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STS-67
SPACE SHUTTLE
MISSION REPORT

May 1995

National Aeronautics and
Space Administration

Lyndon B. Johnson Space Center
Houston, Texas

NOTE

The STS-67 Space Shuttle Mission Report was prepared from inputs received from the Orbiter Project as well as other organizations. The following personnel may be contacted should questions arise concerning the technical content of this document.

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      of the Shuttle Program, the forty-third flight since the return to flight,
      and the eighth flight of the Orbiter vehicle Endeavour (OV-105). In
      addition, the report summarizes the payload activities and the performance
      of the External Tank (ET), Solid Rocket Booster (SRB), Reusable Solid
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     2012, 2033, and 2031 for SSME's 1, 2, and 3, respectively; and BI-071 for
     the SRB's. The left-hand RSRM was designated 360W043A, and the right-hand
     RSRM was designated 360L043B. The primary objective of this flight was to
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     payload. Secondary objectives of this flight were to complete the
     operations of the Protein Crystal Growth - Thermal Enclosure System
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     Experiments (CMIX), the Shuttle Amateur Radio Experiment-2 (SAREX-2), the
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     payloads.
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STS-67

SPACE SHUTTLE

MISSION REPORT

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May 1995

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INTRODUCTION

The STS-67 Space Shuttle Program Mission Report provides the results of the Orbiter vehicle performance evaluation during this sixty-eighth flight of the Shuttle Program, the forty-third flight since the return to flight, and the eighth flight of the Orbiter vehicle Endeavour (OV-105). In addition, the report summarizes the payload activities and the performance of the External Tank (ET), Solid Rocket Booster (SRB), Reusable Solid Rocket Motor (RSRM), and the Space Shuttle main engines (SSME).

The serial numbers of the other elements of the flight vehicle were ET-69 for the ET; 2012, 2033 and 2031 for SSMEs 1, 2, and 3, respectively; and BI-071 for the SRBs. The left-hand RSRM was designated 360W043A, and the right-hand RSRM was designated 360L043B.

The primary objective of this flight was to successfully perform the operations of the Ultraviolet Astronomy (ASTRO-2) payload. Secondary objectives of this flight were to complete the operations of the Protein Crystal Growth - Thermal Enclosure System (PCG-TES), the Protein Crystal Growth - Single Locker Thermal Enclosure System (PCG-STES), the Commercial Materials Dispersion Apparatus ITA Experiments (CMIX), the Shuttle Amateur Radio Experiment-II (SAREX-II), the Middeck Active Control Experiment (MACE), and two Get-Away Special (GAS) payloads.

The STS-67 mission was planned as a 16-day mission plus two contingency days, one for weather avoidance and one for contingency operations. The sequence of events for the STS-67 mission is shown in Table I, the Orbiter Project Problem Tracking List is shown in Table II, and the Government Furnished Equipment (GFE) Problem Tracking List is shown in Table III. In addition, any Integration in-flight anomalies are referenced in the applicable sections of the report. Appendix A lists the sources of data, both formal and informal, that are used in the preparation of this report. Appendix B provides the definition of acronyms and abbreviations found in the report. All times are listed in Greenwich mean time (G.m.t.) as well as mission elapsed time (MET).

The seven-person crew for STS-67 consisted of Stephen S. Oswald, Civilian, Commander; William G. Gregory, Lt. Col., US Air Force, Pilot; John M. Grunsfeld, Ph. D, Civilian, Mission Specialist 1; Wendy B. Lawrence, USN, CDR (Select), flight engineer and Mission Specialist 2; Tamara E. Jernigan, Ph.D., Civilian, Payload Commander and Mission Specialist 3; Samuel T. Durrance, Ph.D., Civilian, Payload Specialist 1; and Ronald Parise, Ph.D., Civilian, Payload Specialist 2. STS-67 was the third space flight for the Commander and Mission Specialist 3, the second space flight for both payload specialists, and the first space flight for the Pilot, Mission Specialist 1, and Mission Specialist 2.

The STS-67 Space Shuttle Program Mission Report fulfills the Space Shuttle Program requirement as documented in JSC 07700, Volume VIII, Appendix E. The requirement that is stated in that document is that each major 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 Marshall Space Flight Center (MSFC) STS-67 Flight Evaluation Reports contain an in-depth discussion of the performance of each of the elements provided by MSFC. The MSFC Flight Evaluation Report is divided in six volumes as follows:

a. Volume I - Executive Summary
b. Volume II - Solid Rocket Booster Project
c. Volume III - Reusable Solid Rocket Motor Project
d. Volume IV - External Tank Project
e. Volume V - Space Shuttle Main Engine Project
f. Volume VI - Main Propulsion System

Copies of these reports may be obtained from the George C. Marshall Space Flight Center, Marshall Space Flight Center, Alabama 35812.

MISSION SUMMARY

During the countdown, while the fuel cells were still powered by the ground reactants, the performance of fuel cells 2 and 3 degraded more rapidly than normal. The fuel cell 2 voltage dropped from 30.6 Vdc to 29.5 Vdc, and the fuel cell 3 voltage dropped from 30.9 Vdc to 29.6 Vdc over a period of 43 minutes. In addition, the voltage degradation was accompanied by a rise in the fuel cell substack differential voltage. Following the period of the initial degradation, a fuel cell purge was performed and the fuel cell performance was recovered. However, some further degradation was noted and a second purge successfully recovered nominal fuel cell performance. Both performance decays were caused by residual helium in the oxygen supply line between the extended duration Orbiter (EDO) pallet and the fuel cell reactant manifold. The fuel cells were switched to internal reactants to sweep any residual helium from the supply line and a third fuel cell purge was performed. Nominal fuel cell performance was noted, and the fuel cells were switched back to ground reactants for the remainder of the countdown. The fuel cells operated satisfactorily throughout the mission.

As a result of a prelaunch Freon coolant loop (FCL) 2 leak, FCL 2 was topped off with an accumulator quantity of 37 percent, which is the Operational Maintenance Requirements and Specification Document (OMRSD) upper limit. During the countdown, when fuel cell heat loads were placed on the Freon loops, the Freon quantity approached the 39-percent Launch Commit Criteria (LCC) limit, and it was believed that the limit might be violated prior to launch. The LCC limits for the FCL quantity are based on a 117-psia Freon pump inlet pressure with a 39-percent accumulator quantity. Analysis showed that the actual FCL 2 inlet pressure was only 96 psia; consequently, the accumulator quantity could reach 55 percent with no impact. An LCC deviation was processed, and the limit was raised to 45 percent in the ground launch sequencer (GLS).

