

# **STS-80 SPACE SHUTTLE MISSION REPORT**

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February 1997



**National Aeronautics and  
Space Administration**

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

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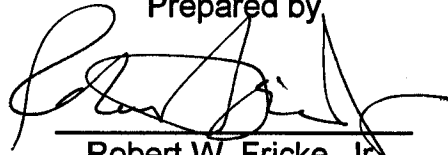
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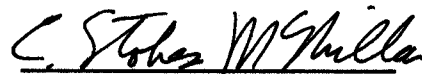
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MISSION REPORT

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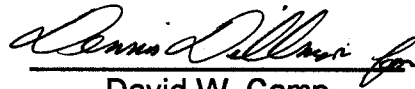


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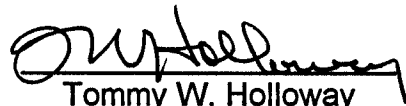
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## INTRODUCTION

The STS-80 Space Shuttle Program Mission Report summarizes the Payload activities as well as the Orbiter, External Tank (ET), Solid Rocket Booster (SRB), Reusable Solid Rocket Motor (RSRM), and the Space Shuttle main engine (SSME) systems performance during the eightieth flight of the Space Shuttle Program, the fifty-fifth flight since the return-to-flight, and the twenty-first flight of the Orbiter Columbia (OV-102). In addition to the Orbiter, the flight vehicle consisted of an ET that was designated ET-80; three Phase-II SSMEs that were designated as serial numbers 2032, 2026, and 2029 in positions 1, 2, and 3, respectively; and two SRBs that were designated BI-084. The RSRMs, designated RSRM-49, were installed in each SRB and the individual RSRMs were designated as 360L049A for the left SRB, and 360L049B for the right SRB.

The STS-80 Space Shuttle Program Mission Report fulfills the Space Shuttle Program requirement as documented in NSTS 07700, Volume VII, Appendix E. The requirement stated in that document is that each organizational element supporting the Program will report the results of their hardware (and software) evaluation and mission performance plus identify all related in-flight anomalies.

The primary objectives of this flight were to perform the operations necessary to fulfill the requirements of the Orbiting Retrievable Far and Extreme Ultraviolet Spectrometer-Shuttle Pallet Satellite (ORFEUS-SPAS) and Wake Shield Facility (WSF). The secondary objectives of this flight were to perform the operations of the Physiological and Anatomical Rodent Experiment/National Institutes of Health-Rodents-04 (PARE/NIH-R-04), the Commercial Materials Dispersion Apparatus (MDA) Instrumentation Technology Associates (ITA) Experiments (CMIX), Space Experimentation Module (SEM)/Get-Away Special (GAS), Visualization in an Experimental Water Capillary Pumped Loop (VIEW-CPL), Extravehicular Activity (EVA) Development Flight Test-05 (EDFT-05), Cell Culture Module - Configuration A (CCM-A), Biological Research in Canister (BRIC), and the Midcourse Space Experiment (MSX) as a payload of opportunity.

The STS-80 mission was planned as a 16-day flight plus two contingency days, which were available for weather avoidance or Orbiter contingency operations. The sequence of events for the STS-80 mission is shown in Table I, and the Orbiter In-Flight Anomaly List is shown in Table II. The Government Furnished Equipment/Flight Crew Equipment (GFE/FCE) Problem Tracking List is shown in Table III. Table IV contains the EVA Equipment Problem Tracking List. Appendix A lists the sources of data, both formal and informal, that were used to prepare this report. Appendix B provides the definition of acronyms and abbreviations used throughout the report. All times during the flight are given in Greenwich mean time (G.m.t.) and mission elapsed time (MET).

The five-person crew for STS-80 consisted of Kenneth D. Cockrell, Civilian, Commander; Kent V. Rominger, Commander, U. S. Navy, Pilot; Tamara E. Jernigan, Ph. D, Civilian, Mission Specialist 1; Thomas D. Jones, Ph. D., Civilian, Mission Specialist 2; and Story Musgrave, M. D., Civilian, Mission Specialist 3. STS-80 was the sixth flight for the Mission Specialist 3; the fourth space flight for Mission Specialist 1; the third space flight for the Commander and Mission Specialist 2; and the second space flight for Pilot.

## MISSION SUMMARY

The STS-80 vehicle was launched at 324:19:55:46.990 G.m.t. (2:55:47 p.m. e.s.t.) on November 19, 1996, after one Launch-Commit-Criteria (LCC) preplanned procedural hold of 2 minutes 47 seconds at T-31 seconds in the countdown. The launch phase was completed satisfactorily, the vehicle was inserted into the planned orbit, and no Operational Maintenance Requirements and Specification Document (OMRSD) violations were noted.

A violation of the aft compartment gaseous hydrogen (GH<sub>2</sub>) concentration LCC limit of 300 ppm occurred during liquid hydrogen (LH<sub>2</sub>) tank prepressurization at T-1 minute 57 seconds (Flight Problem STS-80-V-01). Near the end of the LCC effectivity period at T-31 seconds, a 2-minute hold was called to evaluate the aft hydrogen concentration in accordance with the LCC pre-planned contingency. The aft hydrogen concentration oscillated about the established 600-ppm limit for this time in the countdown as it was monitored by the Kennedy Space Center (KSC) Launch Team. The launch team determined that the data did satisfy the conditions of the pre-planned procedure and the countdown was resumed after a 2-minute 47-second hold. A successful launch followed with no other significant hazardous gas concentrations detected.

All SSME and RSRM start sequences occurred as expected and the launch phase performance was satisfactory in all respects. First stage ascent performance was as expected. SRB separation, entry, deceleration, and water impact occurred as anticipated with no anomalies noted. Second stage performance of the SSMEs, ET, and main propulsion system (MPS) was normal.

A determination of vehicle performance was made using vehicle acceleration and preflight propulsion prediction data. From these data, the average flight-derived engine specific impulse (Isp) that was determined for the time period between SRB separation and start of 3g throttling was 452.4 seconds. The MPS tag value was 452.37 seconds.

No orbital maneuvering subsystem (OMS) 1 maneuver was required. The OMS 2 maneuver was performed at 324:20:36:11.5 G.m.t. [00:00:40:24.5 mission elapsed time (MET)]. The maneuver was 181 seconds in duration and the differential velocity ( $\Delta V$ ) was 279 ft/sec. The vehicle was inserted into an orbit of 190 by 188 nmi.

After main engine cutoff (MECO), all four liquid oxygen (LO<sub>2</sub>) engine cutoff (ECO) sensors flashed dry. This routinely occurs as the vehicle acceleration drops from 3-g to zero-g. Also, SSME shutdown purges at this time (prior to prevalve closure) may have contributed to this condition, as the purges cause some turbulence in the feed system.



Water spray boiler (WSB) 3 failed to provide cooling during ascent. The auxiliary power unit (APU) 3 lubrication oil return temperature reached approximately 298 °F prior to switching to the B controller at 324:20:07:34 G.m.t. (00:00:11:47 MET). The lubrication oil return temperature reached approximately 328 °F prior to spray cooling, which was observed approximately five seconds before APU 3 was shut down. The lubrication oil return temperature was 329.6 °F at shutdown. This condition has been observed on previous flights and did not impact the successful completion of the mission.

Payload bay door opening occurred at 324:21:36:25 G.m.t. (00:01:40:38 MET), with dual-motor times noted. The Ku-band antenna was deployed at 324:22:56 G.m.t. (00:03:00 MET).

The deployment of the ORFEUS-SPAS, using the remote manipulator system (RMS), was successfully accomplished at 325:04:10:50 G.m.t. (00:08:15:03 MET). The arm was cradled, latched, and powered down at 325:05:05 G.m.t. (00:10:09 MET), and the arm was placed in the temperature-monitor mode. RMS performance was nominal.

The ORFEUS-SPAS separation (SEP) -1 maneuver was executed at 325:04:11:48 G.m.t. (00:08:16:01 MET) and had a duration of approximately 14 seconds. The reaction control subsystem (RCS) maneuver was accomplished with six thrusters providing seven pulses during the maneuver. The SEP-2 maneuver was performed at 325:04:44:11 G.m.t. (00:08:48:24 MET) with an approximate duration of 105 seconds using the RCS.

The RMS was uncradled at 325:21:40 G.m.t. (01:01:44 MET) and used to perform the WSF survey for the Orbiter Space Vision System (OSVS) checkout. The RMS was also used for the payload bay survey.

The forward link to the SPAS payload from the Extended Range Payload Communications Link (ERPCL) was lost at approximately 326:11:20 G.m.t. (01:15:24 MET). Since this occurred during a crew-sleep period, a ground-commanded switch from the ERPCL to the Payload Interrogator (PI) was required to regain forward-link command capability. Following the sleep period, the crew performed a frequency sweep, and this reacquired the forward link from the ERPCL to the SPAS. The link performed nominally.

The WSF completed all science objectives with seven of seven growths completed. While awaiting the rendezvous, additional vacuum measurements were made. The vehicle remained very stable throughout its free-flight period. The RMS was powered up and uncradled at 327:19:09 G.m.t. (02:23:13 MET). The WSF was grappled and unberthed at 327:21:00:14 G.m.t. (03:02:04:27 MET), and after the required WSF checkout, the WSF was released at 328:01:37:40 G.m.t. (03:05:41:53 MET).

The arm was cradled, latched, and powered-down at 328:02:40 G.m.t. (03:06:44 MET).

While the ORFEUS-SPAS and WSF were deployed, the ORFEUS-SPAS was closing the distance between the two spacecraft at a faster rate than expected. Mission management was considering retrieving the WSF earlier than planned, but the decision was made to temporarily suspend experiment operations on the ORFEUS-SPAS instead. The ORFEUS-SPAS was then placed in a lower resistance (drag) attitude, thus slowing the rate of closure with the WSF. As a result, the rendezvous safety margins were maintained and early retrieval of the WSF was not required.

The SPAS false-lock to the ERPCL phenomenon recurred following a period where the WSF was being commanded through the ERPCL. The WSF command-plan used the ERPCL for occasional commanding, and this resulted in a disruption of the SPAS forward link when the payload signal processor (PSP) was reconfigured. To avoid this problem, the PI was used to command the SPAS during the WSF free flight, and the ERPCL was used for SPAS telemetry.

At approximately 329:06:45 G.m.t. (04:10:49 MET), the crew downlinked video of a ding in window W8. This condition did not affect the mission.

During the WSF rendezvous, the Ku-band radar locked onto the WSF at a range of 126,650 ft and tracked the WSF to a range of 100 ft. The RMS was powered up and uncradled, and the RMS grappled WSF at 331:02:02 G.m.t. (06:06:06 MET).

The RMS again grappled WSF at 331:02:02:10.7 G.m.t. (06:06:06:23.7 MET) and maneuvered to the WSF hover position at 332:00:07 G.m.t. (07:04:11 MET). The WSF was maneuvered to the atomic oxygen processing (AOPROC) position 20 minutes later, and then to the final AOPROC position. Upon completion of AOPROC activities, the arm moved WSF to the OSVS side-view position, and then to the OSVS top-view position approximately 10 minutes later. The RMS berthed WSF in the payload bay at approximately 331:02:33:51 G.m.t. (06:06:38:04 MET).

A cabin depressurization in preparation for the planned EVAs was completed with a cabin pressure of 10.4 psi at 332:08:42 G.m.t. (07:12:46 MET). The airlock was depressurized at 334:02:04 G.m.t. (09:06:08 MET).

At approximately 334:02:30 G.m.t. (09:06:34 MET), the crew reported that the outer hatch of the airlock could not be unlatched and opened (Flight Problem STS-80-V-02). At 334:03:04 G.m.t. (09:07:08 MET), the airlock was pressurized to 3.84 psia to provide assistance in blowing the hatch thermal cover down so that the external side of the airlock outer hatch could be viewed using the RMS cameras. The RMS was used to support troubleshooting the outer-hatch-opening difficulties. This support included a video survey of the outer hatch and video of attempts to unlatch the outer hatch. At

334:03:59 G.m.t. (09:08:03 MET), the airlock was pressurized to cabin pressure following the decision to delay EVA 1 because of difficulties opening the outer hatch.

The RMS wrist camera was used to perform additional video surveys of the outer hatch. A daylight survey was completed at 334:10:28 G.m.t. (09:14:32 MET) and a night-time survey was completed at 334:11:07 G.m.t. (09:15:11 MET). A more thorough and systematic video survey of the hatch mechanism while the crew was moving the inner handle was also performed. The crew downlinked camcorder video of the inner side of the hatch to demonstrate actual handle travel.

As a result of the uncertainty as to the cause of the external airlock failure-to-open, the decision was made by the Mission Management Team (MMT) to cancel the planned EVAs. The crew module was repressurized to 14.7 psia at 336:11:37 G.m.t. (11:14:41 MET) following the cancellation.

At 338:05:47 G.m.t. (13:09:51 MET), the RMS was used to perform another survey of the outer airlock hatch. Following the survey, the arm was cradled and put in temperature monitor mode.

During the ORFEUS-SPAS rendezvous, the Ku-band radar performed satisfactorily in acquiring the ORFEUS-SPAS satellite at a range of 130,000 feet and tracking the satellite to a range of 86 feet.

The trajectory control sensor (TCS) was activated to support ORFEUS-SPAS rendezvous and commanded to begin auto acquisition at a seed range of 20,000 feet. At approximately 339:07:15 G.m.t. (14:11:19 MET), at a range of 6060 feet, the TCS began tracking the target. The sensor was shutdown by the crew at 339:09:15 G.m.t. (14:13:19 MET). TCS performance was nominal.

At 339:08:25:46 G.m.t. (14:12:29:59 MET), the RMS grappled the ORFEUS-SPAS to conclude the rendezvous and retrieval of the satellite. The RMS then maneuvered the satellite through the relative global positioning system (RGPS) high and low positions. At 339:11:35 G.m.t. (14:15:39 MET), a series of OSVS-related berthing maneuvers was initiated. The final berthing of the satellite was completed at 339:13:13:48 G.m.t. (14:17:18:01 MET) when the payload was latched in the payload bay and released by the RMS. The keel latch trunnion-in-place system 2 indication remained off after latching (Flight Problem STS-80-V-04). This was no concern for entry since latch operation was nominal and the redundant trunnion-in-place indication showed the correct feedback. The RMS was powered down and its tasks were completed for the mission.

At approximately 339:09:22 G.m.t. (14:13:26 MET), shortly after rendezvous with the ORFEUS-SPAS, the inertial measurement unit (IMU) 1 attitude began degrading and the IMU was deselected by the crew (Flight Problem STS-80-V-03). Several built-in test equipment (BITE) messages were

annunciated, and the unit was considered failed. The IMU was taken to standby at 339:10:09 G.m.t. (14:14:13 MET). Following the IMU data review and analysis, the decision was made to power-up IMU 1 because the failure appeared to be intermittent. At approximately 340:04:00 G.m.t. (15:08:04 MET), IMU 1 was transitioned to operate, aligned, and left deselected so that its performance could be monitored.

