 secondary priority task, satisfactory aliveness and functional tests were performed on the gyros. As a result, the HST has six functioning gyros.

g. Replace the failed Solar Array Drive Electronics 1 assembly with a new Solar Array Drive Electronics package. This SADE replacement task was completed successfully during the fifth EVA. The electronics were used to successfully unfurl the solar arrays.

The secondary servicing tasks consisted of the following items which are listed in order of priority:

a. Install a power supply redundancy kit for the Goddard High Resolution Spectrometer. This installation task was completed successfully during the fifth EVA. The replaced hardware passed the aliveness and functional tests.

b. Install a 386 coprocessor on the HST's DF-224 primary computer. This task was completed successfully during the fourth EVA. Aliveness and functional tests were satisfactorily completed on flight day 7. Subsequent to the coprocessor installation, a downlink communications anomaly occurred. Stored program miscompares were attributed to marginal Ku-band transmission strength. The condition existed before coprocessor installation. Continued testing isolated the fault to the A side of data interface unit 2 (DIU-2), one of four installed onboard the HST. Operations were switched over to the B side and the problem was cleared.

c. Install new magnetic sensing system 2. This replacement task was completed successfully during the third EVA. A satisfactory functional test of the unit was completed.

During the installation operations, the crew recovered two loosened sides from the original MSS-2 instrument. A team of ground personnel was formed to determine if corrective action repairs were required to the newly installed unit to protect the HST from any pieces of degrading foam from the MSS instruments. Protective covers were fabricated by the crew and were placed on the MSS units during the fifth EVA.

d. Install four new 6-ampere gyro fuse plugs in place of the current 3-ampere plugs. This task was completed successfully during the first EVA.

e. Replace electronic control unit 1. This replacement task was also completed successfully during the first EVA. Aliveness and functional testing was completed satisfactorily.

Following completion of all servicing tasks, the HST was grappled and lifted from the FSS, the reaction wheels and safe-mode electronics assembly were activated, and the aperture door was opened. The HST was positioned for release and the pointing system was initialized. HST release occurred at 344:10:26:50 G.m.t. (08:07:59:50 MET). Tip-off rates at release were 0.054 deg/sec, [(V1) 0.041 deg/sec, (V2) 0.003 deg/sec, and (V3) 0.012 deg/sec). The maximum allowable tip-off rate was 0.2 deg/sec.

The HST software sun-point capture occurred within 1 minute 20 seconds of release, and the HST was placed under onboard computer control using ground-generated command loads. All HST systems were operating properly as this report was published.

PAYLOAD SERVICING TOOLS AND CREW AIDS

In excess of 200 tools and crew aids were available for use during the five EVAs to service the HST. Throughout the five EVAs, approximately 40 tools were used; the remainder were available for contingencies, but the other tools were not used.

One of the two JSC-supplied HST power tools failed (Flight Problem STS-61-F-07). Indications are that a switch problem developed in the tool and caused the failure. The other power tool also had a speed setting failure, but the tool remained usable.

IMAX CABIN CAMERA AND IMAX CARGO BAY CAMERA

Both IMAX cameras operated properly throughout the mission and all available film [one roll for the IMAX cargo bay camera (ICBC) and seven rolls for the IMAX cabin camera] was exposed. No IMAX camera problems or anomalies were identified.

The ICBC was installed to film HST servicing operations. The ICBC was mounted in the aft port corner of the payload bay (bay 13). The optical axis of the ICBC was in a fixed position with a yaw of 29.7 degrees from port and a pitch of 30 degrees from the centerline of the payload bay. The ICBC was controlled from the crew compartment using the enhanced Get Away Special (GAS) autonomous payload controller (GAPC) which controlled the camera operation at two speeds (HI at 24 frames per second and LO at 3 frames per second).

The IMAX cabin camera was operated from the middeck, and the camera was used to film scenes of HST activities, crew activities, and some Earth scenes. Within 24 hours of landing, the IMAX cabin camera was offloaded, and the film was rushed to a laboratory for developing. Appendix C contains a more in-depth discussion of the IMAX camera operations and results.

AIR FORCE MAUI OPTICAL SITE

The Air Force Maui Optical Site (AMOS) was unable to acquire any tracking of the Space Shuttle because of cloud cover at the ground site.

VEHICLE PERFORMANCE

SOLID ROCKET BOOSTER/REDESIGNED SOLID ROCKET MOTOR

All SRB subsystems performed properly during the prelaunch testing and countdown for the first launch attempt. Data analysis following this launch attempt showed discrepancies in the APU gas generator bed temperatures between the primary and secondary temperature measurements on both SRBs. Subsequent investigation revealed that these measurements were miswired in the Mobile Launch Platform (MLP). A workaround was implemented for the second launch attempt to provide better heater control, which occurred.

All SRB systems performed as expected during the second countdown. The SRB prelaunch countdown was normal, and no SRB or RSRM Launch Commit Criteria (LCC) or Operational Maintenance Requirements Specification Document (OMRSD) violations occurred.

Field joint heaters operated for 10 hours 50 minutes. The total activation time including the scrubbed launch attempt was 25 hours 11 minutes. Power was applied to the heating element an average of 26 percent of the time to maintain the field-joint temperatures in their normal operating range.

Igniter joint heaters operated for 17 hours 50 minutes. The total activation time including the scrubbed launch attempt was 36 hours 43 minutes. Power was applied to the heating elements an average of 50 percent of the time to maintain the igniter-joint temperatures in their normal operating range.

For this flight, the low flow-rate heated ground purge in the SRB aft skirt was used to maintain the case/nozzle joint and flexible bearing temperatures within LCC ranges. At L-25 minutes, the purge was changed to high flow rate to inert the SRB aft skirt.

Data in the following table indicate that the flight performance of both RSRMs was well within the allowable performance envelopes and was typical of the performance observed on previous flights. The RSRM propellant mean bulk temperature (PMBT) was 72°F at liftoff.

This RSRM set (360L023) experienced a tailoff thrust imbalance of 47 percent of the specification limit, and this was the largest thrust imbalance experienced on any motor set during the Space Shuttle Program. This imbalance has been attributed to a burn-rate difference between the forward and center segments on

RSRM PROPULSION PERFORMANCE

Parameter	Left motor, 80°F		Right motor, 80°F	
	Predicted	Actual	Predicted	Actual
Impulse gates				
I-20, 10^6 lbf-sec	64.96	64.72	64.81	64.89
I-60, 10^6 lbf-sec	173.47	172.09	173.13	173.03
I-AT, 10^6 lbf-sec	296.59	295.64	296.56	296.29
Vacuum Isp, lbf-sec/lbm	268.60	267.50	268.50	268.10
Burn rate, in/sec @ 60°F at 625 psia	0.3659	0.3647	0.3654	0.3654
Burn rate, in/sec @ 72°F at 625 psia	0.3691	0.3677	0.3686	0.3684
Event times, seconds				
Ignition interval	0.232	N/A	0.232	N/A
Web time[a]	110.8	111.7	111.0	110.7
Separation cue, 50 psia	120.6	120.9	120.9	121.4
Action time[a]	122.7	123.2	123.0	123.9
Separation command	125.5	126.7	125.8	126.7
PMBT, °F	72.00	72.00	72.00	72.00
Maximum ignition rise rate, psia/10 ms	90.4	N/A	90.4	N/A
Decay time, seconds (59.4 psia to 85 K)	2.8	3.0	2.8	3.3
Tailoff imbalance Impulse differential, KLBF-sec	Predicted N/A		Actual 876.6[b]	

Note:
[a] All times are referenced to ignition command time except where noted by the letter a. Those items are referenced to lift-off time (ignition interval).
b Impulse imbalance = left motor - right motor

the right-hand motor. During preflight preparation of this motor set, the right-hand forward segment (RSRM-23) was found to have propellant chips in the inhibitor. As a result, the segment was exchanged with a forward segment cast with raw materials for a different set of motors (RSRM-37).

Both SRBs were separated from the External Tank (ET) at T + 126.4 seconds, and reports from the recovery area indicated that the deceleration subsystems performed as designed. Both SRBs were observed during descent and were returned after recovery to Cape Canaveral and in turn, Kennedy Space Center for disassembly and refurbishment.

During the postflight inspection of the RSRM set, a small section of cork (0.5 inch axial by 2.0 inches circumferential by 0.2 inch radial) was missing from the forward edge of the aft ground environment instrumentation (GEI) run at the station 1099, 220° location on the forward center segment of the right-hand motor. Medium to heavy soot was observed on the remaining surface indicating the loss occurred before splashdown. The cork-to-case bond remained intact as evidenced by cork cohesive failure. These observations indicate the cork run was impacted by an unknown object. As a result, an integration in-flight anomaly (Flight Problem STS-61-I-01) has been opened.

EXTERNAL TANK

ET performance was excellent, and all objectives and requirements associated with ET propellant loading and flight operations were met. All ET electrical equipment and instrumentation operated satisfactorily. ET purge and heater operations were monitored and all performed properly. No ET LCC or OMRSD violations were identified.

Typical ice/frost formations were observed on the ET during the countdown. There was no observed ice or frost on the acreage areas of the ET. Normal quantities of ice or frost were present on the LO_2 and LH_2 feedlines and on the pressurization brackets. These observations are acceptable per NSTS 08303. The Ice/Frost "Red Team" reported that no anomalous thermal protection system (TPS) conditions existed on the vehicle. However, a single crack in the TPS occurred where the foam bridges between the vertical strut cable tray and fitting fairing. The crack is a recurring TPS defect caused by joint rotation during tanking and is not a problem.

The ET pressurization system functioned properly throughout engine start and flight. The minimum LO_2 ullage pressure experienced during the ullage pressure slump was 14.0 psid.

The postflight ET impact occurred approximately 74 nmi. uprange of the preflight predicted point.

SPACE SHUTTLE MAIN ENGINE

All SSME parameters were normal throughout the prelaunch countdown and were typical of prelaunch parameters observed on previous flights. Engine "ready" was achieved at the proper time, all LCC were met, and engine start and thrust buildup were normal.

SSME performance during ascent was nominal with all Interface Control Document (ICD) and shutdown transient requirements met. Flight data indicate that SSME performance during mainstage, throttling, shutdown and propellant dump operations was normal. High pressure oxidizer turbopump (HPOTP) and high pressure fuel turbopump (HPFTP) temperatures appeared to be well within specification throughout engine operation. SSME cutoff occurred at T + 511.28 seconds. There were no failures or significant SSME problems noted during the flight.

The data review revealed some items of note which are discussed in the following paragraphs.

The SSME 2 hot gas injection pressure measurement froze at engine start plus 270 seconds. The phenomenon has been observed previously and is attributed to ice formation in the sensing line.

The SSME 1 main-fuel-valve skin-temperature measurements were slow to respond to the liquid temperatures during ascent. These measurements have been trending downward for the last two flights and are believed to be an indication that the gauges are becoming debonded. As a result, the gauges will be replaced during the next flow of this engine.

The SSME 2 HPOTP had an apparent rotor slow-down at engine cutoff plus 2.1 seconds that recovered 0.7 second later. This phenomenon has been observed before on other pumps during ground testing with the cause being attributed to interstage seal rub. Post-test inspections and torque checks of these pumps were acceptable and all of these pumps accumulated additional hot-fire time plus flights with no other anomalies.

Review of the SSME 2 chamber coolant valve actuator (CCVA) checkout module data indicates an upward trend of the channel A - channel B position differential. The data indicate that if the trend continues, the CCVA could violate the checkout limit (1.5 percent) during the next set of checkouts. The flight limit is 3 percent. The recommendation has been made to remove the actuator for analysis. The CCVA was acceptable for flight since it has been very repeatable when chilled. The CCVA performance was the same during this flight as on previous flights.

SHUTTLE RANGE SAFETY SYSTEM

Analysis of the flight data indicates nominal performance of the SRSS. 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 turned off at the appropriate times. All SRSS measurements indicated that the system operated as expected during the countdown as well as the flight. As planned, the SRB S&A devices were safed, and SRB power was turned off prior to SRB separation. Also, the ET system remained active until ET separation from the Orbiter.

The telemetry data indicated that the received signal strength of all five SRSS integrated receiver decoders (IRDs) was always sufficiently high to maintain system operation to SRB separation. After SRB separation, the ET signal strength exceeded the Range Safety minimum requirement of -85 dBm for a duration of 1 second at liftoff plus 386 seconds. The lowest observed ET signal strength was -101.8 dBm. However, the ET IRD bench test data show a command sensitivity of -112.6 dBm and confirm that the ET IRD would have processed commands from SRB separation to ET separation.