The flash evaporator system (FES) feedline heaters are normally configured to heater string 2 during prelaunch operations. During the countdown, the FES accumulator B feedline temperature began to decrease from 75 °F shortly after cryogenics loading began. The temperature reached 56.6 °F before the heater was reconfigured to string 1. The LCC limit is 56 °F. After the heater reconfiguration, the temperature began to increase; however, the final countdown to launch that begins at T-9 minutes was delayed 1 minute 13 seconds until a positive indication of the temperature increase from the string 1 heater was observed.

The STS-67 Shuttle vehicle was launched at 61:06:38:12.989 G.m.t. (1:38:13 a.m. e.s.t.) on March 2, 1995, after a delay of 1 minute 13 seconds to resolve the FES heater operation anomaly. The ascent phase was nominal in all respects, and no anomalies were identified. All SSME and RSRM start sequences occurred as planned and launch phase performance was satisfactory in all respects. Likewise, first stage ascent performance was as expected. SRB separation, entry, deceleration, and water impact occurred as planned, and the SRB recovery was completed in a nominal manner. Performance of the SSMEs, the ET, and the main propulsion system (MPS) was nominal.

The orbital maneuvering subsystem (OMS) -2 maneuver was performed at 61:07:18:34.5 G.m.t. (00:00:40:21.5 MET). The maneuver was approximately 177.6 seconds in duration and the differential velocity (ΔV) was approximately 279 ft/sec. The Orbiter was in a 187 nmi. circular orbit following the maneuver.

The payload bay doors (PLBDs) were opened for on-orbit operations with the right door open at 61:08:15:13 G.m.t. (00:01:37:00 MET), and the left door open 1 minute 20 seconds later.

At 61:08:54:45 G.m.t. (00:02:16:32 MET), the vernier thruster L5D oxidizer injector temperature became erratic and the thruster was deselected by redundancy management (RM) as FAIL LEAK when the oxidizer temperature dropped below 130 °F. This failure necessitated using the primary reaction control subsystem (RCS) thrusters for vehicle control. The fuel injector temperature did not drop accordingly, thus verifying that this was a false indication. A similar occurrence was noted on STS-68, the last flight of the vehicle. A pre-approved general purpose computer memory (GMEM) change to modify the vernier fail-leak limit for the oxidizer injector temperature was applied at 61:11:59 G.m.t. (00:05:21 MET). The GMEM change allowed the recovery of the vernier thrusters. The GMEM change used was similar to the one used for STS-68 to compensate for a similar problem. The L5D thruster operated nominally throughout the remainder of the mission. Later in the mission, a multiplexer/demultiplexer (MDM) built-in test equipment (BITE) test was performed on channel 7 of card 14 in the FA1 MDM to aid in the troubleshooting of the erratic vernier thruster L5D oxidizer temperature measurement. The BITE test results indicated that the MDM was functioning properly.

At approximately 61:15:19 G.m.t. (00:08:41 MET), the FES, which had been operating in the topping mode on the primary A controller to supplement radiator cooling, went into the standby mode. At approximately 61:16:36 G.m.t. (00:09:58 MET), the FES did not come out of standby as it normally should. It appears that the FES experienced an under-temperature shutdown as it was going into standby. The FES was successfully restarted on the primary A controller and transitioned into and out of standby nominally until approximately 73:11:43 G.m.t. (12:05:05 MET), when the FES went into the standby mode and failed to come out of standby 2 hours and 25 minutes later. Again, the FES had been operating in the topping mode on the primary A controller. This FES experienced a similar occurrence during STS-61 (OV-105 flight 5). It appears that the FES occasionally experiences under-temperature shutdowns when going into standby; however, this cannot be proven conclusively because the instrumentation used by the FES controllers is not available in the telemetry. In all cases, the FES was successfully restarted and there was no mission impact.

RCS primary thruster R4R was deselected by RM due to a fail-leak condition at 61:18:56 G.m.t. (00:12:18 MET). The oxidizer injector temperature decreased to 13.7 °F and the fuel injector temperature went to 42.1 °F. This thruster had not been fired during this mission and no other thruster was firing at the time the leak occurred. At 61:19:18 G.m.t. (00:12:40 MET), when the R4R thruster fuel injector temperature reached 40 °F, the right manifold 4 isolation valves were closed. The oxidizer valve leak rate was estimated at 10,000 scch. After the manifold was isolated, the oxidizer manifold pressure then dropped rapidly to vapor pressure, and fuel manifold pressure slowly dropped due to thermal effects. Beginning at approximately 62:05:00 G.m.t. (00:22:22 MET), the primary thruster R4R fuel and oxidizer injector temperatures tracked each other and cycled in the 80 to 90 °F range as a result of heater operation and the manifold 4 pressure reached 2 psia, indicating all LO_2 had leaked out of the manifold. The right fuel manifold 4 pressure responded to the manifold temperature. The pressure was as high as 200 psia and as low as 45 psia. This manifold pressure response indicated that the R4R fuel valve leakage, if any, was very small.

At 61:21:54 G.m.t. (00:15:16 MET), the crew reported no intercommunications (ICOM) or air-to-ground (A/G) capability using the mid-deck audio terminal unit (ATU) and that the middeck speaker audio had failed. It was also reported that the circuit breaker that powers the middeck ATU was open. A telemetry review showed a 15-ampere spike with a 1-second duration had occurred approximately 16 minutes after launch. It was reported by the crew that a hand-held microphone (HHM) was being configured at that ATU at about the same time. They also stated that the same HHM did not work when used at the airlock ATU. For on-orbit operations, the crew used the airlock ATU with a headset. Later in the mission, the crew performed the ATU and HHM troubleshooting in-flight maintenance (IFM) procedure and called down the results. The results were evaluated, and although a failure was not identified from the data, the breaker was not reset during the remainder of the mission. During the troubleshooting of the ATU and HHM, it was discovered that the incorrect digital multimeter leads were manifested.

The left-hand outboard main landing gear (MLG) tire pressure 1 measurement became erratic at 62:17:39 G.m.t. (01:11:01 MET) for approximately 40 minutes. At 62:18:53 G.m.t. (01:12:15 MET), the erratic behavior resumed. Seven minutes later the measurement went off-scale low, where it remained until 65:02:00 G.m.t. (03:19:22 MET), when the measurement returned to a normal reading. A redundant measurement exists, thus this erratic behavior did not affect the mission.

The fuel cell 1 hydrogen flowmeter operated erratically throughout the mission, fluctuating ± 0.2 lb/hr from the typical reading of 0.5 lb/hr. This condition was also noted on STS-59 and STS-68 (the previous two flights of OV-105) and the decision was made to fly as-is. At 72:00:00 G.m.t. (approximately 11 days MET), the measurement began drifting upward and fluctuated around 0.7 lb/hr. The flowmeters are criticality 3 and are only removed and replaced on a non-interference basis. This flowmeter (S/N H444) and fuel cell S/N 110 have flown on STS-44, -45, -46, -59, -68, and this flight.