APU 1 was used to perform the flight control system (FCS) checkout. The APU was started at 340:02:41:27.5 G.m.t. (15:06:45:40.5 MET), ran for 4 minutes 50 seconds, and consumed 15 lb of fuel. All APU and hydraulic system parameters appeared normal during the FCS checkout. Because of the short APU run-time, no WSB cooling was observed.

The RCS hot-fire was performed beginning at 340:03:41 G.m.t. (15:07:45 MET) with each thruster being fired twice. There were no fail-off or fail-leak indications; however, thruster R2U exhibited a slower-than-normal increase in chamber pressure on its first hot-fire pulse, which was also its first firing of the mission. The second pulse was normal, and there were good chamber pressures and injector temperatures on all other thrusters.

The mission was originally planned as a 16-day plus 2 contingency-day flight; however, the mission was extended one day to provide the ORFEUS-SPAS with an opportunity to complete all of their experiment objectives, which were accomplished. Because of weather concerns on December 6 at KSC and Edwards Air Force Base, CA., the MMT made a decision to enter on the originally planned landing day of December 5, 1996. All entry stowage and deorbit preparations were completed in preparation for entry on the nominal end-of-mission landing day.

At 340:08:49:55 G.m.t. (15:12:54:08 MET), the payload bay doors were successfully closed and latched. System performance was nominal.

The landing was not performed because of unacceptable weather conditions at the KSC Shuttle Landing Facility (SLF) and predicted marginal weather conditions at Edwards Air Force Base, CA. The landing was rescheduled for Friday, December 6, 1996. The payload bay doors were reopened at 340:13:33:32 G.m.t. (15:17:37:45 MET) because of the landing delay.

During star tracker reactivation following the entry wave-off on December 5, the -Y star tracker annunciated a pressure BITE for approximately five minutes beginning at 340:14:32 G.m.t. (15:18:36 MET) (Flight Problem STS-80-V-05). After the BITE cleared, the star tracker functioned nominally, successfully acquiring stars. It is believed that the internal star tracker pressure was near the real BITE limit and the BITE was correct; however, the star tracker will continue to operate with a total loss of pressure, and no impact to flight operations occurred.

Prior to the flight day 15 sleep period, IMU 1 was taken to standby to prevent any recurrences of the BITE from waking the crew. However, during the sleep

period, an inner-roll-null BITE was annunciated and the IMU powered off. Analysis determined that the BITE resulted from the manner in which the software operates when an IMU is communication-faulted (as occurs when an IMU is taken to standby), and the BITE could recur with the IMU off. Consequently, a command was sent to mask the BITE annunciation for IMU 1. At 341:06:00 G.m.t. (16:10:04 MET), IMU 1 was transitioned back to operate and aligned so that its performance could be monitored. The IMU was left deselected for the remainder of the mission.

The payload bay doors were closed at 341:10:51:18 G.m.t. (16:14:55:31 MET) in preparation for landing on the first contingency day. However, the landing on the first contingency day was not performed because of unacceptable weather conditions (fog) at the KSC SLF and predicted marginal weather conditions (winds) at Edwards Air Force Base, CA. The landing was rescheduled for Saturday, December 7, 1996. The payload bay doors were reopened at 341:13:51:20 G.m.t. (16:17:55:33 MET).

The payload bay doors were closed and latched at 342:08:09:07 G.m.t. (17:12:13:20 MET) in preparation for landing on the second contingency day.

The dual-engine deorbit maneuver for the first landing opportunity at the KSC SLF on the second contingency day was performed on orbit 278 at 342:10:43:02.2 G.m.t. (17:14:47:15.2 MET). The maneuver was 188 seconds in duration with a  $\Delta V$  of 316 ft/sec.

Entry was completed satisfactorily, and main landing gear touchdown occurred on KSC concrete runway 33 at 342:11:49:06 G.m.t. (17:15:53:19 MET) on December 7, 1996. The Orbiter drag chute was deployed at 342:11:49:08 G.m.t. and the nose gear touchdown occurred 9.7 seconds later. The drag chute was jettisoned at 342:11:49:40 G.m.t. with wheels stop occurring at 342:11:50:13 G.m.t. The rollout was normal in all respects. The flight duration was 17 days 15 hours 53 minutes and 19 seconds. The APUs were shut down 16 minutes 45 seconds after landing.

## **PAYLOADS**

Preliminary calculations of experiment operations have shown that 100 percent mission success was obtained with all payloads flown on the STS-80 mission.

### **ORBITING AND RETRIEVABLE FAR AND EXTREME ULTRAVIOLET SPECTROGRAPH-SHUTTLE PALLET SATELLITE II**

The Orbiting and Retrievable Far and Extreme Ultraviolet Spectrograph-Shuttle Pallet Satellite II (ORFEUS-SPAS) was the third use of the German-built ASTRO-SPAS free-flying science satellite, which is a cooperative endeavor between NASA and the German Space Agency, DARA. The goal of this astrophysics mission was to investigate the rarely explored far- and extreme-ultraviolet regions of the electromagnetic spectrum, and study the very hot and very cold matter in the universe.

The STS-80 mission was a very productive mission for the ORFEUS-SPAS payload. The ORFEUS-SPAS accomplished 100 percent of the science mission objectives with the activities that were completed on the extension day added to the mission for ORFEUS-SPAS operations. All three instruments and the SPAS platform operated the entire mission without significant problems, and the overall science data gathering efficiency of 62.5 percent exceeded the most optimistic prelaunch expectations. The data gathering efficiency was almost a factor of two greater than the typical low-Earth orbiting astronomical satellite. A total of 422 observations of almost 150 different astronomical objects were obtained. In comparison to the first ORFEUS-SPAS mission in 1993, all three instruments were noticeably more sensitive and provided much higher quality data and twice as much data on this flight.

The extra day beyond the nominal mission was a major benefit. During that 24-hour period, the ORFEUS-SPAS operated at 66 percent observing efficiency, obtaining almost 50 observations. This extra day was a major factor in completing the science mission.

The guest investigator program, which included investigators from NASA and DARA, was an unqualified success. These investigators obtained 92 percent of their maximum allotted time (prelaunch estimates suggested that acquiring 75 percent was a more reasonable goal).

Equipment onboard the ORFEUS-SPAS consisted of a one-meter diameter telescope with the Far Ultraviolet (FUV) Spectrograph and the Extreme Ultraviolet (EUV) Spectrograph as the primary payload. A secondary, but highly complementary, payload was the Interstellar Medium Absorption Profile Spectrograph (IMAPS). In addition to the astronomy payloads, three other payloads were onboard the ORFEUS-SPAS and these were:

- a. Surface Effects Sample Monitor (SESAM);
- b. Automated Transfer Vehicle (ATV) Rendezvous Pre-Development Project (ARP); and
- c. Student Experiment on ASTRO-SPAS (SEAS).

The deployment of the ORFEUS-SPAS, using the RMS, was successfully accomplished at 325:04:10:50 G.m.t. (00:08:15:03 MET). Alignments were completed and the initial data take began at 325:35:26 G.m.t. (01:15:30 MET). All ORFEUS-SPAS instruments provided data until the end of the science mission activities at 338:22:36 G.m.t. (14:02:41:13 MET). At 339:08:25:46 G.m.t. (14:12:29:59 MET), the RMS grappled the ORFEUS-SPAS to conclude the rendezvous and retrieval of the satellite. The RMS then maneuvered the satellite through the RGPS high and low positions. At 339:11:35 G.m.t. (14:15:39 MET), a series of OSVS-related berthing maneuvers was initiated. The final berthing of the satellite was completed at 339:13:13:48 G.m.t. (14:17:18:01 MET) when the payload was latched in the payload bay and released by the RMS. The keel latch trunnion-in-place system 2 indication remained off after latching (Flight Problem STS-80-V-04). This was no concern for entry since latch operation was nominal and the redundant trunnion-in-place indication showed the correct feedback.

During the course of the mission, a series of RCS maneuvers were performed to maintain separation from the ORFEUS-SPAS payload, and the table in the Reaction Control Subsystem section of this report lists pertinent parameters for these maneuvers.

### **WAKE SHIELD FACILITY**

The free-flying Wake Shield Facility (WSF) successfully completed its third flight on the Space Shuttle and all science objectives with seven of seven growths satisfactorily completed. While awaiting the rendezvous, additional vacuum measurements were made. The facility remained very stable throughout its free-flight period. The facility is a 12-foot diameter, stainless steel disk that is designed to generate an "ultra-vacuum" environment in which to grow semiconductor thin films for use in advanced electronics.

The WSF was grappled and unberthed at 327:21:00:14 G.m.t. (03:02:04:27 MET), and after the required WSF checkout, the WSF was released at 328:01:37:40 G.m.t. (03:05:41:53 MET).

During the free-flight phase, the WSF successfully produced seven of seven possible thin-film structures. On flight day 8, an eighth oxide thin-film was grown while on the RMS and prior to WSF power-down.

The WSF system improvements and rigorous preflight test program resulted in enhanced spacecraft performance from the previous flight. The WSF attitude determination and control system (ADACS) solidly maintained the

spacecraft attitude relative to the velocity vector, and a newly installed scan filter removed the external RF interference experienced on an earlier flight.

The upgraded communications system operated nominally and provided a reliable link between the WSF and the carrier that exceeded preflight communications performance.

The stored Molecular Beam Epitaxy (MBE) automatic sequence commanding in the SC 2 computer operated nominally and allowed autonomous execution of the MBE growth procedures.

The following cooperative experiments were flown and all operated nominally:

- a. AOCON - (Atomic Oxygen Concentrator (Ionwerks);
- b. AOPROC - (Atomic Oxygen Processing/Ionwerks);
- c. ERADS - (Earth Reference Attitude Determination System/Los Alamos;
- d. DMS - (Dual Mass Spectrometer/UT - Dallas, Lamar University;
- e. ADDS - (Autonomous Dynamics Determination System/NASA-JSC and NASA-Langley; and
- f. MMD - Microgravity Measurement Device/NASA-JSC.

After approximately 73 hours of free-flight, the RMS again grappled WSF at 331:02:02:10.7 G.m.t. (06:06:06:23.7 MET) and maneuvered to the WSF hover position. The WSF was maneuvered to the atomic oxygen processing (AOPROC) position 20 minutes later, and then to the final AOPROC position. Upon completion of AOPROC activities, the arm moved WSF to the OSVS side-view position, and then to the OSVS top-view position approximately 10 minutes later. The RMS berthed WSF in the payload bay at approximately 331:02:33:51 G.m.t. (06:06:38:04 MET). The total flight time for the WSF was 77 hours 35 minutes 47 seconds.

## **MIDCOURSE SPACE EXPERIMENT**

The Midcourse Space Experiment (MSX) was performed and the data have been given to the sponsor for evaluation. The results of the experiment will be published in separate documentation.

## **SPACE EXPERIMENT MODULE**

The Space Experiment Module (SEM) was an education initiative under the direction of the Goddard Space Flight Center Shuttle Small Payloads Project. The program targets kindergarten through university-level participants. The SEM provides reusable modules for experiments within a 5-cubic-foot module Get-Away Special (GAS) canister.

The postflight examination of the data files for each SEM experiment, the SEM carrier system performed nominally. Visual inspection revealed a



nominal environment (no loose parts, no leaks, etc.). The experiments were deintegrated and sent to the experimenters for their analysis. The results of these experiments will be posted on the Internet.

This first flight of the SEM contained a number of experiments sponsored by education institutions that were:

- a. Charleston, SC School District -
  1. Gravity and Acceleration Readings;
  2. Bacterial-Agar Research Instrument;
  3. Crystal Research in Space;
  4. Magnetic Attraction Viewed in Space; and
  5. Numerous passive items such as algae, bones, yeast, and photographic film.
- b. Purdue University -
  1. Fluid Thermal Convection;
  2. NADH Oxidase Absorbance in Shrimp; and
  3. Passive Particle Detector Experiment.
- c. Hampton Elementary School - An experiment containing seeds, soil, chalk, crayon, calcite, Silly Putty, bubble solution, popcorn, mosquito eggs, and other organic compounds.
- d. Glenbrook North High School - Surface Tension Experiment.
- e. Albion Junior High School - Heat Transfer Experiment involving copper tubes and pennies.
- f. Poquoson Middle School - Bacteria Inoculation in Space Experiment.
- g. Norfolk Public Schools Science and Technology Advanced Research - Behavior of Immiscible Fluids Experiment.

#### **PHYSIOLOGICAL AND ANATOMICAL RODENT EXPERIMENT/NATIONAL INSTITUTES OF HEALTH - RODENTS**

The Physiological and Anatomical Rodent Experiment/National Institutes of Health - Rodents (PARE/NIHR-04) is the fourth flight of this experiment. This experiment studied blood pressure regulation and function in rats fed either a high- or a low-calcium diet before and during space flight.

The PARE/NIHR-04 payload was received in the ground laboratory at Hangar L on Cape Canaveral Air Force Station, FL. approximately 2.5 hours after landing. The fourteen animals were in excellent condition.

This experiment provided data that will add to the body of knowledge necessary to maintain the health of astronauts during space flight. In addition, it provided new data to a growing body of evidence that calcium is a mineral with myriad functions critical to the normal function of human life. The results of this experiment will be published in separate documentation.

### **CELL CULTURE MODULE-A**

The Cell Culture Module-A (CCM-A), formerly known as a National Institutes of Health experiment, is sponsored by three experimenters from the Mayo Clinic in Rochester, Minnesota. The experiment was one in a series of bone cell experiments that have been conducted on Space Shuttle. Results of this experiment that was flown on STS-69 indicate that bone is affected at the cellular level by microgravity. The STS-80 experimenters hope that the experiment will confirm the STS-69 findings, and further test the hypothesis that the absence of gravity has a negative effect on bone formation.

This CCM-A unit performed exceptionally well throughout the mission. All 17 temperature measurements showed that temperatures were maintained within the nominal range of 35 to 39 °F. There were no anomalies or problems of any kind with this unit during the mission. The results of this experiment will be reported in separate documentation.

### **OSTEOBLAST ADHESION AND PHENOTYPE IN MICROGRAVITY**

An additional bone loss experiment tested the hypothesis that microgravity can produce direct effects on osteoblastic cells similar to those of parathyroid hormone (PTH), which are direct targets for breakdown stimulating agents. The study also examined whether microgravity altered the interaction of osteoblastic cells with their matrix, thereby resulting in changes in shape and cellular organization known to affect the function of numerous cell types. The experimenters are members of the staff of the Mount Sinai School of Medicine in New York. The results of this experiment will be published in separate documentation.