ORBITER SUBSYSTEMS

Main Propulsion System

The overall performance of the MPS was as expected with no in-flight anomalies noted. LO_2 and LH_2 loading were performed as planned with no stop-flows or reverts. No OMRSD or LCC violations occurred.

The loading for the first launch attempt was nominal. However, the LH_2 5-percent sensor flashed dry for about 2 minutes as detanking was nearing completion. It then indicated wet for 30 minutes even though the low-level cutoff sensors showed dry. The sensor performed nominally during the second tanking and during ascent. Postflight troubleshooting has noted no Orbiter MPS anomalies.

Throughout the period of preflight operations for the second launch attempt, no significant hazardous gas concentrations were detected. The maximum hydrogen concentration level in the Orbiter aft compartment, which occurred shortly after the start of the LH_2 recirculation pumps, was approximately 126 ppm (corrected). This value compares favorably with previous data for this vehicle.

The LH_2 loading operations were normal through chilldown, slow-fill, fast-fill, topping and replenish. Based on an analysis of loading system data, the LH_2 load at the end of replenish was 231,793 lbm. Compared to the inventory (predicted) load of 231,853 lbm, this assessment yields a difference of -0.03 percent, which is well within the required MPS loading accuracy of $\pm$ 0.37 percent.

The LO_2 loading operations were normal through chilldown, slow-fill, fast-fill, topping and replenish. Based on an analysis of loading system data, the LO_2 load at the end of replenish was 1,387,542 lbm. Compared to the inventory (predicted) load of 1,387,828 lbm, this assessment yields a difference of -0.02 percent, which is well within the required MPS loading accuracy of $\pm$ 0.43 percent.

Ascent MPS performance was completely normal. Data indicate that the LO_2 and LH_2 pressurization systems performed as planned, and that all net positive suction pressure (NPSP) requirements were met throughout the flight. The gaseous hydrogen (GH_2) flow control valves (FCVs) performed nominally with eight cycles on FCV 1 and 2 and 42 cycles on FCV 3.

One MPS-unique configuration change was instituted for STS-61. The MPS LO_2 bleed check valves were redesigned and flown for the first time. The spring between the flappers was replaced with a 30-degree wedge. All three valves performed nominally and closed within 10 seconds as verified by all LO_2 inlet pressures. This valve configuration is presently being installed on all vehicles.

During entry, helium consumption was 57.4 lbm, which is well within the experience base. The LO_2 bleed valves again performed nominally with all valves being closed within 10 seconds.

Reaction Control Subsystem

The RCS performed satisfactorily. Propellant consumption was 4981.1 lbm. The HST reboost maneuver was 61 seconds in duration and was performed with forward RCS thrusters F1F, F2F, F3D, and F4D at 343:02:26 G.m.t. (06:16:59 MET).

One in-flight anomaly occurred when thruster L2U failed off at 338:02:34:20 G.m.t. (01:17:07:20 MET) during the height adjust (NH) maneuver (Flight Problem STS-61-V-03). Thruster L2U was deselected by the RM at the time and remained deselected for the remainder of the mission. Injector temperatures did drop, although less than normal for a full-valve opening, showing both oxidizer and fuel flow. Additionally, the temperatures did not rise above the prefiring temperature, which normally occurs when combustion takes place, and this agrees with the indication of no chamber pressure. Due to the TFL being used at the time, L2U was in a group of thrusters with a downlist data rate of only one sample/second. As a result, data indicating the actual pressure was not captured.

Orbital Maneuvering Subsystem

The OMS performance was satisfactory with six straight-feed firings performed; four with both engines and two with one engine. Total firing time was 603.0 seconds for the left engine and 600.7 seconds for the right engine. A total of 23,048 lbm of propellants was consumed during the mission.
No OMS-1 maneuver was required. The 201.4-second OMS-2 maneuver provided a differential velocity (ΔV) of 324.3 ft/sec. During the early part of the firing, the left OMS total fuel quantity indication suddenly shifted downward to 44.6 percent following the lockout period (Flight Problem STS-61-V-04). Later in the mission during the coelliptic rendezvous maneuver (NSR), the quantity indication returned to proper operation. The indication continued to operate nominally for the remainder of the mission. A similar anomaly occurred on two previous missions, and the anomaly was traced to a damaged wire at pin 1 of the forward fuel probe electronics connector.

The following table shows pertinent details of the six OMS firings.

OMS firing	Engine used	Time, G.m.t./MET	Firing duration, sec	ΔV ft/sec
2	Both	336:10:10:30.2 G.m.t. 00:00:43:30.2 MET	201.4	324.3
3 (NC-1)	Both	336:14:54:28.9 G.m.t. 00:05:27:28.9 MET	59.2	98.0
4 (NSR)	Both	337:13:10:59.7 G.m.t. 01:03:43:59.7 MET	30.0	49.8
5 (NC-2)	Left	337:13:44:14.3 G.m.t. 01:04:17:14.3 MET	17.1	14.1
6 (NC-3)	Right	338:03:22:30.1 G.m.t. 01:17:55:30.1 MET	14.8	12.1
Deorbit	Both	347:04:14:45.2 G.m.t. 10:18:47:45.2 MET	295.3	523.4

During the NC1 rendezvous maneuver (one second after ignition), the right OMS helium tank pressure indication (V43P5122C) dropped from 3550 psia to 130 psia (Flight Problem STS-61-V-02). This tank has a redundant sensor for this measurement, and data from that measurement were good. At 338:03:21 G.m.t. (01:17:51 MET), just prior to the NC3 rendezvous maneuver, the indication was restored when the right OMS helium isolation valves were opened. The measurement continued to operate properly for the remainder of the mission.

Power Reactant Storage and Distribution Subsystem

The performance of the power reactant storage and distribution (PRSD) subsystem was nominal with no known operational problems. A total of 2679 lb of oxygen was used during the mission with 159 lb of that total being used for crew breathing. A total of 317 lb of hydrogen was used by the fuel cells for electrical power generation. The Orbiter landed with 1219 lb of oxygen and 135 lb of hydrogen remaining in the system. A 94-hour mission extension at the average power level of 14.1 kW was possible with the reactants remaining at landing. STS-61 was the first flight of the fifth tank set on this vehicle. Tank sets 4 and 5 were depleted to residual quantities. Tank set 5 was equipped with its own cryogenic control box and a heater control pressure transducer for each tank, thus allowing independent heater operation for tank set 5.

Fuel Cell Powerplant Subsystem

The three fuel cells performed nominally throughout the mission with 3,666 kWh of electrical energy at an average power level of 14.1 kW and average load of 460 amperes being produced. A total of 2520 lb of oxygen and 317 lb of hydrogen was used by the fuel cells during the mission, and 2837 lb of water were produced as the by-product.

Five fuel cell purges were performed, and these occurred at approximately 15, 86, 159, 231, and 252 hours MET. The actual fuel cell voltages at the end of the mission were 0.1 volt above the predicted value for fuel cells 1 and 3, and 0.15 volt above the predicted value for fuel cell 2.

The leakage signature of the check valve in the fuel cell 2 alternate water line was the same as observed on STS-54 and STS-57. Following both prior instances of this problem, the water line check valves were tested for proper crack and reseat pressures and all were within specification.

Auxiliary Power Unit Subsystem

The APUs met all requirements during the mission; however, three anomalies were noted and these are discussed in the final paragraphs of this section. The following table shows the run times for each APU as well as the fuel consumption for each APU.

Flight Phase	APU 1 (S/N 204)		APU 2 (S/N 311)		APU 3 (S/N 410)	
	Time, min:sec	Fuel consumption, lb	Time, min:sec	Fuel consumption, lb	Time, min:sec	Fuel consumption, lb
Ascent	21:47	53	21:30	60	21:59	51
FCS checkout	04:38	13				
Entry[a]	62:08	123	94:11	203	62:09	122
Total[a,b]	88:33	189	115:41	263	84:08	173

Notes:

[a] APU's 1, 2, and 3 ran for 18 minutes, 39 seconds after landing.

[b] Totals include ascent, FCS checkout, entry, and a hydraulic loads test after landing.

STS-61 was the first flight in which a crew procedure change was implemented that moved the APU tank/fuel line water system heater activation to just after APU shutdown following ascent. This change was made to prevent test line temperature fault detection and annunciation (FDA) violations which have occurred on several previous flights. Previous heater activation was about one hour after launch.

A review of the upper and lower FDA thermal limits to incorporate the effects of recent temperature sensor relocations and major modifications to the fuel isolation valve and APU has been completed. When the proposed limit changes are approved, these should avoid the potential nuisance alarms and frequent updates required to change current limits.

The APU 3 X-axis accelerometer data was anomalous during ascent (Flight Problem STS-61-V-01). The X-axis acceleration signal output did not represent the true vibration level of the APU during the last 19 minutes of the 22-minute ascent run. The signal was zero with numerous intermittent spikes primarily in the 0- to 5-g peak-to-peak range. The same signature was seen during entry. The data review from the acceptance test procedure (ATP) and a confidence run revealed the same signature, which indicates a problem with the accelerometer or its wiring in the APU. This APU (S/N 410) does not have a history of high vibration.

At approximately 340:15:15 G.m.t. (04:05:48 MET), the APU 2 fuel line, fuel pump, and gas generator valve module (GGVM) system A heaters did not turn on at the expected cycle-on temperature of approximately 83°F (Flight Problem STS-61-V-05). The bypass line temperature dropped from 83°F to 66°F over a 6-hour period and slowed to a steady decay rate of 1°F/hour. The lower FDA limit for this measurement is 60°F. The crew switched to the system B heater at 341:00:06 G.m.t. (04:14:39 MET), and proper operation was observed. To aid in troubleshooting, the APU 2 fuel line, GGVM and fuel pump heaters were switched to system A at 345:04:15 G.m.t. (08:18:48 MET). The system A heater did not cycle on, and the APU 2 bypass line temperature decreased to 68°F, well below the 83°F turn-on temperature of the heater. Control was switched back to the B heaters. The problem has been isolated to the thermostat.

FCS checkout was performed with all systems operating nominally. APU 1 was started at 346:02:28:37 G.m.t. (09:17:01:38 MET) and operated for 4 minutes 38 seconds, consuming approximately 13 lb of fuel.

During entry, the APU 3 exhaust gas temperature (EGT) 1 data were erratic for 23 minutes of the 62-minute entry run. The data tracked the EGT 2 signature before and after the period of erratic operation.

After APUs 1 and 2 were shut down following landing, an apparently excessive and oscillating hydraulic load was seen imposed on APU 3 during its last six seconds of operation. The excessive load was observed from the APU chamber pressure. The high loading began after APU 1 was shut down when the system 1 hydraulic load was switched to system 3. This APU signature is typical of high loads, but the source of the apparently excessive loading is being analyzed. This anomaly is discussed in more detail in the Hydraulics section of this report.

Hydraulics/Water Spray Boiler Subsystem

Subsystem performance during the mission was nominal. During ascent, WSB 2 had a momentary freeze-up, which allowed the lubrication (lube) oil in APU 2 to reach 286.6°F prior to the initiation of WSB 2 spray cooling. The WSB specification requires spray initiation prior to the lube oil temperature reaching 275°F. The initiation of cooling was followed by a momentary over-cooling down to 212.8°F because of the normal delay in the controller going from high spray rate to normal spray rate as the controller was attempting to compensate for the initial over-temperature condition. Following these events, the WSB performed nominally for the remainder of the mission.

Also during ascent, WSB 3 lube oil outlet temperature reached 261°F prior to the initiation of cooling. This was not considered an over-temperature condition. However, once spraying started, an over-cool to 229°F occurred. This is considered an over-cool given the relatively low lube oil outlet temperature at which cooling started. The WSB performed nominally after the over-cool condition cleared.

During the post-ascent bakeout period, the WSB 1 system A vent heater temperature signature was erratic. After several cycles, a switch was made to the system B heater. Performance of the B heater was nominal. It is possible that ice in the nozzle was causing the erratic response on the A heater. The last cycle of the system A heater after the heater was turned off, but prior to system B control, appeared nominal. The system A heaters were used for flight control system checkout and nominal performance was observed. The erratic performance observed earlier in the mission has been attributed to ice buildup and removal from the vent.