When the crew was loading the fourth Hasselblad film canister of the mission at approximately 66:08:13 G.m.t. (05:01:35 MET), the crewmember noted that the data module was missing the Hasselblad data recording system (HDRS) option. The HDRS option prints data such as time and exposure number on the film. An IFM procedure, which included removing and replacing the battery and performing the initialization procedure was completed successfully and proper operation was recovered.

The crew reported at 66:21:42 G.m.t. (05:16:04 MET) that the camcorder power interface (CCPI) failed while being used to power the compact portable light (CPL). The problem was traced to an intermittent contact at the CPL-to-battery-adapter connector. The problem was not previously apparent because an open deadface switch in this connector prevented reading a voltage at the CPL-to-battery-adapter contacts. During subsequent troubleshooting with the deadface switch depressed, the proper CCPI output of 8 volts was observed. An IFM restored the CPL to full operational capability.

While the crew was downlinking video at 69:03:05 G.m.t. (07:20:27 MET), degradation of the video was noted with tearing at the top and bottom of the image. Troubleshooting isolated the problem to the commercial (TEAC) video tape recorder.

The FES feedline heaters were reconfigured from system 1 to system 2 at 69:05:22 G.m.t. (07:22:44 MET). Nominal heater cycles were seen on the FES supply B accumulator/hi-load line system 2 heater. This heater exhibited marginal prelaunch performance when the accumulator feedline temperature approached the LCC limit, and a switch to the system 1 heater was required.

At 69:12:09 G.m.t. (08:05:31 MET), during the first switchover from oxygen (O_2) to nitrogen (N_2) flow following the pressure control system (PCS) reconfiguration from system 1 to system 2, a peak N_2 flow rate of 4.56 lbm/hr was observed. During the next O_2-to-N_2 switchover at 69:22:11 G.m.t. (08:15:33 MET), the peak observed flowrate was 4.0 lbm/hr. During nominal O_2-to-N_2 switchovers, the typical transient response from a cabin regulator lasts for 10 to 20 seconds with a peak flow rate of 1.0 to 1.5 lbm/hr. To prevent nuisance alarms, the caution and warning for this measurement (set at 4.9 lbm/hr) was inhibited. The behavior of PCS system 2 was similar to that observed during the last flight of this vehicle (STS-68) on the first few O_2-to-N_2 switchovers. The hardware caution and warning for N_2 flow was reactivated because data signatures of the O_2-to-N_2 switchovers became nominal.

However, during a switchover at 74:21:49 G.m.t. (13:15:11 MET), the flow went off-scale high (over 5.0 lbm/hr) for about 1.5 minutes and tripped the caution and warning N_2 flow rate alarm which was set at 4.9 lbm/hr. Performance of the regulator following each switchover transient was nominal. Data from previous flights of OV-105 reveal similar transient high PCS 2 N_2 flow behavior; however, this behavior typically disappeared after the first 2 or 3 switchover cycles, but this was not the case on this flight. The caution and warning alarms were inhibited prior to subsequent O_2-to-N_2 switchovers on PCS 2.

Testing of a method to provide communications through the zone of exclusion (ZOE) was successfully conducted on 19 occasions during the mission. The tests were performed in support of the upcoming Mir docking mission, and the procedure used an existing spare Tracking and Data Relay Satellite (TDRS) in concert with the Canberra, Australia, ground station. The tests provided uninterrupted communications throughout a complete orbit of the Earth.

Flight control system (FCS) checkout was completed at approximately 74:18:35:59 G.m.t. (13:11:57:11 MET) with nominal system performance. In support of the FCS checkout, auxiliary power unit (APU) 1 was run for approximately 3 minutes and 36 seconds and consumed 12 lb of fuel. All APU 1 and hydraulic system 1 parameters were nominal. Due to the short APU run-time, water spray boiler (WSB) cooling was not required. Following the checkout, the APU system B heaters were selected at 74:21:17 G.m.t. (13:14:39 MET). All heaters performed nominally.

The extremely successful ASTRO-2 scientific mission was brought to a close with the completion of the last observation, which was that of the moon, at 76:05:05 G.m.t. (14:22:27 MET). All three principal investigators expressed deep satisfaction with the quantity and quality of the data collected. The instrument pointing system (IPS) was stowed at 76:05:36 G.m.t. (14:22:58 MET).

The RCS hot-fire was performed at 76:14:17 G.m.t. (15:07:40 MET). All thrusters except R1A fired nominally. Thruster R1A was deselected by the RM system as failed off because of low chamber pressure (8 psia) during a 320-ms firing. Both oxidizer and fuel flow occurred during the firing, and low heat soak-back confirmed the low performance. During the prelaunch period, the ice inspection team had reported that a clear liquid was dripping from the lip of this thruster.

All entry stowage and deorbit preparations were completed on the nominal end-of-mission landing day (March 17). However, all landing opportunities on March 17 were waived because of unfavorable weather at the Shuttle Landing Facility (SLF). The crew completed all deorbit preparations for a landing at Kennedy Space Center (KSC) on March 18; however, unacceptable weather again forced cancellation of the landing at KSC. A decision was made to land at Edwards Air Force Base (EAFB) on orbit 262. The payload bay doors were closed and latched at 77:18:07 G.m.t. (16:11:29 MET). The deorbit maneuver for an EAFB landing was performed at 77:20:39:13 G.m.t. (16:14:01:00 MET), and the maneuver was 299.4 seconds in duration with a ΔV of 520.5 ft/sec.

Entry was completed satisfactorily, and main landing gear touchdown occurred on EAFB concrete runway 22 at 77:21:47:01 G.m.t. (16:15:08:48 MET) on March 18, 1995. The nose gear touchdown occurred at 77:21:47:14 G.m.t., and the Orbiter drag chute was deployed satisfactorily 2 seconds later. The drag chute was jettisoned at 77:21:47:43 G.m.t., with wheels stop occurring at 77:21:48:00 G.m.t. The rollout was normal in all respects. The flight duration was 16 days 15 hours 8 minutes and 48 seconds. The APUs were shut down 18 minutes 33 seconds after landing.

PAYLOADS

The primary payload of the STS-67 flight was the ASTRO-2. The secondary payloads consisted of the Middeck Active Control Equipment (MACE), the Protein Crystal Growth (PCG) Experiments, the Commercial Materials Dispersion Apparatus Instruments Technology Associates Experiments (CMIX), the Shuttle Amateur Radio Experiments (SAREX-II) and the Get-Away Special payloads.