### **BIOLOGICAL RESEARCH IN CANISTER-09 EXPERIMENT**

The Biological Research in Canister (BRIC) -09 experiment studied the influence of microgravity on genetically altered tomato and tobacco seedlings that have been modified to contain elements of soybean genes. This experiment may provide crucial information on how to improve plant growth rates and biomass production of space-grown plants as well as information on enhancing crop productivity on the Earth. This experiment used 200 seeds evenly distributed on the Nylon membrane inside 22 petri dishes, which were loaded into five BRIC canisters. The investigator is associated with Kansas State University at Manhattan, KS. All operations of this unattended experiment were nominal, and the results of this experiment will be published in separate documentation.

## **COMMERCIAL MATERIALS DISPERSION APPARATUS ITA EXPERIMENT**

STS-80 was the last of five flights of the Commercial Materials Dispersion Apparatus (CMDA) Instrumentation Technology Associates (ITA) experiment (CMIX-5). This experiment provided research data in the areas of diabetes treatment; cell reaction in microgravity that may lead to tissue replacement techniques; development of gene combinations that are toxic to insect pests, but not other species, thus creating a natural pesticide; and an environmental monitoring model using mysid shrimp. The key activity of this experiment was attempting to grow large protein crystals of urokinase for research linked to breast cancer inhibitors. A total of over 900 individual experiments were included in this payload. Results of this experiment will be published in separate documentation.

## **VISUALIZATION IN AN EXPERIMENTAL WATER CAPILLARY PUMPED LOOP**

The Visualization in an Experimental Water Capillary Pumped Loop (VIEW-CPL) was a complete success with all 14 planned tests completed. No in-flight anomalies were noted in the experiment. Analysis of the many hours of video footage began soon after landing, and the results of this experiment will be published in separate documentation.

The capillary pumped loop (CPL) technology provides an option for spacecraft thermal management. A CPL collects and transports excess heat to a space radiator without the use of a mechanical pump. The Visualization in an Experimental Water Capillary Pumped Loop (VIEW-CPL) experiment provided liquid and vapor visual data along with temperature and pressure data to refine the theories on CPL operational modes. The experiment was sponsored by the University of Maryland.

Based on the preliminary viewing of the downlinked video, the VIEW-CPL was fully operational. Some oscillating motion of the vapor in the evaporator core was observed. This observation was very interesting since the goal of the experiment was to correlate fluid motions based on pressure and temperature data that were recorded and apply it in predicting fluid motions in CPL systems that do not have flow-visualization capability.

## **RISK MITIGATION EXPERIMENTS**

RME 1309 - In-Suit Doppler Ultrasound for Determining the Risk of Decompression Sickness During Extravehicular Activities - The Risk Mitigation Experiment (RME) was not performed as the EVAs were cancelled because the hatch could not be opened.

RME 1311 - GPS Relative Navigation Experiment - The GPS Relative Navigation Experiment (RGPS) initial activity of sending the user-ephemeris command, the most critical command, to the WSF carrier-based GPS receiver during flight day 1 activities was unsuccessful. After development of a workaround procedure, the command was again executed at 327:01:56 G.m.t. (02:06:00 MET) successfully. If that command could not be processed, this RME would not have met any of its objectives. The RGPS RME completed successful ORFEUS-SPAS rendezvous/retrieval operations. RME 1311 achieved all of its mission objectives.

During the ORFEUS-SPAS deployment, the RGPS risk mitigation experiment processed single vehicle mode quadrex GPS data successfully. However, no dual vehicle operations were performed because of the problem discussed in the previous paragraph.

During the ORFEUS-SPAS retrieval, the RGPS successfully achieved all mission goals in that four or more common satellites were tracked during expected periods. The TCS acquired the SPAS at a range of 6060 feet and continuously tracked the SPAS throughout the rest of the RGPS operations. The TCS data will be used as a "truth" model for comparison during postflight analyses.

## VEHICLE PERFORMANCE

### **SOLID ROCKET BOOSTERS**

All Solid Rocket Booster (SRB) systems performed nominally. The SRB prelaunch countdown was normal, and no SRB Launch Commit Criteria (LCC) or Operational Maintenance Requirements and Specifications Document (OMRSD) violations occurred. For this flight, the high pressure heated ground purge in the SRB aft skirt was used to maintain the case/nozzle joint temperatures within the required LCC ranges. No in-flight anomalies were noted from the data or the postflight inspection.

Both SRBs were successfully separated from the External Tank (ET) 124.004 seconds after liftoff, and visual reports from the recovery area indicate all deceleration subsystems performed as designed. Both SRBs were recovered and returned to KSC for disassembly and refurbishing. Postflight inspection of the SRBs did not reveal any anomalous conditions.

### **REUSABLE SOLID ROCKET MOTORS**

Data indicate that the Reusable Solid Rocket Motors (RSRMs) performed satisfactorily. No RSRM LCC or OMRSD violations were encountered during the prelaunch process. No in-flight anomalies were noted in the data evaluation or postflight inspection.

Power-up and operation of all igniter (11.2 hours of operation) and field joint heaters (11.35 hours of operation) was routine during the countdown. All RSRM temperatures were maintained within acceptable limits throughout the countdown. The aft skirt purge was activated during the countdown to maintain the nozzle/case joint temperatures above the minimum LCC temperature. During the LCC applicability time frame, the nozzle/case joint sensor temperatures ranged from 80 to 83 °F and 78 to 83 °F for the left and right motors, respectively. The propellant mean bulk temperature (PMBT) was 72 °F, and the flex bearing mean bulk temperature was 82 °F.

Data 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 maximum trace-shape variation of pressure vs. time was calculated to be 1.02 percent at 71.5 seconds for the left motor, and 1.22 percent at 68 seconds for the right motor. Both values are well within the 3.2 percent allowable limit.

The left-hand and right-hand nozzles exhibited striated axial erosion on the throat and forward exit cone. All erosion was within contract end item (CEI) requirements. All engineering and CEI specification requirements were met on all components.

The following table shows the RSRM propulsion performance during ascent.

### RSRM PROPULSION PERFORMANCE

Parameter	Left motor, 72 °F		Right motor, 72 °F	
	Predicted	Actual	Predicted	Actual
Impulse gates				
I-20, 10 <sup>6</sup> lbf-sec	65.87	66.45	65.89	66.56
I-60, 10 <sup>6</sup> lbf-sec	175.50	176.47	175.54	177.36
I-AT, 10 <sup>6</sup> lbf-sec	296.92	296.72	297.13	297.93
Vacuum Isp, lbf-sec/lbm	268.5	268.4	268.5	269.3
Burn rate, in/sec @ 60 °F at 625 psia	0.3689	0.3707	0.3687	0.3706
Burn rate, in/sec @ 72 °F at 625 psia	0.3721	0.3739	0.3719	0.3738
Event times, seconds <sup>a</sup>				
Ignition interval	0.232	N/A	0.232	N/A
Web time <sup>b</sup>	109.3	108.4	109.4	106.3
50 psia cue time	119.1	119.0	119.1	118.2
Action time <sup>b</sup>	121.1	121.0	121.2	120.3
Separation command	124.0	124.0	124.0	124.0
PMBT, °F	72	72	72	72
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	2.9	2.8	2.9
Tailoff Imbalance Impulse differential, Klbf-sec	Predicted		Actual	
	N/A		403.3	

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

<sup>a</sup>All times are referenced to ignition command time except where noted by a <sup>b</sup>

<sup>b</sup>Referenced to liftoff time (ignition interval).

### EXTERNAL TANK

All objectives and requirements associated with the ET propellant loading and flight operations were met. All ET electrical and instrumentation operated satisfactorily. The ET purge and heater operations were monitored and all performed properly. No ET LCC or OMRSD violations were encountered during the countdown.

No unexpected ice/frost formations were observed on the ET during the countdown. Also, no ice or frost was observed on the acreage areas of the ET. However, normal quantities of ice or frost were present on the liquid oxygen (LO<sub>2</sub>) and liquid hydrogen (LH<sub>2</sub>) feed-lines, the pressurization line brackets, and along the LH<sub>2</sub> protuberance air load (PAL) ramps. All observations were acceptable under guidelines established in NSTS-08303. Also, the Ice/Frost Inspection Team reported that there were no anomalous

thermal protection system (TPS) conditions. No in-flight anomalies or significant ET problems were noted in the evaluation of the data.

The ET pressurization system functioned properly throughout engine start and flight. The minimum LO<sub>2</sub> ullage pressure experienced during the ullage pressure slump was 15.4 psid.

Satisfactory ET separation was confirmed from photographic data, and ET entry and break-up was 74 nmi. uprange from the predicted impact point, which was within the predicted footprint.

## **SPACE SHUTTLE MAIN ENGINES**

All Space Shuttle main engine (SSME) parameters were nominal 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 no OMRSD violations were noted; and engine start and thrust build-up were normal.

Flight data indicate that SSME performance during mainstage, throttling, shutdown and propellant-dump operations was nominal with cutoff times of 516.41, 516.52, and 516.63 seconds for SSMEs 1, 2, and 3, respectively. The high pressure oxidizer turbopump (HPOTP) and high pressure fuel turbopump (HPFTP) temperatures were well within specification throughout engine operation. The  $I_{sp}$  was rated as 452.4 seconds based on reconstructed trajectory data. No failures or significant SSME problems were identified from the data.

## **SHUTTLE RANGE SAFETY SYSTEM**

The Shuttle Range Safety System (SRSS) closed-loop testing was completed as scheduled with no anomalies or problems reported. 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 throughout the countdown and powered flight nominally.

As planned, the SRB S&A devices were safed, and SRB system power was turned off prior to SRB separation. The ET system has been deleted.

## **ORBITER SUBSYSTEM PERFORMANCE**

### **Main Propulsion System**

The overall performance of the main propulsion system (MPS) was nominal and as expected. All environmental compartment and MPS purges were performed as planned and met required specifications. All MPS valves functioned as required by the software with timing of all valves within requirements. There were no OMRSD violations during the countdown;

however, one LCC violation occurred and it is discussed in the following paragraphs.

LO<sub>2</sub> and LH<sub>2</sub> loading were performed as planned except for one stop flow condition during LH<sub>2</sub> topping. This condition resulted from ET intertank (I/T) ground umbilical carrier plate (GUCP) leakage. The I/T GUCP hydrogen (H<sub>2</sub>) concentration peaked at 49,200 ppm (LCC limit is 44,000 ppm). The ET vent valve was cycled closed for 30 seconds during topping and the concentrations reduced to a range between 4,000 ppm and eventually decreased to 100 ppm. After a short time, the GUCP hydrogen concentration again increased to the 11,000 to 15,000 ppm range for the duration of loading. It is believed that the closure of the ET vent valve allowed the ET I/T GUCP quick-disconnect valve to reseal, which then stabilized the interface and the leakage. Later during the replenish phase of loading, the ET vent valve was cycled a second time (for approximately 15 seconds) to verify that the system was stable. The hydrogen concentration returned to a stabilized reading of 11,000 to 15,000 ppm after the vent valve was reopened.

During the countdown, the aft compartment GH<sub>2</sub> concentration peaked to 550 ppm (corrected) during ET slow fill, and then dropped off and stabilized below 250 ppm. Since the 550-ppm value occurred during slow fill and the 17-inch disconnect temperature was still decreasing, it was believed that the system had not reached thermal equilibrium. The aft compartment helium and ET umbilical GH<sub>2</sub> detectors (LD54/55) showed increases consistent with aft compartment GH<sub>2</sub> concentrations during slow fill. After transition to fast fill, the GH<sub>2</sub> concentration elevated as the system reached thermal equilibrium and reached a maximum of 350 ppm during transients. The aft compartment concentration stabilized in the 195 to 220 ppm range during the reduced fast-fill portion of loading. This is well within the 600-ppm LCC limit and within program experience (although slightly higher than recent data). The concentration returned to a normal value below 150 ppm during LH<sub>2</sub> replenish. The overall signature points to a leak in the low-pressure portion of the LH<sub>2</sub> system, possibly in the Orbiter/ET umbilical area.

A violation of the aft compartment GH<sub>2</sub> concentration LCC limit of 300 ppm occurred during LH<sub>2</sub> tank prepressurization at T-1 minute 57 seconds (Flight Problem STS-80-V-01). Near the end of the LCC effectivity period at T-31 seconds, a pre-planned hold was called to evaluate the aft hydrogen concentration in accordance with the LCC pre-planned contingency procedure. The aft hydrogen concentration oscillated about the established 600-ppm limit for this contingency procedure as it was monitored by the KSC Launch Team. The launch team determined that the data had satisfied the conditions of the pre-planned contingency procedure and the countdown was resumed after a 2-minute 47-second hold and a successful launch followed. No other significant hazardous gas concentrations were detected.

Postflight review of the aft hydrogen concentration during reduced fast fill operations indicated an expected hydrogen concentration of 250 to 400 ppm during LH<sub>2</sub> prepressurization. Data during reduced fast fill are used because



of similar system configuration and pressures; then scaled for a reduction in the aft compartment purge flow rate and slight increase in system pressure. Postflight analysis of the sample bottle data showed that the aft hydrogen concentration was similar to the last two flights of this vehicle. All of these data confirm that the observed system leakage was in the low-pressure portion of the system where leakage is least during ascent. The postflight large volume decay test has been completed indicating a 0.6/psi/hr decay rate, which is within expectations for the OV-102 vehicle. Postflight inspection and testing of the Orbiter/ET umbilical area was progressing as this report was being written.

A comparison of the calculated propellant loads versus the inventory load at the end of replenish resulted in a loading accuracy of 0.03 percent for LH<sub>2</sub> and 0.04 percent for LO<sub>2</sub>. Both of these values were well within the established loading accuracy requirements.

Ascent MPS performance was completely nominal. Performance of the propulsion systems during start, mainstage, and shutdown operations was nominal and all requirements were satisfied. The GO<sub>2</sub> fixed-orifice pressurization system performed as predicted. Data indicate that the LO<sub>2</sub> and LH<sub>2</sub> pressurization systems performed as planned, and all net positive suction pressure (NPSP) requirements were met throughout powered flight. The minimum LO<sub>2</sub> ullage pressure experienced during the period of the ullage pressure slump was 15.23 psid. This value was 1.4 psi higher than expected because of the eight additional prepressurization cycles during the hold at T-31 seconds.

Data show that all four LO<sub>2</sub> engine cutoff (ECO) sensors flashed dry after MECO. This routinely occurs as the vehicle acceleration drops from 3-g to zero-g. Also, SSME shutdown purges at this time (prior to prevalve closure) may have contributed to this condition, as the purges cause some turbulence in the feed system.

STS-80 was the first flight of the reshimmed -1301 configuration of the GH<sub>2</sub> flow control valves (FCVs). The valves are essentially the same as the previous configuration; however, the poppet stroke was reduced to 70 percent/31 percent from 100 percent/18 percent. The GH<sub>2</sub> pressurization system performance was nominal during powered ascent with the ET LH<sub>2</sub> tank-ullage pressure maintained within the ICD-specified control band of 32 to 34 psia. No evidence of sluggish performance was noted on any of the valve cycles.