FCS checkout was performed with all systems operating nominally. APU 1 was started at 346:02:28:37 G.m.t. (09:17:01:38 MET). Hydraulic system 1 performance was also nominal. WSB cooling was not required, due to the short APU run time.

After landing, a satisfactory hydraulic loads test was performed before APU shutdown, although an unusually high load was noted on APU 3 during the APU shutdown (Flight Problem STS-61-V-13). This high load appeared when the no. 1 pitch actuator switched from system 1 to system 3 following APU 1 shutdown. A spike was noted in system 3, followed by erratic pressure when no. 1 pitch actuator switched. Simultaneously, system 3 SSME return accumulator pressure increased from 110 psia to 177 psia. In addition, the brake pressure on two modules showed increased pressure (166 to 193 psia). Postflight testing has identified the cause of the conditions. At the time when these conditions were present, the SSMEs were being driven to the rain drain position. The SSME 1 thrust vector control (TVC) actuator was against its hardstop because of the presence of a +10° retraction commmand and the additional retraction of 0.8° caused by thermal gradients. When APU 1 was shut down, the actuator switched to hydraulic system 3 and went into the "chatter" mode. This mode occurs normally when an actuator is lightly into the hardstop. While operating in the "chatter" mode, the actuator power spool oscillates at approximately 50 Hertz, allowing hydraulic fluid to pass from the supply to return. The hydraulic flow rate can be increased as much as 18 gallons/minute in this mode.

Electrical Power Distribution and Control Subsystem

The electrical power distribution and control (EPDC) subsystem performed nominally throughout the mission. The data review and analysis of every available EPDC measurement revealed no problems or anomalies.

Environmental Control and Life Support System

The environmental control and life support system (ECLSS) operated satisfactorily in meeting all mission requirements.

The atmospheric revitalization system (ARS) performed nominally throughout the duration of the flight. No anomalies were reported; however, when cabin pressure was decreased to 10.2 psia, a lower than previously experienced IMU fan ΔP was observed.

It was noted early in the flight that inertial measurement unit (IMU) fan B was operating at a pressure approximately 0.1 inch of water lower than the last flight with the data toggling between a differential pressure (ΔP) of 2.97 and 3.00 inches of water, which is the lower limit for this fan. The fan typically operates at a ΔP of 3.1 inches of water when at a cabin pressure of 10.2 psia. The crew was asked to switch to fan C and the resulting ΔP was 3.08 to 3.11 inches of water. Normal operation is to use fan B and only operate fans A and C during the redundant checkout. The IMU filters were cleaned and this did not improve the ΔP from fan B. Based on the available data, fan B operation was not degraded. The lower-than-expected ΔP is adequately explained by changes to the flow path implemented to support the new HAINS IMUs. The crew switched back to fan B after cabin repressurization.

The ARS avionics bays water coldplate outlet temperatures peaked at 85°F in bay 1, 89.2°F in bay 2, and 77.8°F in bay 3. The avionics bays 1, 2, and 3 air outlet temperatures peaked at 101.5°F, 101.5°F, and 84.5°F, respectively.

The atmospheric revitalization pressure control system (ARPCS) system performed normally throughout the duration of the mission. During the redundant component checkout, the pressure control configuration was switched to the alternate system. Both systems exhibited normal operation. At 337:04:34 G.m.t. (00:19:07 MET), the cabin was depressurized to 10.2 psia to support the planned EVAs. The cabin was repressurized to 14.7 psia at 345:06:46 G.m.t. (08:21:19 MET).

The new configuration oxygen partial-pressure sensors exhibited outstanding performance throughout the flight. The maximum differential seen between any two of the sensors was 0.06 psia, and normally the indicated difference was 0.04 psia.

The active thermal control subsystem (ATCS) operation was satisfactory throughout the mission. The radiator cold-soak provided cooling during entry through touchdown-plus-9-minutes when ammonia boiler system A was activated using the primary/general purpose computer (GPC) controller. This was the first flight of this ammonia boiler system (ABS) unit since replacement of the leaking heat exchanger, and the unit controlled the Freon temperatures to 36 °F.

After landing, the consumables in tank A lasted 42 minutes before the crew switched to Tank B. System B, using the secondary controller, maintained the Freon temperature at 35 °F during its 14 minutes of operation before ground cooling was activated.

At 337:09:59 G.m.t. (01:00:32 MET), the flash evaporator system (FES) shutdown in the topping mode. Although the lack of instrumentation prevents a definite explanation, it is believed that the FES experienced an under-temperature shutdown as the radiator panels cooled down and the radiator flow controller reached its temperature control band. The FES operated nominally for the remainder of the mission.

The supply water and waste management systems performed nominally throughout the mission. Supply water was managed through the use of the FES and the overboard dump systems. The supply water dump line temperature was maintained between 70°F and 99°F throughout the mission with the operation of the line heater. The waste water dump line temperature was maintained between 53°F and 80°F throughout the mission. The vacuum vent line temperature was maintained between 56°F and 81°F, while the nozzle was between 115°F and 190°F.

Two supply water dumps were performed at a cabin pressure of 10.2 psia with excellent results. The tanks were pressurized for the first dump, resulting in an average dump rate of 1.45 percent/minute (2.4 lb/min). The second supply water dump was performed at 345:03:26:00 G.m.t. (08:17:59:00 MET) as part of Development Test Objective (DTO) 1211 with the tanks vented to the 10.2-psia cabin pressure. This dump resulted in an average dump rate of 0.84 percent/minute (1.38 lb/min) while maintaining an excellent spray profile as viewed on the video.

Waste water was gathered at about the predicted rate. Four waste water dumps were performed, with the first three at an average dump rate of 1.79 percent/minute (2.95 lb/min). The fourth waste dump, which was performed serially with the second supply water dump, was a part of DTO 1211 as discussed in the previous paragraph, and the dump rate was 1.16 percent/minute (1.92 lb/min). The waste tank bladder expanded from and indication of 69 percent of full to an indication of 79 percent when depressurized.

The waste collection system performed adequately throughout the mission. During a WCS commode cycle at 345:04:53 G.m.t. (08:19:26 MET), cabin dP/dT measured -0.040 psi/min for 2.5 minutes while at 10.2-psia cabin pressure (which corresponds to approximately 40 lbm/hr at 14.7 psia) (Flight Problem STS-61-V-12). This repressurization lasted approximately 70 seconds longer than a normal WCS/commode repressurization. There was a similar occurrence during a subsequent commode cycle at 345:15:34 G.m.t. (09:06:07 MET) with the cabin at 14.7 psia. In both cases, the leakage stopped when the crew proceeded through normal WCS use per the cue card. The crew was advised about the abnormal signature, and no further occurrences were observed. Symptoms are consistent with repressurization start prior to full vacuum shutoff causing a larger-than-normal volume of air to flow. This condition can be caused by slow operation of the WCS commode control handle.

Smoke Detection and Fire Suppression System

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

Airlock Support System

The airlock depressurization valve was used to reduce the cabin pressure to 10.2 psia for the five planned EVAs. All five EVAs were performed from the airlock with no reported anomalies. The active system monitor parameters indicated normal output throughout the mission.

Avionics and Software Subsystems

The integrated guidance, navigation and control (IGNC) system performed nominally during ascent, on-orbit, and entry. Likewise nominal operations were indicated for the periods of HST capture, HST berthing to the FSS at 90 degrees, HST attached with the FSS at 45 degrees, solar array jettison, HST reboost, and HST deploy. The dynamics during the reboost maneuver supports the existence of a 2-degree error in -X thrust vector that is stated in the Shuttle Operational Data Book (SODB).

The IGNC operation during HST rendezvous was satisfactory based on crew comments and target state vectors, as well as reaching the V-Bar (position on the target's velocity vector with relative rates nulled) with less than planned fuel consumption. The height adjust/phasing (NH/NC) ground-targeted maneuvers were executed yielding the expected results. The maneuver to the -Z target track was also nominal along with the two star tracker passes prior to the corrective combination (NCC) maneuver. After ignition (TIG) for the NCC maneuver, the rendezvous radar locked on to the target and the subsequent radar sensor pass was nominal. The terminal phase initiation (TI) maneuver was executed with the expected results. All of the midcourse correction maneuvers were small and were executed within the expected parameters. Manual operations following ignition for the fourth midcourse correction (MC4) maneuver up through reaching V-Bar were performed according to procedures.

The flight control system (FCS) performance was nominal throughout the mission. The channel 1, 2, and 3 secondary differential pressures for the right inboard elevon actuator (channel 4 was depinned because of the failure of the transducer) indicated nominal performance for this aerosurface. FCS checkout was performed with all systems operating nominally. APU 1 was started at 346:02:28:37 G.m.t. (09:17:01:38 MET) and operated for 4 minutes 38 seconds during the checkout.

Overall performance of the IMU ship set was satisfactory on this first flight of three High Accuracy Inertial Navigation System (HAINS) IMUs. Gyrocompass performance data from all preflight IMU alignments were within specified limits. Remaining launch hold-time based on IMU performance was unlimited. The maximum alignment errors at liftoff were 10 arc seconds in the A and B axes and 30 arc seconds in the C axis. No uplinked changes of the gyro drift were required during the mission, and only one uplink was required for accelerometer compensation. Both of these conditions are indicative of good IMU stability.

The -Z image dissector tube (IDT) star tracker performance was nominal. However, the -Y solid-state star tracker (SSST) (S/N 002) performance was not totally satisfactory as the unit failed to acquire stars for approximately five hours between 340:20:00 G.m.t. (04:10:33 MET) and 341:01:00 G.m.t. (04:15:51:10 MET) (Flight Problem STS-61-V-06). At 341:01:18:10 G.m.t. (04:16:09:10 MET), a series of three star-tracker self-tests failed. At 341:01:22:56 G.m.t. (04:15:55:56 MET), the star tracker was powered off for 10 seconds. Following the power cycle, the star tracker successfully passed an on-orbit self test, and the unit functioned nominally for the remainder of the mission. There have been no previous failures of a solid-state star tracker, and neither type (SSST or IDT) star tracker has ever failed to acquire navigation stars. Initial indications are that a single-event-upset (SEU) occurred because of the high radiation levels at the altitude flown, and the SSST is more susceptible to SEUs than the IDT star tracker.

The data processing system (DPS) hardware and software performed nominally.

The displays and controls met all requirements of the mission; however, minor problems were noted. The crew reported during postsleep activities on flight day 4 that the aft mission timer circuit breaker (CB12 on panel 015) was in the open (tripped) position (Flight Problem STS-61-V-07). The specification lists the maximum dc power required by the timer as 4 watts (0.14 amperes at 28 Vdc), and the timer is the only hardware connected to this circuit breaker. The timer is not instrumented, and fuel cell 2 current data does not conclusively show when the 3-ampere breaker tripped. Failure history of the timer does not indicate any past high-current problems that would trip a breaker. The decision was made to not reset the circuit breaker, although data indicated that a hard short had not occurred. This loss did not affect mission operations.

The Ku-band rendezvous radar range rate/azimuth indicator unit digit did not illuminate (Flight Problem STS-61-V-08). This anomaly was noted during Ku-band antenna stowage prior to the deorbit maneuver; consequently, the loss of this indicator did not impact the mission.

The starboard aft payload bay floodlight failed during payload bay door closure (Flight Problem STS-61-V-11). This light had worked nominally during the EVA portions of the mission. As a result, the loss of this light did not impact the mission in any manner.

Communications and Tracking Subsystem

The communications and tracking subsystem performed nominally throughout the mission. Some minor problems were noted with the closed circuit television (CCTV) cameras, and these are discussed in the following paragraphs.

The CCTV camera A lens became stuck in the zoomed-in position. Attempts by the ground controllers to unstick the lens were unsuccessful. The camera was allowed to warmup and the power was cycled and the camera began operating normally. Later in the mission, the camera zoom capability was again lost, and the camera was allowed to warm up and it operated properly.

The RMS elbow camera exhibited red/blue/green spots at low-light conditions. These spots did not impact camera operations or camera usefulness.

The master timing unit (MTU) built-in test equipment (BITE) word was observed to toggle at irregular intervals, lasting for periods of from 1 to 4 seconds. The toggling bit indicates an excessive frequency difference between the two MTU oscillators. No drift was observed between either of the MTU1 or MTU2 times and the ground site G.m.t. The cause of this problem is believed to be the result of over-sensitive BITE circuitry and/or higher-than-average drift between oscillators. The problem had no impact on the mission.