ASTRO-2 LABORATORY

The Astro-2 Laboratory, which made its second flight on the Space Shuttle, contained three telescopic instruments mounted on the Spacelab Instrument Pointing System (IPS). The Hopkins Ultraviolet Telescope (HUT) was used to performed spectroscopic observations of the electromagnetic spectrum, providing scientists further insight into the elemental makeup and physical conditions present in the celestial objects. The second instrument, the Ultraviolet Imaging Telescope (UIT), was used to photograph objects in ultraviolet light on film that was developed after return to Earth. The third instrument, the Wisconsin Ultraviolet Photo-Polarimeter Experiment (WUPPE), was used to measure the intensity of ultraviolet light and its polarization. Simultaneous observations using the three telescopes provided complementary perspectives of the same celestial objects.

The ASTRO-2 Laboratory and its Spacelab systems, including the IPS, performed in an outstanding manner from activation on flight day 1 to deactivation on flight day 15. The outstanding performance of both hardware and personnel provided the science community with a plethora of ultraviolet astronomical data. At the end of the mission, the principal-investigator (PI) teams reported that the science obtained far exceeded the pre-mission expectations. The UIT PI reported that all of the targets originally planned had been observed. The HUT team reported that more than 100 HUT targets had been observed, and the WUPPE team reported that they had collected more than three times as much data as collected on the ASTRO-1 (STS-35) mission. Additionally, the ASTRO-2 made the first successful ultraviolet observations of the Earth's moon. This extremely successful scientific endeavor produced a wealth of data that will occupy the ultraviolet astronomy community for some time to come. One of the highest priority observing programs, the search for intergalactic helium, was successfully completed.

MIDDECK ACTIVE CONTROL EXPERIMENT

The Middeck Active Control Experiment (MACE) was used to study the active control of flexible structures in space. A small multi-body platform was assembled and free-floated inside the Space Shuttle. Flight day 12 was planned to be the last day of operations for the MACE; however, at the request of the Commander, MACE operations were extended through flight day 14. As a result, a total of 584 protocol runs were completed, with only 381 runs planned prior to the mission. All experiment hardware and software operations were nominal. The MACE-provided Ku-band Interface System (KIS) was used to uplink and downlink messages in lieu of the portable audio data modem (PADM), which experienced random problems as well as being much slower operationally.

PROTEIN CRYSTAL GROWTH EXPERIMENTS

Two Protein Crystal Growth experiment systems were flown on this mission. One was defined as Protein Crystal Growth - Thermal Enclosure System (PCG-TES), and the second was Protein Crystal Growth - Single-Locker Thermal Enclosure System (PCG-STES). Temperatures of the PCG-TES and PCG-STES were controlled within the specified design of 0.1 °C. STS-67 was the longest-active crystal-growth flight of the PCG program. The experiments were deactivated on flight day 16. Final assessment of the experiments will be determined when the co-investigators analyze the crystals.

COMMERCIAL MATERIALS DISPERSION APPARATUS INSTRUMENTATION TECHNOLOGY ASSOCIATES EXPERIMENT

The Commercial Materials Dispersion Apparatus Instrumentation Technology Associates Experiment (CMIX) was the third in a series of six experiments to fly during the Space Shuttle Program. The CMIX included biomedical, pharmaceutical, biotechnology, cell biology, crystal growth and fluids science investigations. Activation and deactivation of the Material Dispersion Apparatus (MDA) and Bioprocessing Module (BPM) were completed nominally. After the last deactivation of the MDA at approximately 66:06:38 G.m.t. (05:00:00 MET), a circuit breaker on the commercial refrigeration module (CRIM) opened. Apparently a short occurred that disabled the heater on the 20 °C side of the CRIM, and that resulted in the CRIM operating with the heaters off for the remainder of the mission. The temperature of the 20 °C side of the CRIM stabilized at approximately 8.8 °C, and this may have degraded the scientific results of the experiment. The CRIM also experienced occasional temperature excursions that required installing the "elephant trunk" cooling duct to bring the temperature within specification.

GET-AWAY SPECIAL PAYLOAD

The GAS payload (G-387/388) consisted of an Australian-manufactured telescope, named Endeavour, as well as the supporting equipment for operating and recording the results of the ultraviolet observations. Ultraviolet observations of deep space were made to study the structure of galactic supernova remnants, the distribution of hot gas in the Magellanic clouds, the hot galactic halo emission, and emissions associated with galactic cooling flows and jets. The GAS observations were completed at approximately 063:09:40 G.m.t. (02:03:02 MET). Live video of the door closure on the GAS canister containing the telescope was received. The payload data were being analyzed as this report was being written.

SHUTTLE AMATEUR RADIO EXPERIMENT-II

The SAREX-II demonstrated the effectiveness of communications between the Orbiter and low-cost ground stations using amateur radio voice and digital techniques. Students from 26 schools in the U. S., South Africa, India and Australia were contacted by voice using the SAREX-II. In addition, the crew completed seven personal contacts. Six of the seven crewmembers participated in the voice contacts. Amateur radio operators world-wide were able to contact the SAREX-II equipment using the automated reply feature of the system.

VEHICLE PERFORMANCE

The vehicle performance was satisfactory throughout the launch, on-orbit, and entry phases of the mission. A total of seven in-flight anomalies (table II) was defined from the Orbiter and none were defined from the MSFC elements. None of the anomalies impacted the mission.

The vehicle performance determination 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 the start of 3g throttling was 451.9 seconds, as compared to the main propulsion system tag value of 452.74 seconds.

SOLID ROCKET BOOSTERS

All SRB systems performed as expected. The SRB prelaunch countdown was normal, and no SRB LCC or OMRSD violations occurred.

The heated ground purge of the SRB aft skirt was used to maintain the case/nozzle joint temperatures within the required LCC ranges. Due to the cold temperatures, the aft skirt purge was operated intermittently to maintain the mean bulk flex bearing temperature above 60 °F and thereby keep the nozzle-to-case joint warmer prior to the LCC time period. At T-15 minutes, the purge was changed to high pressure to inert the SRB aft skirt.

Both SRBs were successfully separated from the ET at T+125.04 seconds. The SRBs were observed with the retrieval ships radar; however, neither SRB was visually sighted until daybreak. Recovery of the SRBs was completed in a normal manner with no problems or anomalies noted.

REUSABLE SOLID ROCKET MOTORS

The RSRMs performed as designed within the contract end item (CEI) specification. Power-up and operation of the igniter and field joint heaters were performed in a routine manner, and all RSRM temperatures were maintained within acceptable limits throughout the countdown.