Propellant dump and vacuum inerting operations were performed as planned and nominal in all aspects.

### **Reaction Control Subsystem**

The reaction control subsystem (RCS) performed in an exceptional manner throughout the STS-80 mission, and no in-flight anomalies occurred. In

addition to the normal attitude control activities which require primary RCS thruster operation, 32 maneuvers were performed in support of the two rendezvous operations and maintaining the correct separation between the WSF and the ORFEUS-SPAS (see following tables).

### RENDEZVOUS MANEUVERS

Maneuver	Time, G.m.t.	$\Delta V$ , ft/sec
Rendezvous with Wake Shield Facility		
NH	330:21:27:47	1.0
NCC	330:22:48:24	1.3
MC-1	331:00:08:30	0.7
MC-2	331:00:32:45	Not available
MC-3	331:00:44:00	0.3
MC-4	Cancelled	
Rendezvous with ORFEUS-SPAS		
NH	Cancelled	
NCC	339:05:11:29	0.69
MC-1	Cancelled	
MC-2	339:06:56:52	0.4
MC-3	339:07:06:52	0.2
MC-4	339:07:16:52	0.4

A total of 4896.3 lbm of propellants were consumed from the RCS tanks during the mission. In addition, 1352.9 lbm of OMS propellants were consumed from the left OMS tanks, and 1331.5 lbm of OMS propellants were consumed from the right OMS tanks during the mission.

The ORFEUS-SPAS SEP -1 maneuver was executed at 325:04:11:48 G.m.t. (00:08:16:01 MET) and had a duration of approximately 14 seconds. The RCS maneuver was accomplished with six thrusters providing seven pulses during the maneuver. The SEP-2 maneuver was performed at 325:04:44:11 G.m.t. (00:08:48:24 MET) with an approximate duration of 105 seconds using the RCS.

The RCS hot-fire was performed beginning at 340:03:41 G.m.t. (15:07:45 MET) with each thruster being fired twice. There were no fail-off or fail-leak indications; however, thruster R2U exhibited a slower-than-normal increase in chamber pressure on its first hot-fire pulse, which was also its first firing of the mission. The second pulse was normal, and there were good chamber pressures and injector temperatures on all other thrusters.

## RCS MANEUVERS IN SUPPORT OF SEPARATION OPERATIONS

Maneuver	Time of Maneuver, da:hr:min:sec G.m.t./da:hr:min:sec, MET	$\Delta V$ , ft/sec
NC-1	Cancelled, Not Required	-
NC-2	325:18:39:50/00:22:44:03	1.5
NC-3	326:05:10:47/01:09:15:00	1.0
NC-4	326:21:18:49/02:01:23:02	0.8
NC-5	327:07:25:47/02:11:30:00	1.4
NC-6	327:18:10:47/01:22:15:00	0.76
NC-7	328:06:30:46/03:10:34:59	1.1
NC-8	328:20:59:47/04:01:04:00	1.15
NC-9	Cancelled, Not Required	-
NC-10	329:21:49:47/05:01:54:00	1.2
NC-11	330:03:58:23/05:08:02:36	0.7
NC-12	330:20:45:53/06:00:50:06	5.2
NC-13A and B	Cancelled, Not Required	-
NC-14	331:22:27:47/07:02:32:00	0.8
NC-15	332:11:51:47/07:15:56:00	3.6
NC-16	333:00:53:47/08:04:58:00	0.5
NC-17	333:09:17:47/08:13:22:00	0.9
NC-18	Cancelled, Not Required	-
NC-19	Cancelled, Not Required	-
NC-20	335:00:08:47/10:04:12:59	0.43
NC-21	335:10:45:46/10:14:49:59	0.6
NC-22	336:00:31:47/11:04:36:00	0.4
NC-22A	336:06:16:47/11:10:21:00	1.0
NC-23	336:10:55:46/11:14:59:59	0.28
NC-24	337:02:38:46/12:06:42:59	1.0
NC-25	Cancelled, Not Required	-
NC-26	338:02:40:04/13:06:44:17	0.4
NC-27	338:12:53:02/13:16:57:15	0.9
NC-28	339:03:06:17/14:07:10:30	5.5

### Orbital Maneuvering Subsystem

The OMS performed very well throughout the mission. Five OMS maneuvers were planned and completed satisfactorily. The OMS 1 maneuver was not required, and therefore, not performed.

OMS propellant consumption during the mission was 18,303.7 lbm of which 11,456.8 lbm was oxidizer and 6846.9 lbm was fuel. There were two periods of interconnect operation (one left and one right), during which 2684.4 lbm (20.73 percent) of the OMS propellants were consumed.

The following table shows pertinent parameters from each OMS maneuver.

## OMS FIRINGS

OMS firing	Engine	Ignition time, G.m.t./MET	Firing duration, seconds	$\Delta V$ , ft/sec
OMS-2	Both	324:20:36:11.5 G.m.t. 00:00:40:24.5 MET	181	279
OMS-3 (TI)	Right	330:23:45:42.3 G.m.t. 006:03:49:55.3 MET	9	8
OMS-4 (TI)	Right	339:06:08:47.1 G.m.t. 014:10:13:00.1 MET	9	8.0
OMS-5 (orbit adjust)	Left	339:14:52:47.3 G.m.t. 014:18:57:00.3 MET	18	15
OMS-6 (orbit adjust)	Both	341:16:31:12.1 G.m.t. 016:20:35:25.1 MET	15	24
Deorbit	Both	342:10:43:02.2 G.m.t. 017:14:47:15.2 MET	188	316

At 331:01:25 G.m.t. (06:05:29 MET), when a repressurization of the left OMS oxidizer and fuel tanks was performed using the A-leg side of the repressurization system, the resulting engine-inlet pressure (272 psia) was higher than expected. A repressurization that occurred earlier in this mission resulted in a lock up at an indicated pressure of approximately 255 psia.

A historical data review of the left OMS pod (LP05) revealed that the observed signature was not unusual and has been observed on previous flights. Previous OMS propellant-tank repressurizations through the A-leg had two distinct signatures depending on the initial fuel-ullage pressure. With an initial fuel-ullage pressure less than 245 psia, repressurizations tended to occur within approximately 10 seconds (a "slam"), and the resulting regulator lockup pressure was higher than the nominal primary-regulator lockup pressure. If the initial fuel-ullage pressure was greater than 246 psia, the repressurization occurred within 1 to 2 minutes, with the resulting pressure within the expected primary-regulator lockup pressure range, which is less than 266 psia. Thus, the repressurization that resulted in the higher-than-expected lockup pressure may not be an unusual system characteristic; however, the apparent trend toward increasing pressures during this operation has raised a concern for possible degradation in performance. Further data review to characterize repressurizations during non-flow conditions on other OMS pods and the B-leg of left OMS pod will be performed.

### Power Reactant Storage and Distribution Subsystem

The power reactant storage and distribution (PRSD) subsystem performed nominally throughout the mission which was the ninth flight of the Extended

Duration Orbiter (EDO) pallet. No PRSD in-flight anomalies were observed in the flight data during this mission which was the longest of the Space Shuttle Program.

The PRSD subsystem supplied 3989 lbm of oxygen and 502 lbm of H<sub>2</sub> for the production of electrical energy, and 156 lbm of oxygen was supplied to the environmental control and life support system (ECLSS). A 155-hour mission extension capability existed at landing based on average power levels, and a 182-hour mission extension capability existed at extension-day power levels (11.8 kW).

### **Fuel Cell Powerplant Subsystem**

The fuel cell prelaunch start-up procedure was performed nominally and no fuel cell problems were noted during prelaunch operations. Likewise, fuel cell flight performance was nominal with no in-flight anomalies noted in the data. The fuel-cell average power level during the mission was 13.8 kW and the total Orbiter load averaged 447 amperes. The fuel cells produced 5856 kWh of electrical energy and 4492 lbm of potable water. The fuel cells consumed 3989 lbm of oxygen and 502 lbm of hydrogen (H<sub>2</sub>) during the mission. At the end of the mission, a total of 2319, 1273, and 1196 hours of operation were accumulated on fuel cells 1, 2, and 3, respectively.

The fuel cells were purged nine times during the mission. The performance degradation rates were not significantly different from the previous flight, STS-78. The actual fuel cell voltages at the end of the mission were 0.15 volt above the predicted values for fuel cells 1 and 3, and 0.05 volt above the predicted value for fuel cell 2.

The overall performance of the fuel cell water relief, water line and reactant purge systems was nominal. Both the A and B systems water relief and water line systems were used during the mission with nominal operation. All of the water system heaters also operated nominally, and the fuel cell purge vent-line heaters operated nominally in the automatic and manual modes.

The fuel cell 3 H<sub>2</sub> pump motor current measurement experienced three step-changes from the nominal range of 0.48 to 0.52 Vdc to a range of 0.38 to 0.42 Vdc. This was a recurrence of the H<sub>2</sub> pump sensor circuit failure that occurred during STS-66 and STS-78 on the same serial number (118) fuel cell. The observed values were well within the nominal range of 0.28 to 0.75 Vdc stated in the Shuttle Operational Data Book (SODB), and an impending pump-stall condition will not occur until the measurement rises to 2.0 Vdc. Furthermore, the signature, a decrease in voltage, was not indicative of a failure to remove water from the fuel cell. Postflight analysis by the fuel cell vendor following STS-66 concluded that the motor-phase current-sensing circuit failure was the most probable cause of the low-signal level and not the motor.

Fuel cell 1 continues to have a slightly high condenser exit temperature (TCE), which is a characteristic of this serial number (109) fuel cell. The TCE has been fluctuating in the range of 156 to 159 °F since the fuel cell was refurbished as a zero-hour fuel cell five flights ago. All other indications in the fuel cell are nominal and, as a result, there is no concern about possibly violating the LCC.

### Auxiliary Power Unit Subsystem

The auxiliary power unit (APU) subsystem performed nominally throughout the mission, and no in-flight anomalies were identified from the data. The run times and fuel consumption for the APUs are summarized in the following table.

### APU RUN TIMES AND FUEL CONSUMPTION

Flight phase	APU 1 (S/N 401) (a) (b)		APU 2 (S/N 303) (a)		APU 3 (S/N 403) (a)	
	Time, min:sec	Fuel consumption, lb	Time, min:sec	Fuel consumption, lb	Time, min:sec	Fuel consumption, lb
Ascent	22:58	60	23:13	66	21:14	57
FCS checkout	04:50	15				
Entry <sup>a</sup>	60:32	113	87:59	190	60:50	120
Total	88:20	188	111:12	256	82.04	177

<sup>a</sup> APUs were shut down 16 minutes 35 seconds after landing.

<sup>b</sup> APU 1 was used for the FCS checkout.

APU 1 was used to perform the FCS checkout. The APU was started at 340:02:41:27.5 G.m.t. (15:06:45:40.5 MET), ran for 4 minutes 50 seconds, and consumed 15 lb of fuel. All APU and hydraulic system parameters appeared normal during the FCS checkout. Because of the short APU run-time, no WSB cooling was observed.

### Hydraulics/Water Spray Boiler Subsystem

The hydraulics/WSB subsystem performed nominally with no in-flight anomalies identified.

WSB 3 failed to provide cooling during ascent. The APU 3 lubrication oil return temperature reached approximately 298 °F prior to switching to the B controller at 324:20:07:34 G.m.t. (00:00:11:47 MET). The lubrication oil return temperature reached approximately 328 °F prior to spray cooling, which was observed approximately 5 seconds before APU 3 was shut down. The lubrication oil return temperature was 329.6 °F at shutdown. This condition,

which has been observed on previous flights, did not impact the successful completion of the mission.

Development Test Objective (DTO) 416 - WSB Quick Restart - was performed this flight to determine WSB support capability of orbit-2 aborts and AOA conditions. This is the third of seven flights planned for this DTO.

The results of the DTO will be used in determining the capability of the WSB to support a revolution 2 deorbit and AOAs. As planned, all three WSB vent heaters were turned on when the corresponding APU lubrication oil temperatures reached 240 °F.

Planning for FCS checkout was based on using APU 3 and hydraulic system 3; however, APU 1 and hydraulic system 1 were used because of thermal concern for the OMS high-point bleed line. The APU ran only 4 minutes 50 seconds; consequently, no WSB spray cooling was observed.

Hydraulic performance during entry was nominal. However, WSB system 3 experienced a slight under-cooling condition followed by a slight over-cooling condition prior to achieving a steady-state temperature of approximately 253 °F. During both conditions, the system 3 lubrication oil return temperature reached 273 °F and 237 °F, respectively. A similar signature was observed during entry of the previous two flights of this unit (STS-75 and STS-78).

### **Electrical Power Distribution and Control Subsystem**

The electrical power distribution and control (EPDC) subsystem performed nominally throughout the STS-80 mission with no in-flight anomalies identified from the mission data.

### **Environmental Control and Life Support Subsystem**

The atmospheric revitalization pressure control system (ARPCS) performed normally throughout the mission. The crew cabin was depressurized to 10.2 psia from 332:08:19 G.m.t. (07:12:23 MET) to 336:11:06 G.m.t. (11:15:10 MET) for the planned EVAs. However, the EVAs were not performed because of the hatch opening anomaly.

The active thermal control system (ATCS) operation was satisfactory throughout the mission. None of the flash evaporator system (FES) problems that were experienced on the vehicle during the previous two missions (STS-75 and STS-78) recurred. Corrective actions taken during the turnaround activities following STS-78 included the following;

- a. Entire system A and B feedwater systems were back-flushed and verified clean;
- b. High load valves were removed and replaced;

- c. Excess zinc chromate putty was removed from around the drain port on the inside surfaces of the cores; and
- d. Flow-rate of Freon cooling loop (FCL) 1 was decreased to minimize the flow-rate imbalance between two FCLs.

All of these actions contributed to the enhanced FES operation during STS-80.

Two long-duration and one short-duration supply water dump were initiated through the flash evaporator system (FES). The first long-duration dump occurred between 328:18:46 G.m.t. (03:22:50 MET) and 329:10:26 G.m.t. (04:14:30 MET). The FES performed nominally for the 15-hour 40-minute dump. Later in the flight, a second nominal long-duration supply water dump through the FES was initiated at 329:19:25 G.m.t. (04:23:29 MET) and terminated at 330:03:26 G.m.t. (05:07:30 MET). A third supply water dump through the FES (short-duration) was initiated at 339:13:16 G.m.t. (14:17:29 MET) and completed at 339:14:54 G.m.t. (14:18:58 MET). Net water quantity-reduction during the dump was 20.8 lbm. For the mission, the FES was used for three water dumps with a total duration of 25 hours 19 minutes, and FES operation was nominal during all three dumps.