Operational Instrumentation/Modular Auxiliary Data System

The operational instrumentation and modular auxiliary data system (MADS) operated nominally throughout the mission. Some minor problems were noted and are discussed below, but none of these impacted the mission.

An apparent one-time failure in the logic circuitry of operations recorder 2 occurred at 343:03:31 G.m.t. (06:18:04 MET). This problem is discussed in the GFE section of this report.

At 345:04:32 G.m.t. (08:19:05 MET), in preparation for recording the global positioning system (GPS) DTO (700-8) data, the (MADS) was powered up. The MADS recorder BITE indication failed to go from "FAIL" to "GOOD" when the recorder and master power were switched on (Flight Problem STS-61-V-10). The BITE changed to "GOOD" after the "WB-ON" and "PCM-ON" commands were sent. Subsequent operations of the recorder were nominal. During postflight crew debriefings, the crew reported that the onboard switch had not been placed in the correct position.

Structures and Mechanical Subsystems

The structures and mechanical subsystems performed nominally throughout the mission. No problems were noted; however, the port and starboard payload bay door system 2 drive motors exceeded the File IX in-flight checkout requirement of 63 seconds maximum with drive times of 65 and 66 seconds, respectively.

The inboard tire of the right main gear showed tread wear from the landing. The landing and braking data are presented in the following table.

During the postflight inspection of the payload bay doors, a clip that is used to retain the dogbone between the port payload bay door panels 1 and 2 broke away from the graphite/epoxy retaining angle (Flight Problem STS-61-V-14). The failure resulted in a 1.25 by 0.5 inch missing section of the angle and an area of delamination. The broken section is on panel 2 near the centerline. The retaining angle will be repaired and inspections of all payload bay door expansion joints will be made.

STS-61 was the twelfth flight which used the drag chute. The drag chute was deployed at 347:05:25:41.4 G.m.t., 4.6 seconds prior to nose gear touchdown. The air speed at deployment was 167.4 knots equivalent air speed (keas). Preliminary data indicate nominal drag chute performance, although the chute was offset to the left of the vehicle approximately 3 degrees as demonstrated with previous five-ribbon-out chutes. This drag chute was the standard configuration with five ribbons removed from the canopy. The drag chute was jettisoned at 347:05:26:07.6 G.m.t., 26.2 seconds after deployment.

LANDING AND BRAKING PARAMETERS

Parameter	From threshold, ft	Speed, keas	Sink rate, ft/sec	Pitch rate, deg/sec
Main gear touchdown	2903	200.9	~1.5	n/a
Nose gear touchdown	6635	149.9	n/a	3.04

Braking initiation speed	120.8	knots (keas)
Brake-on time	34.6	seconds (sustained)
Rollout distance	7,911	feet
Rollout time	53.4	seconds
Runway	33	(concrete) at KSC SLF
Orbiter weight at landing	212,828	lb (landing estimate)

Brake sensor location	Peak pressure, psia	Brake assembly	Energy, million ft-lb
Left-hand inboard 1	1236	Left-hand outboard	20.64
Left-hand inboard 3	1224	Left-hand inboard	20.21
Left-hand outboard 2	1248	Right-hand inboard	14.23
Left-hand outboard 4	1236	Right-hand outboard	11.59
Right-hand inboard 1	1032		
Right-hand inboard 3	1032		
Right-hand outboard 2	996		
Right-hand outboard 4	924		

Aerodynamics, Heating, and Thermal Interfaces

The ascent and entry aerodynamics were nominal with no problems or anomalies noted. The aerodynamic and plume heating was nominal during ascent and the aerodynamic heating during descent was also nominal. The prelaunch analysis of the thermal interfaces showed no temperatures in excess of limits. In addition, the gaseous helium and gaseous nitrogen pressures were within limits, and the aft compartment helium concentration was within the experience base.

Thermal Control Subsystem

The performance of the thermal control subsystem was satisfactory during all phases of the mission and all Orbiter subsystem temperatures were maintained within acceptable limits.

At approximately 340:15:15 G.m.t. (04:05:48 MET), the APU 2 fuel line, fuel pump, and GGVM system A heaters did not turn on at the expected cycle-on temperature of approximately 83°F. This problem is discussed in the Auxiliary Power Unit section of this report.

During entry, the APU 3 EGT 1 data were erratic. The problem is discussed in greater detail in the Auxiliary Power Unit section of this report.

Aerothermodynamics

The acreage heating was nominal during entry with all structural temperatures remaining within limits. Also, the structural temperature rise-rates were within the experience base, and TPS damage was within the experience base and less than the average experienced on previous flights.

Thermal Protection Subsystem

The TPS performed satisfactorily throughout the mission based on structural temperature response data, which indicates average entry heating. The overall boundary layer transition from laminar flow to turbulent flow occurred 1215 seconds after entry interface on the forward centerline of the vehicle and 1175 seconds after entry interface on the aft centerline of the vehicle. Based on the data evaluated, the transition was asymmetric from right to left on the vehicle. Transition occurred at 1170 seconds on the right side of the vehicle and at 1265 seconds on the left side of the vehicle.

Overall debris damage was below average. The TPS showed debris impact damage at 120 sites, of which 13 had a major dimension of one inch or greater. This total does not include the numerous hits on the base heat shield attributed to the flame arrestment sparkler system on the mobile launch platform. A comparison of these numbers with statistics from 43 previous missions of the same configuration indicates both the total number of hits and the number of hits one inch or greater was less than average.

The lower surface sustained a total of 59 hits (flight average is 93 hits), of which seven (flight average is 15) had a major dimension of one inch or greater. The distribution of hits on the lower surface does not suggest a single source of debris, but rather indicates a shedding of ice and TPS debris from random sources. The largest tile damage sites measured 5 inches by 1.5 inches by 0.125 inch (right-hand chine area) and 2 inches by 2.5 inches by 0.25 inch deep (left inboard elevon). The shallow depths of these impact sites indicates impacts from low-density objects.

The chin panel gap filler showed some outer mold line (OML) fraying on the left-hand outboard side. The gap between the nose cap and chin panel and the depth of the gap filler were evaluated and accepted for a second flight of that assembly. This marks the first flight of OV-105 where no chin panel assembly will require removal after a flight.

The primary nose landing gear door (NLGD) thermal barrier was in good condition overall with only one torn patch on the right hinge-line. Several tiles on the aft edge of both doors had broken tile lips. Overall, eight NLGD tiles were replaced because of flight damage. The main landing gear door (MLGD) thermal barriers were in good condition overall.

A cluster of 17 hits near the LH_2 ET/Orbiter umbilical was most likely caused by impacts from higher density materials such as ice. The dome-mounted heat shield (DMHS) closeout blanket patches on all three SSMEs were in excellent condition with no material missing. Tiles on the vertical stabilizer stinger and around the drag chute door were intact and undamaged.

ET/Orbiter separation devices EO-1, EO-2, and EO-3 functioned nominally, and all ET/Orbiter umbilical separation ordnance retention shutters were closed properly. No debris was found on the runway beneath the umbilical cavities.

Orbiter windows 3 and 4 were moderately hazed, and only a light haze was present on the other windows. Surface wipes were taken of all windows for laboratory analysis, the results of which will be published in separate documentation.

The postlanding walkdown of the runway resulted in the recovery of all drag chute hardware, which showed no signs of abnormal operation. No organic (bird) debris was found, and two Q-felt plugs, most likely from the base heat shield area, were recovered in the vicinity of the drag chute.

The Shuttle thermal imager was used to measure the Orbiter nose cap reusable carbon carbon (RCC) temperature, which was 200 °F nine minutes after landing. Twenty-four minutes after landing, the right-hand wing leading edge panel 9 RCC was 83 °F and panel 17 was 72 °F.

REMOTE MANIPULATOR SYSTEM

The RMS was utilized extensively during this mission in the retrieval, repair, and redeployment operations of the HST. The RMS maneuvered the HST during retrieval and deploy operations. A suited crewmember using the manipulator foot restraint (MFR) was positioned by the RMS during each of the five EVAs. No RMS problems or anomalies were identified.

During post-insertion activities, the RMS was initialized with the roll-out of the manipulator positioning mechanism (MPM), the release of the shoulder brace and configuration of the system into the GPC temperature monitoring mode. When the arm was deselected [i.e., power to the arm-based electronics (ABE) was removed], an "ABE COMM" message was annunciated. The same message occurred on deselection of the arm after RMS initialization on the previous flight (STS-57) of this arm/manipulator controller interface unit (MCIU) combination, and similar communication glitches have been observed at arm deselection on previous RMS flights. On STS-61, a note was flown for the first time in the Flight Data File that indicates that the messages at arm deselection should be ignored.

The arm was uncradled for the first time in the mission to perform the RMS checkout per the nominal procedures at approximately 337:09:27 G.m.t. (00:18:30 MET). All checkout signatures were nominal. After the checkout, the arm was used to conduct a pre-mission planned CCTV survey of the payload bay and HST FSS. The arm was cradled at about 337:12:30 G.m.t. (00:21:30 MET). Cradling required about 6 minutes 30 seconds from receiving the forward ready-to-latch (RTL) indications to receiving the aft RTL indications. The crew remarked that the recently revised RMS training techniques were helpful in accomplishing the cradling task.

The RMS was equipped with a new generation color CCTV camera at the elbow position and as a result, several planned surveys were revised in real-time to take advantage of the higher quality image the elbow camera provided. In fact, at times, arm positions were modified to favor the use of the elbow camera over the black-and-white RMS wrist camera.

RMS activities began with the the retrieval of the HST on flight day 3. At approximately 338:06:57 G.m.t. (01:21:30 MET), the arm was powered and maneuvered to the HST-capture position. Rendezous maneuvers continued until the Orbiter was positioned within the arm's reach of an HST grapple fixture. Grapple occurred at 338:08:46:56 G.m.t. (01:23:19:56 MET). The arm/HST was maneuvered to a position directly above the FSS, and the HST was berthed in the FSS 35 minutes after capture. The three latches on the FSS were successfully closed and the HST was released by the RMS. CCTV surveys of the HST were conducted using the RMS cameras. At the end of each usage, the arm was placed in a preplanned extended-park position to save set-up time prior to the first EVA.

HST repair activities commenced on flight day 4 with an EVA crewmember-assisted grapple of the MFR by the RMS end effector (EE). An EVA crewmember ingressed the MFR at 339:04:05 G.m.t. (02:18:38 MET). Typical EVA operations during all five EVAs were performed with one EVA crewmember in the MFR on the arm and the other crewmember working from a stationary portable foot restraint (PFR) or a tethered position. At times, however, both crewmembers were translated on the end of the arm to reduce repositioning time between tasks.

Two times during attempts to close the RSU bay doors, messages were received indicating that the elbow pitch brake had slipped more than 0.5 degree. The message can only be received when the RMS brakes are commanded on. During most RMS/EVA activities, the brakes were commanded off and the RMS was in the position-hold mode. Brakes were commanded on during the RSU door-closing effort in an attempt to provide a more stable platform for the MFR-based crewmember; however, the crew reported during postflight debriefings that the stability of the RMS position-hold mode matched the brakes-on mode, with both modes providing a good stable operating base. The brake-slip message was not unexpected and no special action was taken in response to the message. However, subsequent arm operations made less use of the brakes.

After installing the WF/PC, the arm CCTV cameras were used to inspect the WF/PC edge seals, as planned. During the flight day 7 EVA for replacement of the COSTAR, and upon the EVA crewmembers initial movement into the MFR, a message was received that indicated a brake slip at the wrist joint. The crewmember had swiveled at the waist and in stopping, had transferred the inertia of the move into the arm via the MFR. Again, the message was not unexpected and it posed no problem to the operator.

During flight day 8 activities, the arm was maneuvered from extended-park to a position best suited for monitoring the HST with the elbow camera during the RCS reboost maneuver. Following stowage of the MFR, the RMS was returned to the park position for deployment of the HST the following day.

The HST was grappled with the RMS end effector (EE) at 344:07:44:14 G.m.t. (07:22:17:14 MET). Unberthing maneuvers followed immediately with HST release occurring at 344:10:26:47 G.m.t (08:00:59:47 MET). The tip-off rate at HST release was 0.054 deg/sec, and the maximum allowable was 0.2 deg/sec.