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 nominal and was calculated to be approximately 1.3 percent at 73.0 seconds (left motor) and approximately 1.3 percent at 80 seconds (right motor) vs. the 3.2 percent allowable. The postflight inspection of the RSRMs indicated nominal performance.

The RSRM propellant mean bulk temperature (PMBT) was 64 °F at liftoff, and the propulsion system performance based on this PMBT is shown in the following table.

RSRM PROPULSION PERFORMANCE

Parameter	Left motor, 64 °F		Right motor, 64 °F	
	Predicted	Actual	Predicted	Actual
Impulse gates				
I-20, 10^6 lbf-sec	64.94	65.18	64.58	64.96
I-60, 10^6 lbf-sec	173.41	174.83	172.63	173.97
I-AT, 10^6 lbf-sec	296.82	296.97	296.94	296.51
Vacuum Isp, lbf-sec/lbm	268.5	268.6	268.5	268.1
Burn rate, in/sec @ 60 °F at 625 psia	0.3677	0.3702	0.3663	0.3693
Burn rate, in/sec @ 81 °F at 625 psia	0.3688	0.3712	0.3673	0.3703
Event times, seconds[a]				
Ignition interval	0.232	N/A	0.232	N/A
Web time[b]	110.8	109.5	111.5	110.3
Separation cue, 50 psia	120.7	119.7	121.3	119.5
Action time[b]	122.8	121.7	123.5	122.2
Separation command	126.2	125.1	126.2	125.1
PMBT, °F	64	64	64	64
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	2.7	2.8	3.4
Tailoff Imbalance Impulse differential, Klbf-sec	Predicted		Actual	
	N/A		836.9	

Impulse Imbalance = left motor minus right motor

[a] All times are referenced to ignition command time except where noted by a [b].

[b] Referenced to liftoff time (ignition interval).

EXTERNAL TANK

All objectives and requirements associated with the ET propellant loading were met satisfactorily. All ET electrical equipment and instrumentation operated nominally. The ET purge and heater operations all performed properly with one exception. The heater on the primary ET liquid hydrogen (LH_2) anti-icing purge failed prior to tanking. The auxiliary unheated higher flow purge was used, and it functioned properly throughout loading. No ET LCC or OMRSD violations were identified.

Typical ice/frost formations were observed on the ET during the countdown. No ice was observed on the acreage areas of the ET. Less than usual quantities of ice or frost were present on the liquid oxygen (LO_2) and LH_2 feedlines and on the pressurization line brackets, and small amounts of ice or frost were observed along the LH_2 protuberance air load (PAL) ramps. All observations were acceptable per NSTS-08303. The Ice/Frost Inspection Team reported that no anomalous thermal protection system (TPS) conditions were present.

The ET pressurization system functioned properly throughout engine start and flight. The minimum ullage pressure experienced during the ullage pressure slump was 13.7 psid.

ET separation was performed satisfactorily, and ET entry and breakup occurred approximately 78 nmi. uprange of the preflight predicted intact impact point.

SPACE SHUTTLE MAIN ENGINES

All SSME parameters appeared normal throughout the prelaunch countdown and were typical of prelaunch parameters observed on previous flights. Engine-ready was achieved at the correct time; all LCC were met; and engine performance during start, thrust build-up, and mainstage were normal.

Flight data indicate that the SSME performance during shutdown and propellant dump operations was normal. Engine shutdown was as predicted with cutoff times for SSME-1, SSME-2, and SSME 3 being 513.33, 513.43, and 513.57 seconds, respectively, as referenced to the engine start command. The high pressure oxidizer turbopump (HPOTP) and the high pressure fuel pump (HPFTP) temperatures appeared to be well within specification throughout engine operation. Space Shuttle main engine cutoff (MECO) occurred 506.96 seconds after liftoff.

Analysis of the data revealed a number of conditions that occurred during SSME operation. The hot gas injection pressure sensor froze during mainstage after the throttle bucket. All three sensors recovered prior to the 3g throttle down. This condition has occurred many times before and is believed to be caused by ice formation in the sense line.

SSME 3 main combustion chamber (MCC) channel B1 pressure sensor exhibited an upward spike at engine start plus 398.9 seconds. This spike occurred later in the ascent phase than spikes attributed to radar. An instrumentation team is studying the issue as a result of the previous in-flight anomalies, and the team is addressing potential spikes resulting from noise sources other than radar. The sensor was removed and replaced, and the erratic sensor will undergo failure analysis.

The SSME 2 HPOTP rotor exhibited slowdown at engine cutoff plus 2.5 seconds, This value is within previous experience.

SHUTTLE RANGE SAFETY SYSTEM

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

As planned, the SRB S&A devices were safed, and SRB S&A system power was turned off prior to SRB separation. The ET system remained active until ET separation from the Orbiter, operating as planned.

ORBITER SUBSYSTEMS PERFORMANCE

Main Propulsion System

The overall performance of the MPS was satisfactory, and no LCC or OMRSD violations were noted.

LO_2 loading was performed with no stop-flows or reverts. However, shortly after the initiation of LO_2 replenish, manual control of the replenish valve was selected, since the auto-replenish algorithm was unable to maintain the proper LO_2 liquid level in the ET. This was the first propellant loading since the new LO_2 replenish valve was installed. After approximately 50 minutes, the LO_2 valve control software was corrected and auto-replenish was reselected. Auto-replenish successfully maintained the LO_2 liquid level for the remainder of the countdown.

Based on an analysis of loading system data, the LO_2 load at the end of the replenish cycle was 1,388,161 lbm, which is within +0.02 percent of the planned load and well within the required loading accuracy.

LH_2 loading was performed with one 32-minute stop-flow that was caused by the LH_2 console C4 at KSC when a circuit breaker was accidentally tripped. The console was brought back on line and reduced fast-fill resumed.

Based on an analysis of the loading system data, the LH_2 load at the end of replenish was 231,877 lbm. Compared with the predicted load of 231,832 lbm, this is a difference of +0.02 percent, well within the required MPS loading accuracy.

Throughout the period of preflight operations, no significant hazardous gas concentrations were detected. The maximum hydrogen concentration level in the Orbiter aft compartment (occurred shortly after start of fast-fill) was approximately 156 ppm. This level compares favorably with previous data from this vehicle.

Ascent MPS performance was completely nominal. Data indicate that the LO_2 and LH_2 pressurization systems performed as planned. Also, all net positive suction pressure

(NPSP) requirements were met throughout the flight. The gaseous hydrogen (GH_2) flow control valve performance was nominal throughout ascent.