The radiator cold-soak provided cooling during entry through landing plus six minutes when ammonia boiler system (ABS) B was activated using general purpose computer (GPC) control. To minimize the thermal stress on the long-duration flight crew, ammonia cooling was activated earlier than usual by selecting the high outlet temperature set point (57 °F) on both FCL radiator flow controllers when the radiator controller outlet temperatures exceeded 40 °F. This configuration provided the necessary heat load for the ABS and avoided the increased cabin temperature and humidity transient that normally occurs during postlanding operations.

The supply and waste water systems performed nominally except for the waste water pressure transducer which failed four days prior to launch. The transducer will be replaced during the STS-80 turnaround operations.

Supply water was managed through the use of the FES and the overboard dump system.

Five additional supply water dumps were made through the overboard dump system. Each had an average dump rate between 1.43 percent/minute and 1.63 percent/minute (2.37 to 2.69 lb/min). Four of the dumps were performed simultaneous with waste water dumps. The supply water dump line temperature was maintained between 76 and 108 °F throughout the mission with the operation of the line heater.

Waste water was gathered at approximately the predicted rate. Five waste water dumps were performed, and each had an average dump rate between 1.85 and 1.99 percent/minute (3.05 to 3.28 lb/min). The waste water dump



line temperature was maintained between 54 and 80 °F throughout the mission. The vacuum vent line temperature was between 60 and 75 °F with the vacuum vent nozzle between 45 and 157 °F.

Simultaneous supply and waste water dumps through the nozzles were performed throughout the mission. These dumps were performed without any problems and dump flow rates were as expected.

The waste collection system performed normally throughout the mission.

A cabin depressurization in preparation for the planned EVAs was completed with a cabin pressure of 10.4 psi at 332:08:42 G.m.t. (07:12:46 MET). The cabin pressure was returned to the nominal 14.7 psia after cancellation of the EVAs.

All atmospheric revitalization system (ARS) systems hardware had performed nominally. The regenerative carbon dioxide removal system (RCRS) performed nominally on this the fourth flight of this particular unit. Partial pressure of carbon dioxide was maintained to levels below 4.38 mmHg without use of the lithium hydroxide. The cabin temperature and humidity control was satisfactory throughout the flight. Likewise, the avionics bays (1, 2, and 3) temperatures were maintained within acceptable limits during the flight.

### **Airlock Support Subsystem**

The airlock support subsystem performed nominally during the attempt to perform the first EVA. The airlock was depressurized at 334:02:04 G.m.t. (09:06:08 MET). At 334:02:30 G.m.t. (09:06:34 MET), when the crew attempted to open the hatch for the first scheduled EVA, they reported that the outer hatch of the airlock could not be unlatched (Flight Problem STS-80-V-02). At 334:03:04 G.m.t. (09:07:08 MET), the airlock was pressurized to 3.84 psia to provide assistance in blowing the outer hatch cover down so that the external side of the airlock outer hatch could be viewed with the RMS elbow camera. The thermal cover was blown down four minutes later. At 334:03:59 G.m.t. (09:08:03 MET), the airlock was pressurized to cabin pressure following the decision to delay EVA 1 indefinitely because of difficulties opening the hatch. Further attempts to perform an EVA were cancelled by the MMT because of the hatch anomaly.

### **Smoke Detection and Fire Suppression Subsystem**

The smoke detection and fire suppression subsystem showed no indications of smoke generation during the mission. Use of the fire suppression subsystem was not required.

## **Avionics and Software Support Subsystems**

The avionics and software support systems performed nominally throughout the flight.

Descent navigation performed nominally for STS-80. There were no in-flight anomalies nor deselections by redundancy management. External sensor data were incorporated into the onboard navigation state vectors at the expected region of operation. Drag measurement processing started at approximately 232,000 ft and ended at 85,000 ft. Tactical air navigation (TACAN) station acquisition occurred at approximately 152,000 ft. All external-sensor measurement residuals and residual-ratio values were nominal with no data editing required. The backup flight system (BFS) navigation data error analysis showed a good comparison between the primary flight system and BFS state vectors.

At approximately 339:09:20:04 G.m.t. (14:13:24:17 MET), shortly after rendezvous with the ORFEUS-SPAS, the inertial measurement unit (IMU) 1 attitude began degrading and the IMU was deselected by the crew (Flight Problem STS-80-V-03). Six built-in test equipment (BITE) messages were annunciated over a 24-minute period, and the unit was considered failed. Data analysis showed that the outer roll loop of IMU 1 opened and this resulted in the inner roll angle increasing until the inner roll gimbal reached the mechanical stop. At 339:09:48:10 G.m.t. (14:13:42:23 MET) the roll loop closed, the inner roll nulled and the other gimbal angles appeared normal. As a result, the decision was made to power-up IMU 1 because the failure had occurred for a period of 28 minutes and then normal operation was exhibited for the 20 minutes remaining that the unit was in the operate mode. However, the erratic temperature-safe and ready discretes, which appeared to be false, remained but are believed to be in some way related to the failure. At approximately 340:03:58 G.m.t. (15:08:02 MET), IMU 1 was transitioned to operate, aligned, and left deselected so that its performance could be monitored.

Prior to the flight day 15 sleep period, IMU 1 was taken to standby to prevent any recurrences of the BITE from waking the crew. However, during the sleep period, an inner-roll-null BITE was annunciated and the IMU was powered off. Analysis determined that the BITE resulted from the manner in which the software operates when an IMU is communication-faulted (as occurs when an IMU is taken to standby), and the BITE could recur with the IMU off. Consequently, a command was sent to mask the BITE annunciation for IMU 1. At 341:06:00 G.m.t. (16:10:04 MET), IMU 1 was transitioned back to operate and aligned so that its performance could be monitored. The IMU was taken to the operate mode but remained deselected after the failure and the IMU operated flawlessly.

During star tracker reactivation following the entry wave-off on December 5, the -Y star tracker annunciated a pressure BITE for approximately 5 minutes beginning at 340:14:32 G.m.t. (15:18:36 MET) (Flight Problem STS-80-V-05).

After the BITE cleared, the star tracker functioned nominally, successfully acquiring stars. This same condition was noted after the flight day 17 wave-off of landing. The unit is normally pressurized to 17.58 psia with argon gas to prevent moisture and contamination from entering the star tracker during entry and ground operations. It is believed that the internal star tracker pressure was near the real BITE limit of 15.44 psia, and the BITE was correct; however, the star tracker continued to operate nominally with no impact to flight operations.

### **Displays and Controls Subsystem**

The displays and controls subsystem performed nominally throughout the flight. Minor problems were noted, but the flight was not impacted.

The crew reported that the Ku-band digital display on panel A2 displayed all zeros during the first Ku-band self-test after applying power. The self-test had failed (expected condition); therefore, the display should have indicated all threes (all eights for a passed test). The crew reported that the display select switch was properly positioned for the self-test. The crew reported all threes for the second self-test that was conducted prior to the ORFEUS-SPAS deployment a few hours later. The display operated properly for all subsequent operations during the mission. Postflight testing of the switch will be performed.

During entry, the Pilot checked the LG extend isolation valve talkback on panel R4 after the valve had automatically been opened by the GPC. The talkback read closed instead of open. The switch was cycled; however, the talkback continued to indicate closed. The Pilot then rapped panel R4 above the talkback and the indicator then showed open. Downlist data showed nominal operation of the valve.

### **Communications and Tracking Subsystems**

The communications and tracking subsystems operated nominally throughout the mission with no in-flight anomalies identified.

During the Tracking and Data Relay Satellite-Z (TDRS-Z)/Canberra pass from 325:08:00 G.m.t. to 325:08:11 G.m.t. (00:12:04 MET to 00:12:15 MET), there were specific downlink frames that contained erroneous data. It is believed to be isolated to the TDRS-Z support, as the data were acceptable after the hand-over to TDRS-W. A subsequent dump of the data that were recorded on the onboard recorders during this time period contained no erroneous data. The problem was corrected after three downlink periods through Canberra were recorded with no data loss.

The forward link to the SPAS payload from the Extended Range Payload Communications Link (ERPCL) was lost at approximately 326:11:20 G.m.t. (01:15:24 MET). Since this occurred during a crew-sleep period, a ground-

commanded switch from the ERPCL to the Payload Interrogator (PI) was required to regain forward-link command capability. Following the sleep period, the crew performed a frequency sweep, and this reacquired the forward link from the ERPCL to the SPAS. The link performed nominally.

The SPAS false-lock to the ERPCL phenomenon recurred following a period where the WSF was being commanded through the ERPCL. The WSF command-plan used the ERPCL for occasional commanding, and this resulted in a disruption of the SPAS forward link when the PSP was reconfigured. To avoid this problem, the PI used to command the SPAS during the WSF free flight, and the ERPCL was used for SPAS telemetry.

During the WSF rendezvous, the Ku-band radar locked onto the WSF at a range of 126,650 ft and tracked the WSF to a range of 100 ft.

During the ORFEUS-SPAS rendezvous, the Ku-band radar performed satisfactorily in acquiring the ORFEUS-SPAS satellite at a range of 130,000 feet and tracking the satellite to a range of 86 feet.

The TCS was activated to support ORFEUS-SPAS rendezvous and commanded to begin auto acquisition at a seed range of 20,000 feet. At approximately 339:07:15 G.m.t. (14:11:19 MET), at a range of 6060 feet, the TCS began tracking the target. The sensor was shutdown by the crew at 339:09:15 G.m.t. (14:13:19 MET). TCS performance was nominal.

### **Operational Instrumentation/Modular Auxiliary Data System**

The operational instrumentation (OI) and Modular Auxiliary Data System (MADS) operated nominally throughout the mission.

When operations recorder 1 was played back at 120 inches/second after recording 192 Kbps or 128 Kbps data at 24 inches/second, frame drops were noted. These frame drops, which were one or two at a time, occurred regularly at 20-second intervals when dumping at 960 Kbps or at 32-second intervals when dumping at 640 Kbps. This signature does not occur on operations recorder 2. Investigation revealed that the dropped frames had the same frame synchronous word (FAF320). This data signature did not occur when dumping at 1024 Kbps after recording 128 Kbps data at 15 inches/second.

When recording data with operations recorder 2, the percent tape remaining indication toggled between two values at the point of changing. This condition occurred near the 10 percent point and was observed with the tape traveling in both directions. The indication reflects a problem in the position-recording electronics that does not affect the operation of the recorder. A data review showed that this same problem was noted on three previous flights of the OV-102 vehicle (STS-73, -75, and -78). The recorder will continue to be flown in the as-is condition.

## Structures and Mechanical Subsystems

The structures and mechanical subsystems performed nominally except for the airlock hatch that was to be used for the EVA. This hatch problem is discussed in the later paragraphs of this section.

The postlanding inspection revealed that the tires and brakes were in average condition for a landing on the SLF concrete runway. Ply under-cutting was noted on the left-hand main inboard tire. The landing and braking data for the mission is shown in the following table.

The postlanding inspection identified a piece of bent metal, approximately 1-inch long by 1/8 inch wide, that was visible on the trailing edge of a shim between two bolt-heads on the inside surface of the LO<sub>2</sub> ET umbilical door. The shim was located at the +X +Y corner of the door. A small piece of wire, 3/8 inch long by 1/32 inch diameter, was wedged against a bolt head in the same general area. The cause of the damage could not be immediately determined. Also, the inspection revealed that no similar shim is located on the LH<sub>2</sub> ET umbilical door which is a mirror image of the LO<sub>2</sub> door.

### LANDING AND BRAKING PARAMETERS

Parameter	From threshold, ft	Speed, keas	Sink rate, ft/sec	Pitch rate, deg/sec
Main gear touchdown	3068	203.4	1.0	N/A
Nose gear touchdown	7100	149.3	N/A	-4.7
Brake initiation speed		115.7 knots		
Brake-on time		40.4 seconds		
Rollout distance		8,705 feet		
Rollout time		59.5 seconds		
Runway		33 (Concrete) KSC		
Orbiter weight at landing		227,523 lb		
Brake sensor location	Peak pressure, psia	Brake assembly	Gross energy, million ft-lb	
Left-hand inboard 1	1032	Left-hand inboard	17.18	
Left-hand inboard 3	1032	Left-hand outboard	18.03	
Left-hand outboard 2	1008	Right-hand inboard	23.6	
Left-hand outboard 4	1068	Right-hand outboard	24.81	
Right-hand inboard 1	1224			
Right-hand inboard 3	1104			
Right-hand outboard 2	1224			
Right-hand outboard 4	1164			

## LANDING AND BRAKING PARAMETERS

Parameter	From threshold, ft	Speed, keas	Sink rate, ft/sec	Pitch rate, deg/sec
Main gear touchdown	3068	203.4	1.0	N/A
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Left-hand outboard 2	1008	Right-hand inboard	23.6	
Left-hand outboard 4	1068	Right-hand outboard	24.81	
Right-hand inboard 1	1224			
Right-hand inboard 3	1104			
Right-hand outboard 2	1224			
Right-hand outboard 4	1164			

334:03:59 G.m.t. (09:08:03 MET), the airlock was pressurized to cabin pressure following the decision to delay EVA 1 because of difficulties opening the outer hatch. The RCRS was subsequently reactivated on controller 2 at 334:04:29 G.m.t. (09:08:33 MET).

After wheel-stop at the SLF, the left main gear down measurement toggled off for 1 minute 17 seconds before returning to nominal (Flight Problem STS-80-V-06). The measurement all toggled again after towing to the Orbiter Processing Facility (OPF). Preliminary troubleshooting indicates that the proximity switch electronics assembly is the most likely cause of the anomaly.

### Integrated Aerodynamics, Heating and Thermal Interfaces

The ascent and entry aerodynamics and plume heating were nominal. The prelaunch thermal interface purges were nominal. The entry aerodynamic heating to the SSME nozzles was also nominal. Evaluation of the MADS data showed that the vertical fin experienced an unusual force during ascent at approximately 65 seconds after liftoff. The majority of the 38 strain measurements on the vertical fin show strain levels 1.5 to 3 times the typical levels, which have been attributed to an out-of-family wind gust. A vibration measurement on the right-hand speed brake also shows an unusually high

amplitude at the same time as the strain measurement peaked. The assessment showed that these stress levels were within the capability of the fin structure.

### **Thermal Control Subsystem**

The thermal control subsystem (TCS) performance was nominal during all mission phases. Minor instrumentation and heater problems were noted; however, the mission was not impacted. All subsystem temperatures were maintained within acceptable limits. A total of 21 simplified thermal evaluation program (STEP) thermal analyses were performed to evaluate changes to the planned attitude time lines.

During the prelaunch period, no anomalous heater performance occurred that resulted in heater reconfigurations. The WSB 2 vent heater was noted to be operating on a 100-percent duty cycle, but this did not impact the satisfactory completion of the countdown.

A camera survey of the payload bay revealed two significant insulation gaps located at the inclined face on the port side of the Extended Duration Orbiter (EDO) pallet. The gaps were on each side of a common snap location and approximately 2.5 inches high (maximum location) by 8 inches long and 1 inch high (maximum location) by 5 inches long. These gaps did not have a deleterious thermal effect on the pallet or its contents.