The final arm use was the pre-planned RMS CCTV monitoring of the supply and waste water dumps (DTO 1211) on flight day 10. The arm was powered up at 345:02:59 G.m.t. (08:17:32 MET), and the arm was cradled and powered down at 345:06:20 G.m.t. (08:20:53 MET). No further RMS activities were conducted during the mission.

EXTRAVEHICULAR ACTIVITY

SUMMARY

All planned activities for the HST servicing mission were completed very successfully with performance of the five planned EVAs. During these five EVAs, the EMUs performed exceptionally well with no anomalies related to EMU performance noted other than those related to the communications. The five EVAs performed were of the duration shown in the following table. With the completion of these EVAs, the EMUs have completed over 300 hours of satisfactory performance.

Extravehicular Activity	Time, hr:min:sec
First (EV1, EV2)*	07:53:58
Second (EV3, EV4)**	06:35:30
Third (EV1, EV2)	06:47:21
Fourth (EV3, EV4)	06:50:52
Fifth (EV1, EV2)	07:21:00
Total	35:28:41

Note: *EV1 - Hoffman, EV2 - Musgrave
**EV3 - Thornton, EV4 - Akers

INITIAL PREPARATIONS

Preparation for EVA began on flight day 1 when the crew cabin was depressurized from 14.7 psia to 10.2 psia. The checkout of the four EMUs was completed on flight day 2. All EMU parameters were within limits except that noise was heard by EV2 in both communications modes (A and B).

FIRST EXTRAVEHICULAR ACTIVITY

The first EVA was begun with normal communications configurations for both crewmembers with crewmember EV1 in mode A and crewmember EV2 in mode B. The configuration was acceptable and noise was not heard by the EV2 crewmember as had been heard during EMU checkout. The first EVA of 7 hours 53 minutes

58 seconds ended with all planned tasks completed. These tasks included replacement of the HST RSU 2 and 3 and fuse plugs, changeout of ECU 1 and 3, and preparations for solar array changeout.

SECOND EXTRAVEHICULAR ACTIVITY

The second EVA of 6 hours 35 minutes 30 seconds was successfully completed as planned. The HST solar arrays were replaced and an aliveness test of the arrays was successfully completed. The partially deployed solar array that was removed was intentionally jettisoned on-orbit, and the other solar array was stowed for return to Earth.

Shortly after the beginning of the second EVA, during a status check of the EMUs, the sublimator outlet temperature on the EV3 EMU was slightly above the freezing point of water. At the same time, it was noted that the sublimator feedwater pressure was not rising as expected. EV3 stated that during the pre-EVA activity, the feedwater switch had been inadvertently placed to the on position causing water to flow into and through the sublimator. As the EMU approached vacuum, this water froze onto the outside of the sublimator and down the feedwater line causing the unexpected temperature and pressure readings. As time passed during the EVA, the ice sublimated away and the temperature and pressure began reading normally.

At the beginning of repressurization to cabin pressure following the EVA, the EV3 crewmember experienced an ear blockage. Consequently, the repressurization was controlled to a slower than normal rate allowing EV3 to keep her ears clear.

THIRD EXTRAVEHICULAR ACTIVITY

All planned tasks for the third EVA, which was 6 hours 47 minutes 21 seconds in length, were completed. These tasks included installation of the Wide-Field/Planetary Camera II (WF/PC II), and the replacement of the MSS -1 and -2. In addition some of the easier tasks planned for the fourth EVA were also completed.

FOURTH EXTRAVEHICULAR ACTIVITY

The fourth EVA was 6 hours 50 minutes 52 seconds in duration, and all planned tasks were completed. These tasks included removal of the HSP for return to Earth, installation of the COSTAR, and installation of the coprocessor. EV3 continued to have intermittent communications problems during the fourth EVA, just as experienced in the second EVA; however, hard-line communications were available in the airlock during all pre-EVA operations. During the periods of intermittent communications, the EV4 crewmember could still communicate with EV3, and as a result, the EVA was continued using the same communications protocol as used during the second EVA.

FIFTH EXTRAVEHICULAR ACTIVITY

The fifth EVA was 7 hours 21 minutes in duration, and all planned tasks were performed. Tasks performed during this final EVA included replacement of the SADE, installation of the GHRS redundancy kit, manual deployment of the PDMs of both solar arrays and installation of protective enclosures for both MSSs. EV2 once again remained in communications mode A for the duration of the EVA.

FLIGHT CREW EQUIPMENT/GOVERNMENT FURNISHED EQUIPMENT

The flight crew equipment/GFE performed nominally. The following paragraphs discuss problems/anomalies that were noted.

Prior to the first EVA after filling the EMU in-suit drink bag for EMU 2, the bag began leaking from the fill port (Flight Problem STS-61-F-03). An in-flight maintenance (IFM) procedure was used in which the drink straw was inserted into the drink port, the straw was bent, and the straw was then taped to the bag. This IFM was successful in stopping the leak. After filling the second in-suit drink bag prior to EVA 3, it also began leaking and the IFM was successfully used to stop that leak. Following EVA 4, the crew reported that the bags were no longer leaking and the IFM was no longer necessary.

Following the first EVA, the battery charging of the expended EMU batteries was initiated; however, one of the two on-charge indication lights on the first middeck battery charger (S/N 002) was not illuminated (Flight Problem STS-61-F-02). These lights indicate that the batteries are charging properly. The crew switched to the second middeck battery charger (S/N 001), and all indications were nominal.

At the beginning of the second EVA, as EV3 (Thornton) egressed the airlock, EV3 could no longer receive communication transmissions from in-cabin crewmembers in either communications mode A or B (Flight Problem STS-61-F-01). However, EV-3 could still receive communications from EV4 (Akers) in both communications modes (A and B). As a result, the EVA was continued with EV4 relaying messages to EV3. About 3 hours 15 minutes into the EVA, EV3 could receive communications from the Orbiter with no actions having been taken by EV3. Near the end of the EVA, Orbiter communications were again lost by EV3. When EV3 switched to hard-line communications in the airlock, EV3 was still unable to receive communications from the Orbiter. The cause of this anomaly is being investigated.

During EVA 5, the biomedical signal was unavailable for over 90 percent of the EVA. Troubleshooting by the crew following the EVA showed no loose connections (Flight Problem STS-61-F-04). Since the normal real-time data system (RTDS) data were still available (providing oxygen consumption and use-rate data for calculation of metabolic rate), the decision was made to continue the EVA as planned.

The CCTV camera B tilt-motion was hindered by the electrical cable routing on several occasions (Flight Problem STS-61-F-05). Panning the camera successfully freed the tilt motion each time the routing interfered with the camera motion.

An apparent one-time failure in the logic circuitry of operations recorder 2 occurred at 343:03:31 G.m.t. (06:18:04 MET) (Flight Problem STS-61-F-06). When a series of commands was sent to the recorder to change record-speed from 15 ips to 24 ips, the recorder speed indicator discretes changed to 24 ips indicating the command was received. However, the logic circuits failed to actually switch the speed of the recorder until the recorder was commanded to stop, change tracks, and restart about 2.5 hours later. As a result, during a recorder playback through the FM system, with the ground configured to handle data recorded at 24 ips, the modulation was unreadable. A subsequent dump to a ground site configured to handle data recorded at 15 ips was successful. This problem did not recur.

During the fine guidance sensor bay closure, the HST power tool abruptly stopped working (Flight Problem STS-61-F-07). Changing the batteries, as well as cycling the switches, failed to resolve the problem.

The crew noted that the two large in-suit drink bags were missing (Flight Problem STS-61-F-08). Investigation by ground personnel revealed that the two drink bags had not been stowed, and as a result, the two regular size in-suit drink bags were used alternately by the crewmembers for all five EVAs.

During the depressurization to vacuum while at the 5.0 psia hold, EV2 experienced a failed suit leak check (Flight Problem STS-61-F-09). Standard procedures allow the crewmember to perform a second leak check if the first fails. EV2 performed a second leak check successfully and the depressurization continued.

CARGO INTEGRATION

The Orbiter-to-cargo integration hardware performed nominally with no anomalies identified. Immediately prior to flight, an electrical jumper cable was provided to facilitate a contingency IFM, should the payload interrogator/payload data interleaver data inversion problem recur. Nominal system operations were noted and the cable was not used.

DEVELOPMENT TEST OBJECTIVES/DETAILED SECONDARY OBJECTIVES

A total of 13 development test objectives (DTOs) and 12 detailed supplementary objectives (DSOs) were assigned to the STS-61 mission. The results of these DTOs and DSOs will be documented separately.

DEVELOPMENT TEST OBJECTIVES

DTO 301D - Ascent Structural Capability Evaluation - Data were collected on the MADS recorder during ascent. The data were given to the sponsor for evaluation.

DTO 305D - Ascent Compartment Venting Evaluation - Data were collected on the MADS recorder during ascent. The data were given to the sponsor for evaluation. Flight data show profiles similar to the data from the last three flights of OV-105 with no data anomalies present.

DTO 306D - Descent Compartment Venting Evaluation - Data were collected on the MADS recorder during descent. The data were given to the sponsor for evaluation. Plots of flight data did not show any anomalies.

DTO 307D - Entry Structural Capability - Data were collected on the MADS recorder during descent. The data were given to the sponsor for evaluation.

DTO 312 - ET TPS Performance (Methods 1 and 2) (No Maneuver) - Photography for this DTO was obtained using the Hasselblad camera with a 250-mm lens (method 2). A total of 18 frames of the ET was acquired by Mission Specialist 2. Mission Specialist 3 also attempted to obtain usable pictures of the ET; however, this was not successful because of the long distance between the ET and Orbiter. The first time the crew saw the ET was after the Orbiter was maneuvered to the OMS-2 firing attitude. The normal pitch maneuver immediately following ET separation was deleted to conserve RCS propellants for the HST operations. The first picture was taken at approximately 36 minutes MET over eastern Mozambique, and the last picture was taken at approximately 39 minutes MET over northern Madagascar. The ET appears very small in all of the pictures because of the greater distance between the Orbiter and the ET than on most previous missions. No anomalies were visible from the pictures of the ET. A booster separation motor burn scar is visible on the intertank. The orientation and details of the ET were difficult to see because of the great distance at which the photographs were taken.

Most of the umbilical well photography of the ET and SRB was not usable because of the lighting conditions present during the early part of the mission.

DTO 414 - APU Shutdown - After ascent, the APU's were shut down in the order requested (2, 1, 3) with greater than five seconds between each APU shut down. This DTO was performed to aid in determining why an anomalous hydraulics system 3 supply pressure hang-up of about 40 seconds was observed when APU 3 was shut down early during ascent on STS-54. The hang-up was theorized to have been caused by back-driving the hydraulic system 3 rudder speedbrake power drive unit (PDU) motor. No rudder/speedbrake PDU back-driving was noted, and all pressure slope changes correspond to switching valve changes-of-state.

DTO 521 - Orbiter Drag Chute System - The Orbiter drag chute was deployed as planned during the landing rollout. The sponsor has reviewed the data and found no adverse conditions, although the drag chute was offset from the vehicle centerline about 3 degrees.

DTO 648 - Electronic Still Camera Photography Test - An electronic still camera was used extensively throughout the mission to document HST anomalies. The photography is being evaluated.

DTO 656 - Payload General Support Computer (PGSC) Single Event Upset Monitoring (Configuration 1 and 2) - Video from the mission showed the supporting equipment for this DTO in operation. Data have been given to the sponsor for analysis.

DTO 667 - Portable In-Flight Landing Operations Trainer - The portable in-flight landing operations trainer (PILOT) equipment for this DTO was exercised extensively by the Commander and Pilot on the day before entry.

DTO 700-2 - Laser Range and Range Rate Device - The Laser Range and Range Rate device was used during the HST rendezvous activities, solar array jettison, and HST deployment activities. The sponsor is evaluating the data collected during these operations.

DTO 700-8 - Global Positioning System Development Flight Test - Data were collected on the MADS recorder, and these data have been given to the sponsor for evaluation. The results of the evaluation will be documented in separate publications.

DTO 1211 - Waste and Supply Water Dump at 10.2 psia - This DTO was completed and the dumps were video-taped for review by ground personnel. The data are being reviewed by the sponsor, and the results will be documented in a separate publication.