The MPS automated dump and vacuum inerting were performed nominally; however, a second LH_2 vacuum inerting was required when the LH_2 manifold pressure reached 34 psia. The manifold pressure was 0 psia after the second inerting. This was the second flight of the OI-23 software with the patch that was intended to eliminate the need for the second vacuum inerting. During the first flight of the patch (STS-63), a second vacuum inerting was not required. The manner in which the vacuum inert procedure will be performed on future flights is under evaluation.

Manifold repressurization in preparation for entry was nominal as was the amount of helium used (62 lb) during entry.

Reaction Control Subsystem

The RCS met all requirements placed on the system during the mission; however, three thruster anomalies occurred that are discussed in the following paragraphs. Propellant consumption by the RCS was 5,208.4 lbm from the RCS, and 3,683 lbm from the OMS.

The RCS vernier thrusters were activated at 61:08:36:48 G.m.t. (00:01:58:35 MET) and operation of all six thrusters was verified. At 61:08:54:45 G.m.t. (00:02:16:32 MET), the vernier thruster L5D oxidizer injector temperature began operating erratically, and the thruster was deselected by RM as FAIL LEAK when the oxidizer temperature dropped below 130 °F (Flight Problem STS-67-V-01). This failure necessitated using the primary RCS thrusters for vehicle control. The fuel injector temperature did not drop accordingly, thus verifying that this was a false indication. A similar occurrence was noted on STS-68, the last flight of the vehicle. A pre-approved GMEM change to modify the vernier fail-leak limit for the oxidizer injector temperature was implemented at 61:11:59 G.m.t. (00:05:21 MET). The GMEM change enabled the recovery of the vernier thruster for attitude control. The GMEM change used was similar to the one used for STS-68 to compensate for a similar problem. The L5D thruster operated nominally throughout the remainder of the mission. Later in the mission, an MDM BITE test was performed on channel 7 of card 14 in the FA1 MDM to aid in the troubleshooting of the erratic vernier thruster L5D oxidizer temperature measurement. The BITE test results indicated that the MDM was functioning properly.

RCS primary thruster R4R was deselected by RM due to a fail-leak condition at 61:18:56 G.m.t. (00:12:18 MET) (Flight Problem STS-67-V-02). The oxidizer injector temperature decreased to 13.7 °F and the fuel injector temperature decreased to 42.1 °F. During prelaunch operations, the butcher paper covering the thruster was noted to be wet. This thruster had not been fired during this mission and no other thruster was firing at the time the leak occurred. The oxidizer valve leak rate was estimated at 10,000 scch. At 61:19:18 G.m.t. (00:12:40 MET), when the R4R thruster fuel injector temperature reached 40 °F, the right manifold 4 isolation valves were closed. In less than one second, the oxidizer manifold pressure dropped to vapor pressure, indicating a significant leak. Fuel manifold pressure slowly dropped due to thermal effects. Beginning at approximately 62:05:00 G.m.t. (00:22:22 MET), the primary thruster R4R fuel and oxidizer injector temperatures tracked each other and cycled in the 80 to 90 °F range as a result of heater operation. These temperatures indicated that the oxidizer valve had stopped leaking. The right oxidizer manifold 4 pressure reached 2 psia, indicating all liquid oxidizer had leaked out of the manifold. The right fuel manifold 4 pressure responded to the manifold temperature. The pressure was as high as 200 psia and as low as 45 psia. This manifold pressure response indicated that the R4R fuel valve leakage, if any, was very small at that time. After the flight, the right fuel manifold 4 isolation valve was found to be leaking 70-100 cch of liquid (12,000 scch gas), and this could have maintained the manifold pressure and hidden any small R4R fuel valve leak that was not detectable by a fuel injector temperature drop or fuel manifold pressure drop.

The RCS hot-fire was performed at 76:14:17 G.m.t. (15:07:40 MET). All thrusters except R1A fired nominally. Thruster R1A was deselected by the RM system as failed off because of low chamber pressure (8 psia) during a 320-ms firing (Flight Problem STS-67-V-05). Both oxidizer and fuel flow occurred during the firing, and low heat soak-back confirmed the low performance. During the prelaunch period, the ice inspection team reported that a clear liquid was dripping from the lip of this thruster. The thruster leaked during the STS-67 flow in the Orbiter Processing Facility (OPF). Iron nitrate contamination in the oxidizer valve is the suspected cause of the failure; consequently, the thruster will be removed and sent to White Sands Test Facility (WSTF) for flushing.

When the crew set up the RCS interconnect to the right OMS at 64:22:42:30 G.m.t. (03:16:04:17 MET), the left RCS 3/4/5 tank isolation valve A was only momentarily placed in the closed position (1 to 2 seconds), then it was placed back to the general purpose computer (GPC) position. It should have been left in the closed position. The one to two seconds in the closed position was an insufficient length of time for the tank isolation valves to fully close. The open indications for the fuel and oxidizer valves were lost at the first switching and did not show "close" until six and a half minutes later when the left RCS 3/4/5 tank isolation valve A was returned to the closed position and left there. In the mean time, when the crossfeed valves were opened, the left RCS propellant tanks were open to the right OMS propellant tanks. The right OMS oxidizer pressure was at 261 psia while the left RCS oxidizer tank was at 244 psia. Both the right OMS and left RCS fuel tanks were at about 250 psia. There was about a 2 percent (27 lb) increase in the left RCS oxidizer quantity as OMS propellant was transferred into the RCS. No pressure transients occurred while propellants were flowing into the RCS as the maximum differential pressure (ΔP) was 17 psid, and a maximum of 30 psid is allowed with propellants flowing.

The RCS was reconfigured from right OMS to left OMS interconnect at 67:22:15 G.m.t. (06:15:37 MET). Following this reconfiguration, the crew was asked to repressurize the right OMS propellant tanks. During this procedure, the right and left OMS propellant tanks were interconnected for about 30 seconds when the right OMS crossfeed valves were inadvertently reopened. A higher pressure in the left OMS propellant tanks resulted in the transfer of propellants from the left to the right OMS propellant tanks. The amount of fuel and oxidizer transferred was estimated at about 43 lb of fuel and 93 lb of oxidizer. During the transfer, the maximum oxidizer ΔP was 16 psid and the fuel ΔP was 12 psid. No damage was suspected because the ΔP did not exceed the 20-psid permissible limit.

Orbital Maneuvering Subsystem

The OMS performed satisfactorily during the two firings, which totaled 477 seconds. The OMS and RCS consumed 22,758 lbm of OMS propellant during the two firings and the interconnect operations. The only problems noted concerned the gaging system. The left forward fuel probe was inoperative and this was known prior to flight. Also, the right oxidizer total quantity was indicating higher than it should have been. Neither of these problems impacted the mission in any way.