### **Aerothermodynamics**

The acreage heating as well as the local heating was nominal. Boundary layer transition was nominal.

### **Thermal Protection Subsystem and Windows**

The TPS performed satisfactorily. Based on lower-surface structural temperature response data (temperature rise), entry heating was nominal. Boundary layer transition from laminar flow to turbulent flow occurred at approximately 1175 seconds after entry interface at the forward and aft centerline of the vehicle. There were no other measurements or other evidence that would indicate asymmetric transition had occurred.

The postlanding inspection revealed a total of 93 impacts of which 8 had a major dimension of 1-inch or larger. This total did not include the numerous damage sites on the base heat shield that were attributed to the flame arrestment sparkler system. A comparison of these numbers to statistics from 64 previous missions of similar configuration indicates both the total number of damage sites as well as the number of damage sites having a major dimension of one inch or larger were much below the average. The distribution of the hits on the Orbiter is shown in the following table.

## TPS DAMAGE SITES

Orbiter Surfaces	Hits > 1 Inch	Total Hits
Lower Surface	4	34
Upper Surface	4	54
Right Side	0	0
Left Side	0	0
Right OMS Pod	0	2
Left OMS Pod	0	3
Total	8	93

The largest lower surface tile damage site was located aft of the LH<sub>2</sub> ET/Orbiter umbilical and measured 3 inches long by ¾ inch wide by ½ inch deep. The damage was most likely caused by an ice impact from the umbilical. Tile damage sites aft of the LH<sub>2</sub> and LO<sub>2</sub> ET/Orbiter umbilicals were otherwise typical in number and size. The damage was most likely caused by impacts from umbilical ice or shredded pieces of umbilical purge-barrier material flapping in the airstream.

No tile damage from micrometeorites or on-orbit debris was identified during the postlanding inspection; however, a number of window damage sites were noted and these are discussed in a later paragraph.

All three SSME dome-mounted heat shield (DMHS) closeout blankets sustained some damage. The SSME 1 DMHS blanket experienced severe damage at the 6:00 o'clock position. Some of the batting appeared to be missing. The SSME 2 blanket experienced moderate damage at the 1:00 o'clock and 4:00 to 5:00 o'clock positions, but no material appeared to be missing. The SSME 3 blanket was slightly frayed on the outboard edge at the 9:00 o'clock position.

A cluster of seven tiles on the base heat shield between SSME 1 and 3 sustained greater than normal damage, which appeared to be the result of debris impacts rather than plume recirculation effects. The tiles were missing a large percentage of surface area with the average depth of the damage being ¼ inch.

On the forward section of the vehicle, the -441 chin-panel gap-filler breach showed a slight increase to approximately 2.3 inches, but the gap-filler appears acceptable for another flight to provide data for possible increasing the OMRSD replacement interval. There were also several breached gap fillers on the left forward RCS side, the most notable being around thruster F5L.

No ice adhered to the payload bay door, and the yellow discoloration on the leading edge of the left-hand payload bay door was noted. One Ames gap-



filler was protruding on the left-hand chine area. No unusual tile damage occurred on the leading edges of the vertical stabilizer and OMS pods.

Hazing and streaking of Orbiter windows 2, 3, 4, and 5 was less than usual. During the mission, the crew identified a hypervelocity impact on window 8. Impacts of this nature are not unusual events (occurring on almost all missions); however, it is unusual for the crew to visibly identify them because of this tiny size. During the postflight inspection, several impacts on several windows were identified. All of the window impacts from this mission are average/typical in size. The following delineates the number of damage sites per window and the flight status of each window.

- a. Window 1 - One impact with window retained for flight, but window is restricted to the Window-1 position;
- b. Window 2 - Seven impacts with window retained for flight, but window is restricted to the Window-2 position;
- c. Window 3 - Six impacts with window retained for flight;
- d. Window 4 - Ten impacts with window retained for flight;
- e. Window 5 - No impacts;
- f. Window 6 - No impacts;
- g. Window 7 - Three impacts and window was scrapped;
- h. Window 8 - Four impacts and window was scrapped;
- i. Window 9 - Inspection continuing;
- j. Window 10 - Inspection continuing; and
- k. Window 11 - No impacts.

The number of impacts sustained by the overhead windows (window 7 and 8) is unusual since the vehicle was flown in a fairly protective attitude for these particular windows for much of the mission duration. This implies that several of these impacts may have been caused by micrometeoroids rather than debris.

Damage sites on the window perimeter tiles (10 on window 2, 7 on window 3, 6 on window 4, and 11 on window 5) were attributed to impacts from the forward RCS thruster paper covers/room temperature vulcanizing (RTV) adhesive.

## REMOTE MANIPULATOR SYSTEM

The STS-80 mission was the forty-sixth flight of the Remote Manipulator System (RMS) in the Space Shuttle as well as the second flight of the serial number 202 arm. The primary RMS activities were the deployment and retrieval of the two free-flying payloads and survey activities of the airlock hatch that could not be opened. The hatch anomaly resulted in the cancellation of the EVAs and one of the planned RMS tasks of support the EVAs. The RMS successfully completed all of the required activities and was powered down for the last time following the berthing of the ORFEUS-SPAS.

The initialization of the RMS was completed approximately 3.5 hours after liftoff on flight day 1. Following satisfactory initialization, the RMS checkout was completed with nominal results. The ORFEUS/SPAS was grappled and satisfactorily deployed using the RMS at 325:04:10:50 G.m.t. (00:08:15:03 MET). On flight day 2, the RMS was uncradled at 325:21:40 G.m.t. (01:01:44 MET) and used to support the OSVS video taping survey of the WSF.

The WSF was deployed on flight day 4; however, prior to deployment the WSF was maneuvered to the ram cleaning position for approximately 2.5 hours followed by 1.5 hours in the WSF attitude determination and control system (ADACS) checkout position. After release of the WSF, the RMS was maneuvered to the WSF viewing position for 30 minutes for video documentation of the WSF separation from the Orbiter.

On flight day 7, the RMS again grappled WSF at 331:02:02:10.7 G.m.t. (06:06:06:23.7 MET) and berthed and latched in the payload bay. The following day, the WSF was again grappled, unberthed and maneuvered to the Atomic Oxygen Processing (AOPROC) cleaning position for 1.5 hours. Following the cleaning, the WSF was maneuvered to the AOPROC position for the final WSF experiment. After completion of the experiment, the WSF was maneuvered to several viewing locations in support of OSVS activities.

Flight day 10 was originally planned as an EVA operations support day for the first EVA; however, cancellation of the EVA deleted these operations. Instead, the RMS was used to perform five video surveys of the airlock hatch during the next five days. The data received from the video was used extensively during the airlock hatch failure investigation.

On flight day 15 at 339:08:25:46 G.m.t. (14:12:29:59 MET), the RMS grappled the ORFEUS-SPAS to conclude the successful rendezvous and retrieval of the ORFEUS-SPAS satellite. Prior to berthing, a number of maneuvers were performed in support of the OSVS documentation activities. Included in these OSVS activities was berthing of the payload three times prior to the final berthing and latching of the payload.

## **FLIGHT CREW EQUIPMENT/GOVERNMENT FURNISHED EQUIPMENT**

The flight crew equipment/government furnished equipment performed nominally throughout the STS-80 mission. Three in-flight anomalies were identified and these are discussed in the following paragraphs.

During a low-light-level period, closed circuit television (CCTV) camera C had an anomalous iris response that resulted in an intermittent flickering appearance in the downlinked image (Flight Problem STS-80-F-01). This camera was a black-and-white low-light unit of an older configuration that was not solid-state. The flickering occurred during all automatic modes and during manual iris operations, and the camera was not usable during low-light level operations. The camera operated properly when used at normal daylight levels. Postflight testing of the unit revealed a problem in the high voltage power supply section of the camera.

One of the camcorders exhibited horizontal tearing in the downlinked video (Flight Problem STS-80-F-02). The crew reported that the onboard display had a normal picture. The crew later played back the same video using the TEAC camcorder, and the tearing was not present in the downlinked video. As a result, the anomalous camera was not used for playback of video during the remainder of the mission. Postflight testing of the unit will be performed.

On several occasions during the mission, the RMS elbow video camera did not indicate active color balance settings when power was applied to the unit (Flight Problem STS-80-F-03). It was necessary for the ground control personnel to use video display (VIDD) to determine the color balance setting because the camera did not have an active color-balance setting. The ground controller was required to command the Sun color-balance on. The color television camera (CTVC) is designed to initialize in the Sun color balance mode and not require commanding from the ground. After removal of this camera from the RMS, postflight testing of the unit will be performed.

During EMU checkout for the EVA, the biomedical signal from extravehicular crew person 2 (EV-2) was lost. The signal from the electrocardiogram (EKG) was not available when this signal is lost. Since the EKG was not required for the EVA, the condition would not have impacted the EVA. In-flight troubleshooting isolated the problem to the EV2 signal conditioner, which was replaced with a unit from the medical kit. Postflight troubleshooting of the failed signal conditioner will be performed.

## **CARGO INTEGRATION**

Integration hardware performance was nominal throughout the mission with no problems or anomalies identified.

The results of the IMAPS spectrograph were noticeably improved over the previous mission (STS-51). The improved results are attributed to the addition of a prelaunch GN<sub>2</sub> purge on STS-80. This purge minimized the possibility of moisture collection on the instrumentation during countdown operations that was believed to be the cause of degraded results on STS-51. The capability was provided through the T-O umbilical using fluid-line mission-kit integration hardware.

## **DEVELOPMENT TEST OBJECTIVES/DETAILED SUPPLEMENTARY OBJECTIVES**

### **DEVELOPMENT TEST OBJECTIVES**

DTO 255 - Wraparound DAP Flight Test Verification - Part 2 - This DTO of opportunity was performed during entry. The data have been given to the sponsor for evaluation. The results will be published in separate documentation.

DTO 312 - ET TPS Performance (Method 1 with maneuver) - Photography of the ET for this DTO was taken using the Nikon 35 mm camera, 300 mm lens and a 2X extender. Nine views of the ET were received with the -Y axis of the ET being imaged. The first picture was taken 15 minutes after liftoff and the last picture was taken 2 minutes 29 seconds later. No anomalies were noted in the photographs of the ET; however, back-lighting from the late afternoon sun hindered analysis.

Three rolls of STS-80 umbilical well camera film of the ET were also reviewed following the flight. Two of the films were 16 mm and the other was 35 mm. The 16 mm cameras were in the LH<sub>2</sub> umbilical and the 35 mm was located in the LO<sub>2</sub> umbilical. Good coverage of the left SRB separation and the ET separation was acquired, and no anomalous conditions were noted.

In addition, one minute and 12 seconds of hand-held video of the ET was downlinked by the crew. The nose of the ET, the -Z and the -Y axes were imaged. The video was degraded by signal break-up and back-lighting from the sun. The ET appears to be in good condition, and no anomalous conditions were noted in the video. Some debris was noted; however, the debris was out of focus and appeared to be near the Orbiter.

DTO 667 - Portable In-Flight Landing Operations Trainer - This Portable In-Flight Landing Operations Trainer (PILOT) was exercised by the Commander and Pilot during the flight. The results of their evaluation will be presented in separate documentation.

DTO 671 - EVA Hardware for Future Scheduled EVA Missions, Test 13 - This DTO was not accomplished as the EVAs were cancelled.

DTO 700-10 - Orbiter Space Vision System Flight Video Taping - Video from payload bay cameras A and C was recorded as the Orbiter separated from the SPAS. In addition, video from cameras A and B was recorded during the SPAS approach and rendezvous. Camera C was to be used for the latter video; however, an intermittent power supply problem resulted in a change to camera B. Both periods of video were recorded and will aid in the evaluation of the rendezvous and proximity operations.

Crew sleep period video was recorded on flight night 1 when cameras A and D were commanded by the Mission Control Center (MCC) to perform a subset of the Orbiter Space Vision System (OSVS) checkout that the crew performed the following day. The cameras viewed OSVS targets on the port and starboard wire trays in bay 3 and targets on the WSF carrier and spacecraft. Downlink video was evaluated and the performance was excellent for all tasks completed.

In addition, on subsequent nights during crew-sleep periods, cameras A and D were commanded by ground controllers to assess a number of photogrammetric procedures and techniques in support of Space Station assembly operations. The video included views that will be used for:

- a. Comparisons of camera aiming using different fields-of-view;
- b. Camera aiming system calibrations with calibrating zoom settings;
- c. Camera aiming system calibrations using uncharacterized fields-of-view;
- d. Camera aiming accuracy based on a single target;
- e. Small target test videos; and
- f. On-Orbit survey assessments.

Three plates were mounted on the top surface of the WSF to simulate OSVS targets on the end-cone surfaces of the International Space Station (ISS) Nodes and Laboratory modules. The targets contained grooves and ridges similar to what will be found on the Node and Laboratory modules. The unloaded RMS was maneuvered to use the wrist camera to view the WSF targets under on-orbit lighting conditions. The video was evaluated by ISS assembly personnel.

On flight day 8, the WSF was maneuvered with the RMS to a position that simulated the camera-to-OSVS target relationship that will be seen for the 2A functional cargo block (FGB) installation task. Video from camera A was recorded of the OSVS targets on two different surfaces, and that video was downlinked for postflight assessment.

Because of the cancellation of the EVA, an additional video task was performed to obtain video data of a series of camera parameter permutations to quantify camera/lighting interaction. The results of these tests will provide useful inputs to quantifying camera response time for the camera control interface function (CCIF) algorithm development.

DTO 700-11 - Orbiter Space Vision System Flight Unit Testing - Based on the activities completed and preliminary results, STS-80 is considered to be an extremely successful mission from the DTO 700-11 standpoint as well as the OSVS program. The system berthing performance for both the WSF and the SPAS was extremely good as well as highly accurate (within 1 inch/degree). All of the higher priority objectives were performed, and most were completed. The video recorded will be valuable in preparing for assembly tasks on ISS mission 2A and 3A. Significant strides were made in the process for

predicting and responding to on-orbit lighting conditions. Also the nearly real-time planned activities on flight day 11 and 13 provided valuable data on the ability of the flight control team to monitor the performance of the onboard unit based solely on downlink video.

One of the lessons learned about this system was the process that was set-up to predict and assess expected lighting conditions during OSVS activities. The flight controllers modified existing Ku-band antenna prediction programs to generate plots and mission elapsed times when the Sun would be in the field-of-view of the camera and when a target array would experience partial shadowing. Plots were generated daily and the results were sent to the crew in uplink messages.

In addition, an analysis was performed to develop pictures of the expected lighting. These pictures were of particular value in understanding the expected lighting during times where Pointer predicts identified potential times of concern. The correlation between the Pointer lighting predictions (timing) as well as the pictures was very good. In the case of the WSF 2A FGB installation video, light-prediction data were used to suggest a different Orbiter attitude that would provide acceptable lighting. On flight day 15, the lighting predictions foretold some of the lighting challenges that were faced by the crew during SPAS berthing that caused some delays in the timeline.