DETAILED SUPPLEMENTARY OBJECTIVES

DSO 326 - Window Impact Observations (Target of Opportunity) - Observations were made for this DSO. These observations were given to the sponsor for analysis.

DSO 469 - In-Flight Radiation Dose Distribution (Configuration 1) - Data were collected from the two crewmember operators for this DSO without incident. The data are used to measure the radiation environment inside the Orbiter, and the types of charged particles and their respective energies. The data have been given to the sponsor for analysis.

DSO 483 - Back Pain Pattern in Microgravity - Data were collected from all seven crewmembers without incident for this DSO on non-EVA days. The data will be used to understand the back pain pattern and height changes as they occur in-flight, as well as etiology of back pain as experienced in microgravity. The data, which are in the form of in-flight logs, have been given to the sponsor for analysis.

DSO 485 - Inter-Mars Tissue Equivalent Proportional Counter (ITEPC) - Data were collected for this DSO, and the data have been given to the sponsor for analysis.

DSO 487 - Immunological Assessment of Crewmembers - Data were collected from all seven crewmembers for this DSO. The data will be used to assess the immune system function using immune cells from the standard blood draws collected during the preflight and postflight physical examinations. The data have been given to the sponsor for evaluation.

DSO 489 - EVA Dosimetry Evaluation - The data were collected without incident from each of the four crewmembers who performed an EVA. Data from this DSO will be used to verify the current EVA radiation exposure measurement system. Each EVA crewmember wore a personal dosimeter under the liquid cooling garment suit. The data have been given to the sponsor for analysis.

DSO 604 - Visual-Vestibular Integration as a Function of Adaptation (OI-3) - The data were collected without incident from three crewmembers for this DSO. This DSO provides data on the paradoxical illusions which occur during re-adaptation to gravity by measuring the accuracy and strategies of target acquisition during normal head and eye movements during flight. The data have been given to the sponsor for analysis and reporting.

DSO 624 - Cardiovascular Responses to Submaximal Exercise (Ergometer) - Data were collected without incident from four crewmembers for this exercise DSO. This DSO provides data on changes in aerobic capacity by using submaximal exercise testing to correlate preflight and in-flight crew activity with postflight aerobic performance. The data will assist in the development of optimal exercise prescriptions and countermeasures to prevent decrements in the nominal cardiorespiratory response and muscle performance. The data have been given to the sponsor for analysis.

DSO 626 - Cardiovascular Responses to Standing Postflight - Postflight data were collected without incident from all crewmembers for this DSO. Data for this DSO characterizes the integrated responses of arterial pressure control systems to standing before and after space flight. The data have been given to the sponsor for analysis.

DSO 901 - Documentary Television - Video tapes were made of all documentary television activities, and all requirements of this DSO were met. The tapes have been returned to the sponsor for evaluation.

DSO 902 - Documentary Motion Picture Photography - All planned documentary motion picture photography objectives were completed. The film has been processed and given to the sponsor for evalution.

DSO 903 - Documentary Still Photography - All planned documentary still photography objectives were completed. The film has been processed and given to the sponsor for evaluation.

PHOTOGRAPHY AND TELEVISION ANALYSES

LAUNCH PHOTOGRAPHY AND VIDEO DATA ANALYSIS

On launch day, 24 videos of the liftoff and ascent operations were reviewed; and following launch day, 51 of the 54 expected films were reviewed. Three cameras did not operate. No potential anomalies were identified from the video and film review.

ON-ORBIT PHOTOGRAPHY AND VIDEO DATA ANALYSIS

No analysis of on-orbit video or film was performed during the mission. However, all of the still photography taken during the mission is being reviewed by the sponsor of DSO 903 - Documentary Still Photography.

ENTRY PHOTOGRAPHY AND VIDEO DATA ANALYSIS

Fourteen videos of the landing, in addition to the NASA Select video, were evaluated, and no anomalies were identified.

TABLE I.- STS-61 SEQUENCE OF EVENTS

Event	Description	Actual time, G.m.t.
APU Activation	APU-1 GG chamber pressure	336:09:22:11.76
	APU-2 GG chamber pressure	336:09:22:12.97
	APU-3 GG chamber pressure	336:09:22:14.13
SRB HPU Activation[a]	LH HPU system A start command	336:09:26:32.103
	LH HPU system B start command	336:09:26:32.263
	RH HPU system A start command	336:09:26:32.423
	RH HPU system B start command	336:09:26:32.543
Main Propulsion System Start[a]	Engine 3 start command accepted	336:09:26:52.442
	Engine 2 start command accepted	336:09:26:52.545
	Engine 1 start command accepted	336:09:26:52.685
SRB Ignition Command (lift-off)	SRB ignition command to SRB	336:09:26:59.983
Throttle Up to 100 Percent Thrust[a]	Engine 2 command accepted	336:09:27:04.385
	Engine 3 command accepted	336:09:27:04.402
	Engine 1 command accepted	336:09:27:04.405
Throttle Down to 73 Percent Thrust[a]	Engine 1 command accepted	336:09:27:27.246
	Engine 2 command accepted	336:09:27:27.266
	Engine 3 command accepted	336:09:27:27.282
Throttle Up to 104 Percent Thrust[a]	Engine 1 command accepted	336:09:27:56.846
	Engine 2 command accepted	336:09:27:56.866
	Engine 3 command accepted	336:09:27:56.883
Maximum Dynamic Pressure (q)	Derived ascent dynamic pressure	336:09:28:07
Both SRM's Chamber Pressure at 50 psi[a]	LH SRM chamber pressure mid-range select	336:09:29:00.903
	RH SRM chamber pressure mid-range select	336:09:29:01.263
End SRM Action[a]	LH SRM chamber pressure mid-range select	336:09:29:03.433
	RH SRM chamber pressure mid-range select	336:09:29:04.133
SRB Separation Command	SRB separation command flag	336:09:29:07
SRB Physical Separation[a]	LH rate APU A turbine speed LOS	336:09:29:06.663
	RH rate APU A turbine speed LOS	336:09:29:06.663
Throttle Down for 3g Acceleration[a]	Engine 1 command accepted	336:09:34:29.491
	Engine 3 command accepted	336:09:34:29.492
	Engine 2 command accepted	336:09:34:29.513
3g Acceleration	Total load factor	336:09:34:29.4
Throttle Down to 67 Percent Thrust[a]	Engine 1 command accepted	336:09:35:25.172
	Engine 3 command accepted	336:09:35:25.173
	Engine 2 command accepted	336:09:35:25.194
Engine Shutdown[a]	Engine 1 command accept	336:09:35:31.292
	Engine 3 command accept	336:09:35:31.294
	Engine 2 command accept	336:09:35:31.314
MECO	Command flag	336:09:35:32
	Confirm flag	336:09:35:33

[a]MSFC supplied data

TABLE I.- STS-61 SEQUENCE OF EVENTS (Continued)

Event	Description	Actual time, G.m.t.
ET Separation	ET separation command flag	336:09:35:51
OMS-1 Ignition	Left engine bi-prop valve position	Not performed - direct insertion trajectory flown
	Right engine bi-prop valve position	
OMS-1 Cutoff	Left engine bi-prop valve position	
	Right engine bi-prop valve position	
APU Deactivation	APU-2 GG chamber pressure	336:09:43:43.02
	APU-1 GG chamber pressure	336:09:43:58.87
	APU-3 GG chamber pressure	336:09:43:13.08
OMS-2 Ignition	Right engine bi-prop valve position	336:10:10:30.2
	Left engine bi-prop valve position	336:10:10:30.2
OMS-2 Cutoff	Right engine bi-prop valve position	336:10:13:51.4
	Left engine bi-prop valve position	336:10:13:51.4
Payload Bay Doors Open	PLBD right open 1	336:10:55:13
	PLBD left open 1	336:10:56:33
OMS-3 Ignition	Right engine bi-prop valve position	336:14:54:28.9
	Left engine bi-prop valve position	336:14:54:28.9
OMS-3 Cutoff	Right engine bi-prop valve position	336:14:55:28.5
	Left engine bi-prop valve position	336:14:55:28.5
Cabin Depressurization	Cabin pressure	337:04:34:05
OMS-4 Ignition	Right engine bi-prop valve position	337:13:10:59.7
	Left engine bi-prop valve position	337:13:10:59.9
OMS-4 Cutoff	Right engine bi-prop valve position	337:13:11:30.2
	Left engine bi-prop valve position	337:13:11:30.3
OMS-5 Ignition	Left engine bi-prop valve position	337:13:44:14.3
	Right engine bi-prop valve position	Not Applicable
OMS-5 Cutoff	Left engine bi-prop valve position	337:13:44:31.7
	Right engine bi-prop valve position	Not Applicable

[a]MSFC supplied data

TABLE I.- STS-61 SEQUENCE OF EVENTS (Continued)

Event	Description	Actual time, G.m.t.
OMS-6 Ignition	Right engine bi-prop valve position	338:03:22:30.1
	Left engine bi-prop valve position	Not Applicable
OMS-6 Cutoff	Right engine bi-prop valve position	338:03:22:45.4
	Left engine bi-prop valve position	Not Applicable
Hubble Space Telescope		
Grapple	Payload captured	338:08:46:56
Berth	Payload latch 1A latched ind.	338:09:24:30
Extravehicular Activity		
First		
EMU on Internal Power	EVA LSS battery charge current 1	339:03:44:26
Repressurization	Airlock differential pressure 1	339:11:38:24
Second		
EMU on Internal Power	EVA LSS battery charge current 1	340:03:29:02
Repressurization	Airlock differential pressure 1	340:10:04:32
Third		
EMU on Internal Power	EVA LSS battery charge current 1	341:03:35:44
Repressurization	Airlock differential pressure 1	341:10:23:05
Fourth		
EMU on Internal Power	EVA LSS battery charge current 1	342:03:12:50
Repressurization	Airlock differential pressure 1	342:10:03:42
Fifth		
EMU on Internal Power	EVA LSS battery charge current 1	343:03:27:33
Repressurization	Airlock differential pressure 1	343:10:50:33
Hubble Space Telescope		
Second Grapple	Payload captured	344:07:44:14
Unberth	Payload latch 1A released ind.	344:07:53:11
Release	Payload captured	344:10:26:47
Cabin Repressurization	Cabin pressure	345:06:45:45
Flight Control		
System Checkout		
APU Start	APU-1 GG chamber pressure	346:02:28:37.80
APU Stop	APU-1 GG chamber pressure	346:02:33:16.36
Payload Bay Doors Close	PLBD left close 1	347:01:36:21
	PLBD right close 1	347:01:37:41
APU Activation For Entry	APU-2 GG chamber pressure	347:04:09:51.76
	APU-1 GG chamber pressure	347:04:41:50.40
	APU-3 GG chamber pressure	347:04:42:00.19
Deorbit Maneuver Ignition	Right engine bi-prop valve position	347:04:14:45.2
	Left engine bi-prop valve position	347:04:14:45.2
Deorbit Maneuver Cutoff	Right engine bi-prop valve position	347:04:19:40.5
	Left engine bi-prop valve position	347:04:19:41.1

TABLE I.- STS-61 SEQUENCE OF EVENTS (Concluded)

Event	Description	Actual time, G.m.t.
Entry Interface (400K)	Current orbital altitude above reference ellipsoid	347:04:54:41
Blackout Ends	Data locked at high sample rate	No blackout
Terminal Area Energy Management	Major mode change (305)	347:05:19:13
Main Landing Gear Contact	LH MLG tire pressure RH MLG tire pressure	347:05:25:33 347:05:25:33
Main Landing Gear Weight On Wheels	LH MLG weight on wheels RH MLG weight on wheels	347:05:25:37 347:05:25:37
Drag Chute Deploy	Drag chute deploy 1 CP Volts	347:05:25:41.4
Nose Landing Gear Contact	NLG tire pressure	347:05:25:46
Nose Landing Gear Weight On Wheels	NLG WT on Wheels -1	347:05:25:46
Drag Chute Jettison	Drag chute jettison 1 CP Volts	347:05:26:07.6
Wheels Stop	Velocity with respect to runway	347:05:26:26
APU Deactivation	APU-1 GG chamber pressure APU-2 GG chamber pressure APU-3 GG chamber pressure	347:05:43:57.53 347:05:44:02.83 347:05:44:08.94