OMS firing	Engine	Ignition time, G.m.t./MET	Firing duration, seconds	ΔV, ft/sec
OMS-2	Both	061:07:18:34.5 G.m.t. (00:00:40:21.5 MET)	177.6	279.0
Deorbit	Both	077:20:39:13.1 G.m.t. (16:14:01:00.1 MET)	299.4	520.5

During the deorbit maneuver, the gaging system totalizer channel decreased throughout the ungagable lockout timer, and then shifted down to 18 percent where it began tracking normally until the end of the maneuver.

Power Reactant and Storage Distribution Subsystem

The power reactant storage and distribution (PRSD) subsystem performed nominally. The STS-67 mission was the fifth flight of the EDO pallet, and the first flight of the pallet on a vehicle other than OV-102. Also, STS-67 was the first nine-tank-set mission. The PRSD subsystem supplied the fuel cells with 5,037 lbm of oxygen and 634 lbm of hydrogen for the production of 7,241 kWh of electrical energy. A total of 226 lbm of the oxygen consumed was used by the environmental control and life support system for crew breathing. The mission extension capability at an average power level of 18.1 kW was 97 hours; and at an average power level of 11.1 kW, a 161-hour mission extension was possible.

Fuel Cell Subsystem

The fuel cell powerplant (FCP) subsystem performed nominally throughout the mission. The fuel cells generated 7,241 kWh of electricity at an average power level of 18.1 kW and a load of 599 amperes. The fuel cells consumed 5,037 lbm of oxygen and 634 lbm of hydrogen, and produced 5,671 lbm of water as a by-product of the electricity production.

During the launch countdown, beginning at 061:02:02 G.m.t., while the fuel cells were still powered by the ground reactants, the output voltage of fuel cells 2 and 3 degraded, indicating a severe performance problem. The fuel cell 2 voltage dropped from 30.6 Vdc at 154 amperes to 29.4 Vdc at 152 amperes, 0.75-volt below the LCC minimum performance curve. Fuel cell 3 voltage dropped from 30.9 Vdc at 50 amperes to 29.6 Vdc at 148 amperes, 0.5-volt below the LCC minimum performance curve. In addition, the voltage degradation was accompanied by a rise in the fuel cell substack differential voltage. Following the period of the initial degradation, all three fuel cells were purged and the fuel cell performance recovered. However, some further degradation was noted and a second purge again successfully recovered fuel cell performance. Both performance decays were caused by residual helium in the oxygen supply line between the EDO pallet and the fuel cell reactant manifold. The fuel cells were switched to internal reactants to sweep any residual helium from the supply line and a third fuel cell purge was performed. Nominal fuel cell performance was noted, and the fuel cells were returned to ground reactants for the remainder of the countdown.

During the first several hours of the mission, the fuel cell 3 water relief valve temperature dropped to approximately 63 °F. The nominal heater-on temperature is 70 °F, but it is not uncommon to have heater-on set-points near 60 °F. The fuel cell relief line temperature was also erratic and decreasing during this period. These signatures were probably due to a slight leakage of water through the fuel cell 3 water relief valve. At 61:12:00:38 G.m.t. (00:05:22:25 MET), the fuel cell water relief heaters were switched to the B system and operation of the fuel cell 3 relief valve heater was obtained. Operation of the A heater was verified during preflight operations; however, the on set-point was not determined. The fuel cell 3 relief valve leak rate appeared to decrease and there was no mission impact. The leakage is a known problem with a waiver in place, and the leakage first occurred on STS-47 (Flight Problem STS-47-V-08).

The fuel cell 1 hydrogen flowmeter operated erratically, fluctuating ± 0.2 lb/hr from the typical reading of 0.5 lb/hr. This condition was also noted on STS-59 and STS-68 (previous two flights of OV-105) and the decision was made to fly as-is. At approximately 72:00:00 G.m.t. (approximately 11 days MET), the measurement began drifting upwards and fluctuated around 0.7 lb/hr. The flowmeters are criticality 3 and are only removed and replaced on a non-interference basis. This flowmeter

(S/N H444) has been installed on fuel cell S/N 110 and flown on STS-44, -45, -46, -59, -68, and this flight.

At 61:18:45 G.m.t. (00:12:07 MET), the fuel cell 3 alternate water-line check-valve began leaking, as evidenced by the fuel cell 3 alternate product water line temperature increasing as the warm product water flowed past the sensor. The fuel cell 2 alternate water check valve also began leaking at 64:00:00 G.m.t. (02:17:22 MET), as evidenced by the change in fuel cell 2 alternate water line temperature. At 72:21:46 G.m.t. (11:15:08 MET), the fuel cell 2 alternate water line temperature exhibited an increase to approximately 115 °F, indicating increased flow. These valves leak frequently and particular valves have a history of leakage (ref. Flight Problem STS-54-V-07). This leakage did not impact the mission.

Auxiliary Power Unit Subsystem

The APUs performed satisfactorily on each of the occasions that they were used. The APUs were shut down after ascent in the order required by Development Test Objective (DTO) 414, Sequence A. The results of this DTO are presented in the Development Test Objective section of this report. APU run-time and fuel-consumption data are presented in the following table.

APU RUN-TIMES AND FUEL CONSUMPTION

Flight phase	APU 1 (S/N 203)		APU 2 (S/N 311)		APU 3 (S/N 410)	
	Time, min:sec	Fuel consumption, lb	Time, min:sec	Fuel consumption, lb	Time, min:sec	Fuel consumption, lb
Ascent	19:29	48	19:33	49	19:20	48
FCS checkout	03:35	12				
Entry[a]	62:50	118	90:40	182	62:36	123
Total	85:54	178	110:13	231	81:56	171

[a] The APUs were shut down approximately 18 minutes 33 seconds after main gear touchdown.

Hydraulics/Water Spray Boiler Subsystem

The hydraulics/water spray boiler (WSB) subsystem performed satisfactorily throughout ascent, on-orbit, and entry. The only deviation from nominal performance was the WSB regulator relief valves, which reseated below the required specification value of 28 psia. System 1 reseated at 27.9 psia and system 3 reseated at 27.59 psia. This below-specification operation did not impact the mission in any manner.