The initial video obtained for this DTO was taken using cameras A and D. The cameras were aimed by ground controllers to record video of the SPAS target array in relation to the Orbiter wire tray target arrays prior to SPAS unlatching and unberthing. The data provided data for ground controllers to assess expected vision-system performance during berthing for use later in the mission.

On flight day 2, the crew set-up two advanced space vision unit (ASVUs) on the aft flight deck (AFD) and performed the OSVS power-up and checkout, which included:

- a. Camera A and D viewing of the starboard and port Orbiter wire tray target arrays;
- b. Camcorder viewing through starboard AFD window of wire tray target arrays;
- c. RMS elbow camera video of the starboard wire tray target array while simulating SPAS unberthing and berthing maneuvering; and
- d. Camera A and D viewing of the WSF carrier and spacecraft target arrays.

The checkout results were nominal.

The crew used the ASVU for additional payload position and attitude information during the WSF unberthing tasks as well as during berthing tasks later in the mission. A synthetic display depicting WSF position and attitude with respect to the carrier was generated by the ASVU and displayed on AFD

monitor 2. The crew reported very good system performance during the unberthing and berthing tasks. Downlink video of the synthetic display used by the crew showed all axes after latching within 0.2 inch and 0.2 degree.

Real-time analysis of the downlink video with the MCC ASVU was showing slight differences from the data that was generated by the onboard ASVU. Specifically, camera aiming calibration data, which uses an iterative process to calculate actual camera location and aiming, was slightly shifted in the camera Y-plane.

Loss of the EVA resulted in the crew performing OSVS operations on flight days 11 and 13. These activities involved a simultaneous aiming system-calibration between the onboard ASVU and the MCC ASVU. Although these tests were not planned preflight, valuable data were obtained that quantified differences in downlink video as compared to the onboard unit. Testing results were factored into decisions on the SPAS flight data-base update later in the flight.

After grappling of the SPAS and completion of the RGPS activities, three hours of OSVS activities were performed. The SPAS was initially placed in a position over the crew cabin that simulated the pump module assembly (PMA) installation task on ISS mission 3A. A camcorder was positioned to point outward through the starboard overhead window, and while in a night pass, the crew evaluated the ability of the high intensity spot light (HISL) to illuminate the SVS target array. Prior to daylight, the Orbiter was maneuvered to a solar inertial attitude to illuminate the SVS target array; however, one of the SPAS targets was shadowed in the selected attitude, and the Orbiter attitude was altered slightly to fully illuminate the target. Following the positioning of the Orbiter, the SPAS was maneuvered through a series of preplanned trajectories to simulate the PMA installation task. Video was recorded for postflight analysis.

The SPAS was then maneuvered to a position that simulated the ISS 6A Space Station remote manipulator system (SSRMS) pallet installation task. The crew performed only the first half of the planned maneuvering matrix (video record only) while evaluating the HISL out the window. This curtailment to the testing was the result of the Orbiter passing through the sunset terminator.

The SPAS was then maneuvered to the low hover position and berthed in the payload bay using camera A and the SVS display. Results of this berthing indicated that all axes were within 0.6 inch/degree. This was the first berthing performed with SVS targets attached to thermal blankets. A target-array-to-payload (TAP) calibration was performed to zero these errors in preparation for the camcorder berthing task.

The AFD camcorder was repositioned to view out the starboard aft window for viewing the wire tray targets and the berthed SPAS targets. The SPAS was berthed and reberthed – this was the first SVS berthing based on a



camcorder. The crew reported good subsystem performance except for an offset in the X-axis; this offset was not observed on the ground ASVU and it will be investigated during postflight testing.

The crew performed the final unberthing and reberthing of the SPAS using the RMS elbow camera, and because of time constraints, the ASVU was not set up for use. The SPAS was latched following the final berthing. Two additional procedures were not performed because of time constraints; however, the MCC commanded cameras A and D to record short segments of video after SPAS was latched in the cargo bay. This post-latching video provided data on system accuracy performance.

DTO 833 - Extravehicular Mobility Unit (EMU) Thermal Comfort and EVA Worksite Thermal Environment Evaluation - This DTO was not accomplished because of the EVA cancellation.

DTO 837 - Vernier RCS Reboost Demonstration - This DTO of opportunity was performed and the data have been given to the sponsor for evaluation. The DTO results will be presented in separate documentation.

DTO 840 - Hand-held Lidar (HHL) Procedures - The equipment for this DTO was exercised by the crew during operations around the Mir. The results of that evaluation were given to the sponsor for further analysis. The results of the analysis will be presented in separate documentation.

#### **DETAILED SUPPLEMENTARY OBJECTIVES**

DSO 485 - Inter-Mars Tissue Equivalent Proportional Counter - The Inter-Mars Tissue Equivalent Proportional Counter (ITEPC) was a passive Detailed Supplementary Objective (DSO) experiment that only required activation and deactivation. The experiment operated satisfactorily for the mission. The equipment has been returned to the primary investigators who will publish the results in separate documentation after completion of the analysis.

## **PHOTOGRAPHY AND TELEVISION ANALYSIS**

### **LAUNCH PHOTOGRAPHY AND VIDEO DATA ANALYSIS**

A total of twelve 16-mm films, nine 35-mm films and 24 launch videos were screened. The only item of significant interest that was noted was the M-7 hold-down post on the left SRB was observed to hang-up during the liftoff. No damage to the left SRB was noted from the films. All other observations made during the screening indicated normal operations.

### **ON-ORBIT PHOTOGRAPHY AND VIDEO DATA ANALYSIS**

#### **External Tank Video Analysis**

One minute and 12 seconds of hand-held video of the STS-80 External Tank (ET) after separation was downlinked by the crew and screened for anomalous conditions. The nose of the ET, and the -Z and the -Y axes of the ET were imaged. The video was degraded because of signal break-up and back-lighting from the Sun. The visible portions of the ET appear in good condition with no anomalous conditions noted. Multiple pieces of white-colored debris are visible; however, the debris is out of focus and appears to be close to the camera.

#### **Hatch Anomaly Video Analysis**

To assist in the investigation of the hatch anomaly, video was analyzed, and the findings were as follows:

1. The orientation of each latch link was measured relative to the deflection angle of each latch link. The total rotation of a latch link from fully latched to its dead-on-center (DOC) perpendicular orientation was 2.15 degrees. Four of the latches were rotated beyond DOC, and the measurements on the other two latch positions could not be measured with exactness.
2. Determining the relative times that the six latches reached the jammed position could not be defined because video of all six latches simultaneously was not available.
3. Video of the simultaneous motion of both deployable legs to determine the relative times that the legs reached the jammed position showed that both legs reached the jammed position within 0.03 second (one video frame) of each other.
4. The inspection of the starboard leg mechanism for debris (smart-bolt theory) did not reveal any debris in the six video segments analyzed.

## **LANDING PHOTOGRAPHY AND VIDEO DATA ANALYSIS**

Eleven videos of landing were screened on landing day. No anomalous conditions were noted in the screening of the videos. Two items of interest were noted during the drag chute deployment process. A piece of debris was noted coming from the pilot chute that traveled aft of the Orbiter. A second piece of string-like debris was first seen near the vertical stabilizer and it also traveled aft of the Orbiter. Neither condition was considered to be a problem.

**TABLE I.- STS-80 SEQUENCE OF EVENTS**

Event	Description	Actual time, G.m.t.
APU Activation	APU-1 GG chamber pressure APU-2 GG chamber pressure APU-3 GG chamber pressure	324:19:48:12.749 324:19:48:14.100 324:19:48:15.163
SRB HPU Activation <sup>a</sup>	LH HPU System A start command LH HPU System B start command RH HPU System A start command RH HPU System B start command	324:19:55:19.120 324:19:55:19.280 324:19:55:19.440 324:19:55:19.560
Main Propulsion System Start <sup>a</sup>	ME-3 Start command accepted ME-2 Start command accepted ME-1 Start command accepted	324:19:55:40.442 324:19:55:40.562 324:19:55:40.651
SRB Ignition Command (Liftoff)	Calculated SRB ignition command	324:19:55:46.990
Throttle up to 104 Percent Thrust <sup>a</sup>	ME-1 Command accepted ME-3 Command accepted ME-2 Command accepted	324:19:55:50.772 324:19:55:50.803 324:19:55:50.803
Throttle down to 97 Percent Thrust <sup>a</sup>	ME-1 Command accepted ME-3 Command accepted ME-2 Command accepted	324:19:56:04.532 324:19:56:04.563 324:19:56:04.563
Throttle down to 67 Percent Thrust <sup>a</sup>	ME-1 Command accepted ME-3 Command accepted ME-2 Command accepted	324:19:56:13.652 324:19:56:13.683 324:19:56:13.683
Throttle up to 104 Percent <sup>a</sup>	ME-1 Command accepted ME-2 Command accepted ME-3 Command accepted	324:19:56:42:293 324:19:56:42:323 324:19:56:42:324
Maximum Dynamic Pressure (g)	Derived ascent dynamic pressure	324:19:56:54
Both RSRM's Chamber Pressure at 50 psi <sup>a</sup>	RH SRM chamber pressure mid-range select LH SRM chamber pressure mid-range select	324:19:57:45.270 324:19:57:46:110
End RSRM <sup>a</sup> Action <sup>a</sup> Time	LH SRM chamber pressure mid-range select RH SRM chamber pressure mid-range select	324:19:57:47:490 324:19:57:48:230
SRB Physical Separation <sup>a</sup>	RH rate APU B turbine speed - LOS	324:19:57:50:990
SRB Separation Command	SRB separation command flag	324:19:57:52
Throttle Down for 3g Acceleration <sup>a</sup>	ME-1 command accepted ME-2 command accepted ME-3 command accepted	324:20:03:19.581 324:20:03:19.606 324:20:03:19.613
3g Acceleration	Total load factor	324:20:03:21.4
Throttle Down to 67 Percent Thrust <sup>a</sup>	ME-1 command accepted ME-2 command accepted ME-3 command accepted	324:20:04:10.462 324:20:04:10.487 324:20:04:10.494
SSME Shutdown <sup>a</sup>	ME-1 command accepted ME-2 command accepted ME-3 command accepted	324:20:04:17.062 324:20:04:17.087 324:20:04:17.094
MECO	MECO command flag MECO confirm flag	324:20:04:18 324:20:04:18
ET Separation	ET separation command flag	324:20:04:37

<sup>a</sup>MSFC supplied data

**TABLE I.- STS-80 SEQUENCE OF EVENTS  
(Continued)**

Event	Description	Actual time, G.m.t.
APU Deactivation	APU-3 GG chamber pressure APU 1 GG chamber pressure APU 2 GG chamber pressure	324:20:09:28.666 324:20:11:10.859 324:20:11:27.023
OMS-1 Ignition	Left engine bi-prop valve position Right engine bi-prop valve position	Not performed - direct insertion trajectory flown
OMS-1 Cutoff	Left engine bi-prop valve position Right engine bi-prop valve position	N/A
OMS-2 Ignition	Left engine bi-prop valve position Right engine bi-prop valve position	324:20:36:11.5 324:20:36:11.5
OMS-2 Cutoff	Right engine bi-prop valve position Left engine bi-prop valve position	324:20:39:12.5 324:20:39:12.5
Payload Bay Doors (PLBDs) Open	PLBD right open 1 PLBD left open 1	324:21:35:04 324:21:36:25
ORFEUS-SPAS Unberthing	PLD SEL 1 latch 1B ready-for-latch	325:02:51:06
ORFEUS-SPAS Release	Payload captured	325:04:10:50
WSF Unberthing	PLD SEL 2 latch 4A ready-for-latch	327:21:00:14
WSF Release	Payload captured	328:01:37:40
OMS-3 Ignition	Left engine bi-prop valve position Right engine bi-prop valve position	N/A 330:23:45:42.3
OMS-3 Cutoff	Left engine bi-prop valve position Right engine bi-prop valve position	N/A 330:23:45:51.7
WSF Capture	Payload captured	331:02:02:11
WSF Berthing	PLD SEL 2 latch 4A ready-for-latch	331:02:33:51
WSF Latch	PLD SEL 2 latch 4B latched indication	331:02:36:01
OMS-4 Ignition	Left engine bi-prop valve position Right engine bi-prop valve position	N/A 339:06:08:47.1
OMS-4 Cutoff	Left engine bi-prop valve position Right engine bi-prop valve position	339:06:08:56.9 N/A
SPAS Capture	Payload captured	339:08:25:47
SPAS Berthing	PLD SEL 1 latch 1A ready-for-latch	339:13:03:41
SPAS Latch	PLD SEL 1 latch 1A latched	339:13:13:48
OMS-5 Ignition	Left engine bi-prop valve position Right engine bi-prop valve position	339:14:52:47.3 N/A
OMS-5 Cutoff	Right engine bi-prop valve position Left engine bi-prop valve position	339:14:53:05.9 N/A
FCS Checkout    APU Start APU Stop	APU 1 GG chamber pressure APU 1 GG chamber pressure	340:02:41:27.499 340:02:46:10.677
Payload Bay Doors Close	PLBD left close 1 PLBD right close 1	340:08:48:13 340:08:49:55
Payload Bay Doors Open	PLBD right open 1 PLBD left open 1	340:13:32:13 340:13:33:32
Payload Bay Doors Close (2)	PLBD left close 1 PLBD right close 1	341:10:49:41 341:10:51:17
Payload Bay Doors Open (3)	PLBD right open 1 PLBD left open 1	341:13:50:01 341:13:51:20

**TABLE I.- STS-80 SEQUENCE OF EVENTS  
(Concluded)**

<b>Event</b>	<b>Description</b>	<b>Actual time, G.m.t.</b>
OMS-6 Ignition	Left engine bi-prop valve position	341:16:31:12.1
	Right engine bi-prop valve position	341:16:31:12.1
OMS-6 Cutoff	Left engine bi-prop valve position	341:16:31:27.7
	Right engine bi-prop valve position	341:16:31:27.7
Payload Bay Doors Close (3)	PLBD left close 1	342:08:07:34
	PLBD right close 1	342:08:09:07
APU Activation for Entry	APU-2 GG chamber pressure	342:10:37:41.262
	APU-1 GG chamber pressure	342:11:04:57.167
	APU-3 GG chamber pressure	342:11:04:58.714
Deorbit Burn Ignition	Left engine bi-prop valve position	342:10:43:02.2
	Right engine bi-prop valve position	342:10:43:02.3
Deorbit Burn Cutoff	Left engine bi-prop valve position	342:10:46:10.7
	Right engine bi-prop valve position	342:10:46:10.8
Entry Interface (400K feet)	Current orbital altitude above	342:11:17:45
Blackout end	Data locked (high sample rate)	No blackout
Terminal Area Energy Mgmt.	Major mode change (305)	342:11:42:52
Main Landing Gear Contact	LH main landing gear tire pressure 1	342:11:49:04
	RH main landing gear tire pressure 2	342:11:49:04
Main Landing Gear Weight on Wheels	LH main landing gear weight on wheels	342:11:49:06
	RH main landing gear weight on wheels	342:11:49:06
Drag Chute Deployment	Drag chute deploy 1 CP volts	342:11:49:08.1
Nose Landing Gear Contact	RGA 1 pitch rate	342:11:49:16.7
Nose Landing Gear Weight On Wheels	NLG no weight on wheels	342:11:49:18
Drag Chute Jettison	Drag chute jettison 1 CP Volts	342:11:49:40.1
Wheel Stop	Velocity with respect to runway	342:11:50:13
APU Deactivation	APU-1 GG chamber pressure	342:12:05:28.709
	APU-2 GG chamber pressure	342:12:05:40.051
	APU-3 GG chamber pressure	342:12:05:49.096