TABLE II.- STS-61 ORBITER PROBLEM TRACKING LIST

Number	Title	Reference	Comments
STS-61-V-01	APU 3 X-Axis Accelerometer Data Clipped LEVEL III CLOSURE	336:09:45 G.m.t. IM 61RF05 IPR 59V-0005 PR APU-0104	The APU 3 X-axis accelerometer data was anomalous during ascent. The X-axis acceleration signal output did not represent the true vibration level of the APU. During the last 19 minutes of the 22-minute run, the signal was primarily zero with intermittent spikes in the 0 to 5 g peak-to-peak range. The same signature was seen during entry. This Troubleshooting isolated the problem to a faulty accelerometer. There was no flight impact. KSC: The accelerometer will be removed and replaced.
STS-61-V-02	Right OMS Helium Tank Pressure Indication (V43P5122C) Failed Low LEVEL III CLOSURE	336:15:00 G.m.t. IM 61RF04 IPR 59V-0002	During the phasing maneuver (NC) 1 firing, the right OMS helium tank pressure indication (V43P5122C) failed low. There is a redundant sensor for this tank and data from that sensor remained good. Just prior to the NC3 rendezvous maneuver, the indication was restored when the right OMS helium isolation valves were opened. There was one firing between the firing where the failure occurred and the firing where it recovered. The problem did not recur. KSC: Pod will be removed and troubleshooting will be performed.
STS-61-V-03	RCS Thruster L2U Fail Off	338:02:34 G.m.t. IM 61RF03 IPR 59V-0003	RCS thruster L2U was deselected by RM at 338:02:34:20 G.m.t. when the thruster was being used during the nominal height maneuver. Injector temperatures indicated both oxidizer and fuel flow occurred, but there was no chamber pressure. L2U is among a group of thrusters with a downlist data rate of only 1 sample/second in format 179, therefore, ground data did not capture the actual pressure signature that tripped RM. The thruster was deselected and was not used during the remainder of the mission. KSC: The pod will be removed and the thruster will be replaced.
STS-61-V-04	Left OMS Total Fuel Quantity Incorrect LEVEL III CLOSURE	336:10:11 G.m.t. IM 61RF06 IPR 59V-0004	Approximately 10 seconds into the OMS-2 maneuver, the left OMS total quantity indication dropped suddenly to 45 percent and remained there throughout the firing. During the NSR maneuver at 337:12:11 G.m.t., the proper quantity indication was restored. There was one firing between the firing when the failure occurred and the firing where it recovered. The problem did not recur. KSC: The pod will be removed and troubleshooting will be performed.
STS-61-V-05	APU 2 Fuel Pump/GGVM System A Heater Failure	340:15:10 G.m.t. IM 61RF07 IPR 59V-0006	At approximately 340:15:10 G.m.t., the APU 2 fuel system A heaters did not turn on at the expected cycle-on temperature. Bypass line temperature dropped from 83°F to 66°F over a 6-hour period and reached a steady decay rate of 1.0 deg/hr. The lower FDA for this measurement is 60°F. The crew switched to the B heaters at 341:00:06 G.m.t., and proper operation was observed. The crew switched back to the A heaters later in the mission to aid in troubleshooting and again the heater was failed. The crew then returned to the B heater. KSC: Troubleshooting is complete and the thermostat will be removed and replaced.

TABLE II.- STS-61 ORBITER PROBLEM TRACKING LIST

Number	Title	Reference	Comments
STS-61-V-06	-Y Star Tracker Not Acquiring Stars	340:20:11 G.m.t. IM61RF11	The -Y star tracker (S/N 2) failed to acquire navigation stars for 5 hours between 340:20 and 341:01 G.m.t. At 341:01:18:10 G.m.t., a series of three star tracker self-tests failed when the test star was not acquired. At 341:01:22:56 G.m.t., the star tracker was powered off off for 10 seconds. Following the power cycle, the star tracker successfully passed a self test and functioned nominally for the remainder of the mission. The cause is believed to be a single-event upset, and no special testing will be performed.
STS-61-V-07	Aft Mission Timer Circuit Breaker (CB12) Popped	339:02:50 G.m.t. IPR 59V-0007 IM61RF13	The crew reported after waking on flight day 3 that the aft mission timer was blank and CB 12 on panel 015 was popped out. The decision was made to leave the circuit breaker open. There was no mission impact. KSC: Troubleshooting has failed to repeat the problem or identify any anomalies.
STS-61-V-08	Ku-Band Range Rate/Azimuth Indicator Units Digit Failed Off LEVEL III CLOSURE	346:11:30 G.m.t. IM 61RF08 IPR 59V-0010 PR COMM-0077	During Ku-Band antenna stowage prior to entry, the crew reported that the range rate/azimuth digital display had the units digit fail off. This display is on panel A2 and is used to display the azimuth angle of of the Ku-Band antenna when it is deployed and powered on and can display range rate information when the Ku-Band antenna is operating in the rendezvous radar mode. The crew also reported that the failure light associated with the range/elevation and range rate/azimuth displays illuminated. KSC: The digital display unit has been removed and replaced. The retest is being scheduled.
STS-61-V-09	APU 3 EGT 1 (V46T0342A) Erratic LEVEL III CLOSURE	347:05:06 G.m.t. IM 61RF09 PR APU-0103	Exhaust gas temperature 1 on APU 3 (V46T0342A) was erratic during the entry run of that APU. The temperature indication was erratic for approximately 20 minutes of the 1 hour 2 minute run. The data tracked the EGT 2 indication (V46T0340A) during the first and the last 20 minutes of the run. KSC: The EGT transducer has been removed and replaced.
STS-61-V-10	MADS BITE "FAIL" S/B "GOOD" LEVEL III CLOSURE	345:04:32 G.m.t. IPR 59V-0013	When the MADS recorder was powered up for the GPS DTO, the MADS recorder BITE indication failed to go from "FAIL" to "GOOD" when the crew switched on the recorder master power. The BITE indication changed to "GOOD" after the "WB-ON" and "PCM-ON" commands were sent. Subsequent recorder operations were nominal. Input from the crew at the crew debriefing indicates that the signature was due to the onboard switch configuration. No special testing is planned.
STS-61-V-11	Aft Starboard Floodlight Failed LEVEL III CLOSURE	347:01:17 G.m.t. IM 61RF10 IPR 59V-0009	The aft starboard payload bay floodlight was confirmed failed during payload bay door closure. There was no evidence of the arcing signature seen during previous floodlight failures. KSC: Troubleshooting will be performed to isolate the problem to the light or FEA.

TABLE II.- STS-61 ORBITER PROBLEM TRACKING LIST

Number	Title	Reference	Comments
STS-61-V-12	Small Cabin Air Leakage Through WCS	345:04:53 G.m.t.	During a commode cycle at 345:04:53 G.m.t., cabin dp/dt measured -0.040 psi/min for 2.5 minutes. During a subsequent commode cycle at 345:15:34 G.m.t., cabin dp/dt measured -0.052 psi/min. The events were 70 and 85 seconds longer than normal WCS/commode repressurizations In both cases, the leakage stopped when the crew proceeded through the normal WCS use per the cue card. Symptoms are consistent with repressurization start prior to full vacuum shut off causing a larger-than-normal volume of air to flow. The WCS has been returned to JSC and checked out. No anomalies were noted. At the WCS debriefing, the crew reported that there were no improper WCS operations.
STS-61-V-13	High Load on APU 3 During Postlanding Shutdown	347:05:44 G.m.t. IM61RF12	During the postlanding shutdown of the APUs, an unexplained load increase was observed on APU 3. APUs 1, 2, and 3 were shut down in that order with approximately 5 seconds between each APU shutdown. The APU 3 load increase, observed following the APU 1 shutdown, remained essentially constant until shutdown. An increase in the SSME 3 return pressure was also noted during the same time period. KSC: Troubleshooting plan has been developed and testing has been scheduled.
STS-61-V-14	Broken Dogbone Retaining Angle	Postflight Inspection IM KB2912 PR STR-1238	A clip used to retain the dogbone between port payload bay door panels 1 and 2 broke away from the graphite/epoxy retaining angle. The failure resulted in a 1.25 by 0.5 inch missing section of the angle and an area of delamination. The broken section is on panel 2 near the centerline. Rockwell-Tulsa personnel will repair the retaining angle. KSC: Inspections of all payload bay door expansion joints and an evaluation of the joint design are planned.

TABLE III.- STS-61 GFE PROBLEM TRACKING LIST

Number	Title	Reference	Comments
STS-61-F-01	EMU 3 Loss of Orbiter Voice	340:03:47 G.m.t.	Upon EVA-2 egress, EMU 3 could not receive transmissions from in-cabin crewmembers while EMU 3 was using communications mode A or B. EVA crewmembers chose to relay messages between the two crewmembers rather than using the backup communications mode. About 3 hours 10 minutes into the EVA (340:06:45 G.m.t.), EMU 3 reception was restored with no action. Later, EMU 3 reception was lost again. EMU 3 was still unable to receive when hooked up hardline in the airlock. Similar problems were experienced with EMU 3 communications during EVA 4.
STS-61-F-02	Middeck Battery Charger (S/N 002) In-Charge Indiction Failure LEVEL III CLOSURE	339:15:24 G.m.t.	The crew reported anomalous behavior when using one of the two middeck battery chargers (S/N 002) following EVA 1. With both batteries connected and powered up, both green lights came on for approximately 5 seconds (which is nominal). However, after the green lights extinguished, only one of the two red lights came on. Each of the red lights indicates that the associated battery is charging. The crew switched to the S/N 001 middeck battery charger which operated nominally. The S/N 002 battery charger was stowed.
STS-61-F-03	In-Suit Dring Bags Leaking From Fill Port	338:12:24 G.m.t.	Prior to EVA 1 after filling the EMU in-suit drink bag for EMU 2, the bag began leaking from the fill port. After filling the other drink bag prior to EVA 3, the second bag also developed a similar leak. An IFM consisting of inserting a drink straw into the port, bending the straw, and taping it to the bag was successfully used for EVAs after each leak was discovered. After EVA 4, the crew reported that the bags were no longer leaking and the IFM was no longer necessary.
STS-61-F-04	EV2 Intermittent Loss of Biomedical Data LEVEL III CLOSURE	343:12:36 G.m.t.	The biomedical signal for EV2 was unavailable for over 90 percent of EVA 5. Troubleshooting done by the crew after EVA 5 showed no loose connections. Since the RTDS data were still available (which includes oxygen consumption and use rate for calculation of metabolic rate), the decisions was made to continue the EVA as planned.
STS-61-F-05	Camera B Cable Hangup	344:05:30 G.m.t.	CCTV camera B tilt motion was hindered by the electrical cable routing on several occasions. Panning the camera successfully freed the tilt motion on each occurrence.
STS-61-F-06	Operations Recorder 2 Record Speed Incorrect LEVEL III CLOSURE	343:11:29 G.m.t.	During the Operations Recorder 2 playback through the FM system over the MILA ground site, the modulation was unreadable at the site. Telemetry and command track indicated that the data should have been recorded at 24 ips (960 kbps playback). Over the next site, DGS, the ground was configured for 192 kbps playback. The recorder was commanded to playback at 15 ips. The site was then able to process data successfully. The record-speed change was seen on track 4 in a segment recorded at 342:05:11 to 343:05:15 G.m.t.

TABLE III.- STS-61 GFE PROBLEM TRACKING LIST

Number	Title	Reference	Comments
STS-61-F-07	HST Power Tool (S/N 1001) Failure LEVEL III CLOSURE	341:06:28 G.m.t.	During the fine guidance sensor bay closure, the HST power tool abruptly stopped working. Changing the batteries, as well as cycling switches, failed to resolve the problem.
STS-61-F-08	Two In-Suit Drink Bags Not Stowed	338:12:15 G.m.t.	Two large in-suit drink bags (IDBs) were not stowed. The EVA crews shared the two IDBs that were stowed.
STS-61-F-09	EMU 2 Failed 5-psi Leak Check Prior to EVA 5	343:05:00 G.m.t.	EV2 failed the automated leak check performed at 5 psi during airlock depressurization prior to EVA 5. EV2 passed subsequent leak checks prior to continuing the depressurization. Suit performance during EVA 5 was nominal.

TABLE III.- MSFC ELEMENTS PROBLEM TRACKING LIST

Problem/Title	Element	Description	Comments/Status
STS-61-B-01 Right SRB APU (Rock Position) Turbine Wheel Damage	Solid Rocket Booster (USBI) A15802	During refurbishment of the right SRB APU (rock position, S/N 171) at Sundstrand, portions of 62 of the 123 second-stage turbine wheel blades were found missing.	The concern associated with the loss of turbine blades is potential turbine imbalance and subsequent turbine rupture (identified as a criticality 1 failure). However, the most likely result would be similar to that observed on S/N 171, which supported nominal TVC performance on the STS-61 mission. A materials analysis determined that the turbine blade damage was precipitated by a unique machining feature which was present on the second-stage blades of the turbine wheel. The feature introduced a stress riser which accelerated growth of the known cracks. The turbine mapping inspection reports were reviewed for the APUs installed on the STS-60 mission. These reports verified that no unique manufacturing defects existed which could precipitate turbine wheel damage. This IFA was baselined on January 31, 1994, on directive no.S044898. The Level II IFA closure is pending an assigned action to define steps taken during manufacturing/inspections which ensure this problem does no recur. In addition, the Level III PRACA tracking number will be be added to the Flight Problem Report (FPR).
STS-61-I-01 Right RSRM Forward Center Segment Aft GEI Run Missing TPS	Integration (JSC) 360L023B-01	During postflight inspection of the right RSRM forward center segment, missing cork was observed at the forward edge of the aft GEI TPS run (station 1099) at 220 degrees.	The missing cork material measured 0.5 inch axially by 2.0 inch circumferentially by 0.2 inch radially. Evidence of medium-to-heavy sooting on the leading edge of the cork TPS indicated the material was most likely lost during ascent. The RSRM Project determined the loss of cork material was not due to a material and/or processing failure since there was no indication of a cork-to-case failure as experienced on STS-26, further suggesting an ascent debris impact caused the damage. The cork failure mode was confirmed to be cohesive, as the cork-to-case bond (adhesive) passed all pull-strength tests. The remaining cork conditions and noted sooting indicate that some object impacted the subject area during ascent. This problem was presented to the PRCB by the RSRM Project, however, due to the unknown source of the impacting object and vehicle implications, the IFA was assigned to the Space Shuttle Engineering Integration Office at JSC. Appropriate inputs/coordination were made with the MSFC RSRM and SRB offices relative to the resolution of the anomaly. No right-hand SRB debris sources were identified forward of the damage site nor were any unusual debris damage observed on the ORBITER RH lower surface.

TABLE III.- MSFC ELEMENTS PROBLEM TRACKING LIST

Problem/Title	Element	Description	Comments/Status
STS-61-I-01 (Continued)			The vehicle experienced typical prelaunch ice/debris conditions in the acceptable areas such as the feedline brackets and bellows. Review of the ET separation photographs are inconclusive to identify any ET TPS anomalies, since the right upper portion of the ET is not in the camera's field of view. Review of the wind tunnel oil flow data indicated a potential transport mechanism of ice/debris particles from the right side of the ET to the right-hand SRB exists. The Orbiter shock wave causes the flow to be in a downward and outboard direction. Ice particles from the outboard side of the feedline could be transported towards the SRB. It was concluded the the most probable cause of the SRB cork damage resulted from an impact from the random shedding of ice along the right side of the ET (LO2 feedline). The loss of GEI cork during ascent due a debris impact at this location is not considered a debris concern since an impact with the Orbiter lower surface is not expected, and no evidence of a void induced vertical upward transport exists.
STS-61-I-02 Delta Slip Loads on Right SRB Tension HDPs 1 and 2	Integration (JSC)	A postflight HDP loads reconstruction revealed slip loads in posts 1 and 2, just prior to SRB ignition.	The reconstruction indicated slip loads in the Y and Z directions on posts 1 and 2. Approximately 30 to 40 KIPS were experienced in the lateral loads near peak SSME buildup (post 1: Y and Z loads, post 2: Y loads only). There was no slip apparent in any of the axial loads or in any compression posts. Similar tension post loads have occurred flights (STS-27, STS-33, STS-33, and STS-36); however, no slips have been observed since STS-36. Several possible explanations are being considered for this condition: a. Bushing/bearing rotation; b. Bushing/bearing translation; c. HDP installation procedure; d. Moment relief mechanism; and e. Aft skirt dishing. Although this in-flight anomaly was initially assigned to KSC, it was later transferred to the Integration Office at JSC. The SRB Project and USBI personnel will assist in the investigation to coordinate inputs (if any).

DOCUMENT SOURCES

In an attempt to define the official as well as the unofficial sources of data for this mission report, the following list is provided.

1. Flight Requirements Document
2. Public Affairs Press Kit
3. Customer Support Room Daily Reports
4. MER Daily Reports
5. MER Mission Summary Report
6. MER Quick Look Report
7. MER Problem Tracking List
8. MER Event Times
9. Subsystem Manager Reports/Inputs
10. MOD Systems Anomaly List
11. MSFC Flash Report
12. MSFC Event Times
13. MSFC Interim Report
14. Crew Debriefing comments
15. Shuttle Operational Data Book

ACRONYMS AND ABBREVIATIONS

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

ABE	arm-based electronics
AMOS	Air Force Maui Optical Site Alignment Test
APU	auxiliary power unit
ARPCS	atmospheric revitalization pressure control system
ARS	atmospheric revitalization system
ATCS	active thermal control system
ATP	acceptance test procedure
BITE	built-in test equipment
CB	circuit breaker
CCTV	closed circuit television
CCVA	chamber coolant valve actuator
COSTAR	Corrective Optics Space Telescope Axial Replacement
DIU	data interface unit
DMHS	dome-mounted heat shield
DPS	data processing system
DSO	Detailed Supplementary Objective
DTO	Development Test Objective
ΔP	differential pressure
ΔV	differential velocity
ECLSS	Environmental Control and Life Support System
ECU	electronic control unit
EE	end effector
EGT	exhaust gas temperature
EMU	extravehicular mobility unit
EPDC	electrical power distribution and control subsystem
ET	External Tank
EVA	extravehicular activity
EV1	extravehicular crewmember 1 (Hoffman)
EV2	extravehicular crewmember 2 (Musgrave)
EV3	extravehicular crewmember 3 (Thornton)
EV4	extravehicular crewmember 4 (Akers)
FCS	flight control system
FCV	flow control valve
FDA	fault detection annunciation
FES	flash evaporator system
FM	frequency modulation
FSS	Flight Support System
ft/sec	feet per second
g	gravity
GEI	ground environment instrumentation
GFE	Government furnished equipment
GGVM	gas generator valve module
GH_2	gaseous hydrogen
GHRS	Goddard High Resolution Spectrometer
G.m.t.	Greenwich mean time
GPC	general purpose computer
GPS	Global Positioning System
GSE	ground support equipment

HAINS	High Accuracy Inertial Navigation System
HPFTP	high pressure fuel turbopump
HPOTP	high pressure oxidizer turbopump
HSP	High Speed Photometer
HST	Hubble Space Telescope
ICBC	IMAX Cargo Bay Camera
ICD	Interface Control Document
IDT	image dissector tube
IFM	in-flight maintenance
IGNC	Integrated Guidance, Navigation and Control
IMAX	Canadian Camera System
IMU	inertial measurement unit
ips	inches per second
IRD	integrated receiver decoder
Isp	specific impulse
ITEPC	Inter Mars Tissue Equivalent Proportional Counter
JSC	Johnson Space Center
keas	knots equivalent air speed
KSC	Kennedy Space Center
kWh	kilowatt hours
LCC	Launch Commit Criteria
LESC	Lockheed Engineering and Sciences Company
LH_2	liquid hydrogen
LO_2	liquid oxygen
lube	lubrication
MADS	modular auxiliary data system
MC	midcourse correction maneuver
MCIU	manipulator controller interface unit
MECO	main engine cutoff
MET	mission elapsed time
MFR	manipulator foot restraint
MHz	MegaHertz
MLGD	main landing gear door
MLP	Mobile Launch Platform
MPM	manipulator positioning mechanism
MPS	main propulsion system
MSFC	George C. Marshall Space Flight Center
MSS	Magnetic Sensing System
MTU	master timing unit
NASA	National Aeronautics and Space Administration
NCC	corrective combination maneuver
NC	phase adjust maneuver
NH	height adjust maneuver
NLGD	nose landing gear door
nmi.	nautical mile
NPSP	net positive suction pressure
NSR	Coelliptic rendezvous maneuver
NSTS	National Space Transportation System
OML	outer moldline
OMRSD	Operations and Maintenance Requirements and Specifications Document
OMS	orbital maneuvering subsystem
PDM	primary deployment mechanism
PDU	power drive unit
PFR	portable foot restraint

PGSC	Payload General Support Computer
PILOT	Portable In-Flight Landing Operations Trainer
PMBT	propellant mean bulk temperature
ppm	parts per million
PRSD	power reactant storage and distribution
RCC	reusable carbon carbon
RCS	reaction control subsystem
RM	redundancy management
RMS	remote manipulator system
RSRM	Redesigned Solid Rocket Motor
RSU	Rate Sensing Unit
RTDS	real-time data system
RTL	ready-to-latch
S&A	safe and arm
SADE	Solar Array Drive Electronics
SDM	secondary drive mechanism
SEU	single event upset
SLF	Shuttle Landing Facility
S/N	serial number
SODB	Shuttle Operational Data Book
SRB	Solid Rocket Booster
SRSS	Shuttle Range Safety System
SSME	Space Shuttle main engine
SSST	solid-state star tracker
STS	Space Transportation System
TFL	telemetry format load
TI	terminal initiation
TIG	time of ignition
TPS	thermal protection subsystem
VBAR	position on velocity vector with relative rates nulled
WCS	Waste Collection System
WF/PC	Wide Field/Planetary Camera
WSB	water spray boiler

IMAX POST LAUNCH MISSION OPERATION

TITLE: Imax CABIN CAMERA & Imax CARGO BAY CAMERA (ICBC)

ACTUAL LAUNCH DATE AND TIME: The Imax Cameras were flown on the Orbiter, Endeavor (OV-105), on the STS 61 mission. The flight lifted off from KSC at 4:27 a.m. Eastern Standard Time (EST) on December 2, 1994, and landed at KSC at 00:26 a.m. EST on December 13, 1994, after a mission duration of 10 days, 19 hours and 59 minutes.

OBJECTIVE: The objective of the Imax camera system was to film the Hubble Space Telescope (HST) servicing operations. To capture the repair activity from the vantage point of the cabin, seven rolls of film, five exterior and two interior, were used to film scenes of repair and crew activities, as well as some earth scenes. The ICBC was mounted in the aft port corner of the payload bay (bay 13). The optical axis of the ICBC was in a fixed position designed provide the optimum viewing angle to capture the most significant activities of the retrieval and re-deploy of the HST. Footage also was taken of the re-boost of the HST to a higher altitude to increase its orbital longevity.

INITIAL RESULTS: The Cabin film was removed from the Orbiter and rushed to a California laboratory for processing and review. The laboratory personnel commented that the film from this mission was the cleanest of all Imax shuttle missions. The Imax film producer, Graeme Ferguson, reviewed the film and reported it to be sensational. He also confirmed that using "slower" interior film and extra photofloods on this mission greatly reduced the destructive effects of radiation (fogging of film) on the image quality. Overall, response from the crew was that all Imax equipment worked extremely well and problems were non-existent.

NON-PLANNED EVENTS: Operations were nominal.

CURRENT STATUS: At the present time, no further IMAX activity has been planned, STS-61 was the last mission on which the Imax equipment will be used in space.

SIGNIFICANT DATA:

- o Using "slower" interior film and extra photofloods on this mission greatly reduced the destructive effects of radiation on the image quality.

- o The crew wished for an alternative to the GAPC to control ICBC and suggested replacing the existing 60-minute audio tapes (provided by Imax to create an audio record) with longer tapes.

- o The crew stated that many more exceptional shots could have been made if there had been a second ICBC mounted in the forward part of the payload bay.

SUMMARY: The Imax ICBC camera system provided a spectacular view of the retrieval, re-deploy, and finally the re-boost of the HST into a higher orbit. The final ICBC shot captured the closing of the payload bays doors, and the close-out of Imax in space. The Imax In-cabin camera provided sensational footage to record HST repairs, crew activity and earth scenes. All Imax equipment worked well and no problems were encountered, during the STS-61 mission, with all objectives achieved.

JSC- 08288 - STS-61 Space Shuttle Mission Report Distribution List

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