TABLE II.- STS-80 ORBITER IN-FLIGHT ANOMALY LIST

No.	Title	Reference	Comments
STS-80-V-01	Aft Hydrogen Concentration High	324:19:53 G.m.t. Prelaunch CAR 80RF01 IPR 83V-0005	Following the initiation of LH <sub>2</sub> prepressurization at T-1 minute 57 seconds, the aft H <sub>2</sub> concentration exceeded the 300-ppm LCC limit (HAZ-03). As a result of the limit being exceeded, the preplanned contingency procedure to hold the countdown for two minutes to confirm that the concentration did not exceed 600-ppm, was invoked. An equilibrium concentration of approximately 600 ppm was observed and, after a hold of approximately 2 minutes 47 seconds, the decision was made to launch the vehicle as planned.
STS-80-V-02	Airlock Outer Hatch Failure To Unlatch	334:02:30 G.m.t. 009:06:34 MET CAR 80RF04 IPR 83V-0006 PR MEQ-2-22-0865	The crew reported that they were unable to unlatch the outer hatch of the airlock when they attempted to open the hatch for the extravehicular activity (EVA) scheduled for flight day 10. This was the first attempt to unlatch the hatch during this mission. The crew description of the difficulty, as well as video downlink of the payload-bay side and airlock side of the hatch, and airlock qualification hardware were analyzed and evaluated to determine what may have caused the failure of the hatch to open. Further attempts to turn the handle past the 30-deg point were unsuccessful. As a result, the planned EVAs were cancelled.  The post-mission inspection determined that the cause of the failure was a loose screw within the hatch actuator mechanism. The screw had backed out and was lodged within the actuator's gears.
STS-80-V-03	IMU 1 Failure	339:09:21 G.m.t. 014:13:25 MET CAR 80RF05 PR GNC-2-22-0123	At approximately 339:09:21 G.m.t. (14:13:25 MET), shortly after rendezvous with the ORFEUS-SPAS, the inertial measurement unit (IMU) 1 attitude began degrading, and the IMU was deselected by the crew. Several built-in test equipment (BITE) indications were annunciated (redundant rate fail, platform fail, IMU good, and platform temperature) and the IMU was taken to standby at 339:10:09 G.m.t. (14:14:13 MET). Data review indicates that the IMU failure occurred for a period of 28 minutes and then recovered and remained operational for the remaining 20 minutes that the unit was in the operate mode.  Because IMU 1 appeared to have recovered before it was transitioned to standby, it was transitioned to operate at 340:03:58 G.m.t. (15:08:02 MET), aligned, and left deselected for the flight day 16 landing attempt. The IMU performed nominally but was taken back to standby when the decision was made to wave-off landing due to unacceptable weather. During the crew sleep period, an inner roll null BITE was annunciated, and the

TABLE II.- STS-80 ORBITER IN-FLIGHT ANOMALY LIST

No.	Title	Reference	Comments
STS-80-V-03 (Continued)	IMU 1 Failure (Continued)	339:09:21 G.m.t. 014:13:25 MET CAR 80RF05 PR GNC-2-22-0123 (Continued)	<p>ground asked the crew to take IMU 1 to off. However, analysis determined that the BITE resulted from the way the software operates when the IMU is communications faulted. This is a known condition and has a user note (DR 47741). A DEU equivalent was sent to mask the BITE indications for IMU 1 during crew sleep periods.</p> <p>The following day the crew again transitioned IMU 1 to operate for the flight day 17 landing attempt. The IMU was deselected with its BITEs masked. The landing attempt was waved off due to unacceptable weather; however, IMU 1 operated faultlessly. For sleep, the ground had the crew turn-off the IMU and its BITEs remained masked. For the flight day 18 entry, IMU 1 was powered on, put in operate, and left deselected. It performed nominally during entry and landing.</p>
STS-80-V-04	SPAS Keel Latch Trunnion-In-Place System 2 Indication Failed	339:12:45 G.m.t. 014:16:49 MET CAR 80RF06 IPR 83V-0011	<p>During berthing of the ORFEUS-SPAS, the keel latch trunnion-in-place system 2 indication did not transfer on as required. The keel latch trunnion-in-place system 1 indication was on and the keel latch was subsequently latched (both latch indications received). The system 2 trunnion-in-place indication remained off.</p>
STS-80-V-05	-Y Star Tracker Pressure BITE	340:14:32 G.m.t. 015:18:36 MET CAR 79RF12 PR GNC-2-22-0124	<p>During star tracker (ST) reactivation following the flight day 16 entry wave-off, the -Y ST (S/N 5) annunciated a pressure BITE for approximately five minutes beginning at 340:14:32:10 G.m.t. (15:18:36:23 MET). After the BITE cleared, the ST functioned nominally, successfully acquiring stars. The same thing occurred after the flight day 17 entry wave-off. It is expected that the BITE is real, and that the pressure is near its lower BITE limit of 15.44. The ST is normal pressurized with argon gas to 17.58 psia to prevent moisture and contamination from entering the ST during entry and ground operations. The ST continued to operate nominally with no impact to flight operations.</p>
STS-80-V-06	Left Main Gear Down and Locked Indication Toggled	342:12:07:11 G.m.t. 017:16:11:24 MET (Postlanding) CAR 80RF08	<p>Between one and two minutes after APU shutdown postlanding, the left main landing gear down-and-locked indication (V51X0125E) changed from on to off. About 78 seconds later, the indication toggled back to on where it remained. The indicator is a proximity-type sensor.</p>



TABLE III.- GOVERNMENT FURNISHED EQUIPMENT PROBLEM TRACKING LIST

No.	Title	Time	Comments
STS-80-F-01	CCTV Camera C Flickering	325:08:45 G.m.t. 00:12:49 MET VJCS-2-22-0299	During a low-light-level period, closed circuit television (CCTV) camera C (P/N 2294819-508, S/N 030; MLA P/N 2294820, S/N F002) had an anomalous iris response, resulting in an intermittent flickering appearance of the downlinked image. This camera is a black and white low-light unit (old style, not solid-state). The flickering occurred during all automatic modes and during manual iris operations. The camera operated properly when used during daylight.
STS-80-F-02	Camcorder S/N 1020 Downlink Playback Bad	325:18:54 G.m.t. 00:22:59 MET	The downlinked video image for the ET photographic DTO and payload bay door opening showed a jumpy picture (horizontal tearing). The crew reported their onboard display was nominal. The crew later played back the same video using the TEAC recorder and the tearing was not present in the downlinked image. The camcorder will be used for recording or as a stand-alone camera, but will not be used for playback. Postflight testing of the camcorder will be performed.
STS-80-F-03	RMS Elbow Camera Experienced No Active Color Balance Setting	337:15:48 G.m.t. 12:19:53 MET IPR 83V-0009 VJCS-2-22-0300	At 337:15:48 G.m.t. (12:19:53 MET), the RMS elbow camera (CTVC) did not indicate active color balance settings upon power-up. The ground controller used the VIDD to determine the camera setting because the camera did not have an active color balance setting. The ground controller commanded the SUN color balance on. The CTVC cameras are designed to initialize in the SUN color balance mode and not require additional commanding from the ground. The event appears to be random, and occurred several times during the mission.

TABLE IV.- EVA EQUIPMENT PROBLEM TRACKING LIST

No.	Title	Time	Comments
STS-80-X-01	EV 2 Biomedical Signal Conditioner Failed	334:02:33 G.m.t. 09:06:39 MET CAR 80RF06	During EMU checkout for the EVA, the biomedical signal for EV2 was lost. The signal from the electrocardiogram (ECG) is not available when this signal is lost. Since the ECG was not required for this EVA, the condition would not have impacted the EVA operations. In-flight troubleshooting isolated the problem to the EV2 signal conditioner. The EV2 signal conditioner was replaced with a unit from the medical kit. Postflight troubleshooting of the signal conditioner will be performed.

## 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 (CSR) Daily Science Reports, and Final CSR Report
4. MER Daily Reports
5. MER Mission Summary Report
6. MER Problem Tracking List
7. MER Event Times
8. Subsystem Manager Reports/Inputs
9. MOD Systems Anomaly List
10. MSFC Flash Report
11. MSFC Event Times
12. MSFC Interim Report
13. Crew Debriefing comments
14. 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.

ABS	ammonia boiler system
ADACS	attitude determination and control system
ADDS	Autonomous Dynamics Determination System
AFD	aft flight deck
AOA	Abort Once Around
AOCON	Atomic Oxygen Concentrator
AOPROC	Atomic Oxygen Processing
APU	auxiliary power unit
ARP	Automated Rendezvous Project
ARPCS	atmospheric revitalization pressure control system
ARS	atmospheric revitalization system
ASVU	advanced space vision unit
ATV	Automated Transfer Vehicle
BFS	backup flight system
BITE	built-in test equipment
BRIC	Biological Research in Canister
CCIF	camera control interface function
CCM-A	Cell Culture Module - Configuration
CCTV	closed circuit television
c.d.t.	central daylight time
CEI	contract end item
CMDA	Commercial Materials Dispersion Apparatus
CMIX	Commercial Materials Dispersion Apparatus Instrumentation Technology Associates Experiments
CPL	capillary pumped loop
CTVC	color television camera
DARA	German Space Agency
DMHS	dome-mounted heat shield
DMS	Dual Mass Spectrometer
DSO	Detailed Supplementary Objective
DTO	Developmental Test Objective
$\Delta V$	differential velocity
ECLSS	Environmental Control and Life Support System
ECO	engine cutoff
EDFT	Extravehicular Activity Development Flight Test
EDO	Extended Duration Orbiter
EKG	electrocardiogram
EMU	extravehicular mobility unit
EPDC	electrical power distribution and control
ERADS	Earth Reference Attitude Determination System
ERPCL	Extended Range Payload Communications Link
ET	External Tank
EUV	Extreme Ultraviolet
EVA	extravehicular activity

FCE	flight crew equipment
FCL	Freon coolant loop
FCS	flight control system
FCV	flow control valve
FES	flash evaporator system
FGB	functional cargo block
ft/sec	feet per second
FUV	Far Ultraviolet
g	gravity
GAS	Get Away Special
GFE	Government furnished equipment
GH <sub>2</sub>	gaseous hydrogen
G.m.t.	Greenwich mean time
GPC	general purpose computer
GPS	Global Positioning System
GUCP	ground umbilical carrier plate
H <sub>2</sub>	hydrogen
HHL	Hand-Held LIDAR
HISL	high intensity spot light
HPFTP	high pressure fuel turbopump
HPOTP	high pressure oxidizer turbopump
IMAPS	Interstellar Medium Absorption Profile Spectrograph
IMU	inertial measurement unit
Isp	specific impulse
ISS	International Space Station
I/T	intertank
ITA	Instrumentation Technology Associates
ITEPC	Inter-Mars Tissue Equivalent Proportional Counter
JSC	Johnson Space Center
kbps	kilobits per second
KS	Kansas
KSC	Kennedy Space Center
kW	kilowatt
kWh	kilowatt/hour
lb	pound
lbm	pound mass
lb/min	pound per minute
LCC	Launch Commit Criteria
LH <sub>2</sub>	liquid hydrogen
LMES	Lockheed Martin Engineering and Science
LO <sub>2</sub>	liquid oxygen
MADS	Modular Auxiliary Data System
MBE	Molecular Beam Epitaxy
MCC	Mission Control Center
MDA	Material Dispersion Apparatus
MECO	main engine cutoff
MET	mission elapsed time
MMD	Microgravity Measurement Device
mmHg	millimeters of Mercury
MMT	Mission Management Team

MPS	main propulsion system
MSX	Midcourse Space Experiment
NASA	National Aeronautics and Space Administration
NCC	corrective combination maneuver
NH	height adjust maneuver
nmi.	nautical mile
NPSP	net positive suction pressure
NSTS	National Space Transportation System (i.e., Space Shuttle Program)
OI	Operational Instrumentation
OMRSD	Operations and Maintenance Requirements and Specifications Document
OMS	orbital maneuvering subsystem
OPF	Orbiter Processing Facility
ORFEUS-SPAS	Orbiting Retrievable Far and Extreme Ultraviolet Spectrometer-Shuttle Pallet Satellite
OSVS	Orbiter Space Vision System
PAL	protuberance air load
PARE/NIH-R-04	Physiological and Anatomical Rodent Experiment/National Institutes of Health-Rodents-04
PI	payload interrogator
PILOT	Portable In-Flight Landing Operations Trainer
PMA	pump module assembly
PMBT	propellant mean bulk temperature
ppm	parts per million
PRSD	power reactant storage and distribution
PSP	payload signal processor
PTH	parathyroid hormone
RCRS	regenerative carbon dioxide removal system
RCS	reaction control subsystem
RGPS	relative global positioning system
RME	Risk Mitigation Experiment
RMS	Remote Manipulator System
RSRM	Reusable Solid Rocket Motor
RTV	room temperature vulcanizing (material)
S&A	safe and arm
SEAS	Student Experiment on ASTRO-SPAS
SEM	Space Experimentation Module
SEP	separation
SESAM	Surface Effects Sample Monitor
SLF	Shuttle Landing Facility
SODB	Shuttle Operational Data Book
SPAS	Shuttle Pallet Spacecraft
SRB	Solid Rocket Booster
SRSS	Shuttle range safety system
SSME	Space Shuttle main engine
SSRMS	Space Shuttle Remote Manipulator System
STEP	Simplified Thermal Evaluation System
STS	Space Transportation System
TACAN	Tactical Air Navigation
TAP	Target-array-to-payload

TCE	condenser exit temperature
TCS	trajectory control sensor/thermal control subsystem
TDRS-Z	Tracking and Data Relay Satellite-Canberra
TI	terminal phase initiation
TPS	thermal protection system/subsystem
Vdc	volts direct current
VIDD	video display
VIEW-CPL	Visualization in an Experimental Water Capillary Pumped Loop
WSB	water spray boiler
WSF	Wake Shield Facility