Through 66:17:00 G.m.t. (05:10:22 MET), the system 2 hydraulic circulation pump had run 15 times. On five of the runs (6, 7, 8, 9 and 15), the E2 yaw actuator switching valve switched from primary (hydraulic system 1) to standby (hydraulic system 2). After the ninth run, the E2 yaw actuator switching valve did not switch back to primary until 66:14:37 G.m.t. (05:07:59 MET), just prior to the fifteenth run. On two of the runs (7 and 8), the E3 pitch actuator switching valve switched from primary (hydraulic system 3) to standby (hydraulic system 2). The hydraulic system 2 thrust vector controller (TVC) isolation valve had been closed since shortly after ascent. The most probable cause of the switching valve movement is leakage through the hydraulic system 2 TVC isolation valve. As of 74:01:00 G.m.t. (12:18:22 MET), the hydraulic system 2 circulation pump had run 42 times, and no further switching had been noted. A review of previous flight data revealed no movement on the switching valve with APU 2 started for entry at low pressure and the other two APUs not running. The TVC isolation valve experienced an estimated 800 psig, and no movement of the switching valves was noted. This switching condition did not affect the performance of the hardware nor did it impact the mission.

The FCS checkout performance was nominal on hydraulic system 1 and WSB 1. The APUs ran for 3 minutes 36 seconds during the FCS checkout and this is the shortest period required to perform that checkout. The lubrication oil return temperature reached only 169 °F, thus no spray cooling was required. Spray cooling begins at 275 °F.

WSB system 2 used a large amount of water (46 lb) during descent. The water usage exceeds the 45 lb maximum limit. The usage of this amount of water caused an investigation for leaks; however, none were found. The amount of usage over the maximum did not affect the mission.

Electrical Power Distribution and Control Subsystem

The electrical power distribution and control (EPDC) subsystem performed satisfactorily throughout the mission with no anomalies or problems identified.

An electrical circuit breaker operated as designed when it opened because of an anomaly in the communications system. The anomaly is discussed in the Communications and Tracking System section of this report.

Environmental Control and Life Support System

The environmental control and life support system performed nominally.

The active thermal control system (ATCS) performed satisfactorily.

The FES feedline heaters are normally configured to heater string 2 during prelaunch operations. During the countdown, the FES accumulator B feedline temperature began to decrease from 80 °F shortly after cryogenic fluid loading began. The temperature reached 56.6 °F before the heater was reconfigured to string 1 (Flight Problem

STS-67-V-07). The LCC limit is 56 °F. After the heater reconfiguration, the temperature began to increase; however, the final countdown to launch that begins at T-9 minutes was delayed 1 minute 13 seconds until a positive indication of that increase from the string 1 heater was observed. A review of STS-68 flight data showed that this sensor cycled between 70 °F and 85 °F on that flight. The FES feedline heaters were reconfigured from system 1 back to system 2 at 69:05:22 G.m.t. (07:22:44 MET). Nominal heater cycles were seen on the FES supply B accumulator/hi-load line system 2 heater.

At approximately 61:15:19 G.m.t. (00:08:41 MET), the FES, which had been operating in the topping mode on the primary A controller to supplement radiator cooling, went into the standby mode. At approximately 61:16:36 G.m.t. (00:09:58 MET), the FES did not come out of standby as it normally should. The FES experienced an under-temperature shutdown as it was going into standby. The FES was successfully restarted on the primary A controller and transitioned into and out of standby nominally until approximately 73:11:43 G.m.t. (12:05:05 MET), when the FES went into the standby mode and again failed to come out of standby 2 hours and 25 minutes later. This FES has experienced a similar occurrence during STS-61 (OV-105 flight 5). Initial indications are that the FES is occasionally experiencing under-temperature shutdowns when going into standby; however, this cannot be proven conclusively because the instrumentation used by the FES controllers is not available in the telemetry. In all cases, the FES was successfully restarted and there was no mission impact.

As a result of a prelaunch Freon coolant loop (FCL) 2 leak, FCL 2 was topped off with an accumulator quantity of 37 percent, which is the OMRSD upper limit. During the countdown, when fuel cell heat loads were placed on the Freon loops, the Freon quantity approached the 39-percent LCC limit, and it was believed that the limit might be violated prior to launch. The LCC limits for the FCL quantity are based on a 117-psia Freon pump inlet pressure with a 39-percent accumulator quantity. Analysis showed that the actual FCL 2 inlet pressure was only 96 psia; consequently, the accumulator quantity could reach 55 percent with no impact. An LCC deviation was processed, and the limit was raised to 45 percent in the GLS.

The radiator cold-soak provided cooling during entry through touchdown plus 15 minutes when ammonia system A using the primary GPC controller was activated. System A operated for 24 minutes until the ammonia was depleted. The ammonia system A was disconnected and the ground cooling cart was connected a few minutes later. The ammonia tank was depleted about 10 minutes faster than usual because the onboard switches had placed both Freon loops in the radiator bypass position before ammonia activation, resulting in a larger heat load on the ammonia system.

The atmospheric revitalization system (ARS), as well as the atmospheric revitalization pressure control system (ARPCS), performed satisfactorily throughout the mission.

At 69:12:09 G.m.t. (08:05:31 MET), during the first switchover from oxygen (O_2) to nitrogen (N_2) flow following the pressure control system (PCS) reconfiguration from system 1 to system 2, a peak N_2 flow rate of 4.56 lbm/hr was observed. During the next O_2-to-N_2 switchover at 69:22:11 G.m.t. (08:15:33 MET), the peak observed flowrate was 4.0 lbm/hr. During nominal O_2-to-N_2 switchovers, the typical transient response from a cabin regulator lasts for 10 to 20 seconds with a peak flow rate of 1.0 to 1.5 lbm/hr. To prevent nuisance alarms, the caution and warning for this measurement (set at 4.9 lbm/hr) was inhibited. The behavior of PCS system 2 was similar to that observed during the last flight of this vehicle (STS-68) on the first few O_2-to-N_2 switchovers. The hardware caution and warning for N_2 flow was reactivated because data signatures of the O_2-to-N_2 switchovers became nominal.

However, during a switchover at 74:21:49 G.m.t. (13:15:11 MET), the flow went off-scale high (over 5.0 lbm/hr) for about 1.5 minutes and tripped the caution and warning N_2 flow rate alarm which was set at 4.9 lbm/hr. Performance of the regulator following each switchover transient was nominal. Data from previous flights of OV-105 reveal similar transient high PCS 2 N_2 flow behavior; however, this behavior typically disappeared after the first 2 or 3 switchover cycles, which was not the case on this flight. The caution and warning alarms were inhibited prior to subsequent O_2-to-N_2 switchovers on PCS 2.

The ARPCS system 2 cabin pressure regulator was noted to be controlling cabin pressure up to 0.16 psia lower than the system 1 regulator. Troubleshooting to determine the cause of the two ARPCS problems will be performed.

Supply water tank D began exhibiting erratic behavior at approximately 68:20:18 G.m.t. (07:13:40 MET). The condition continued to worsen over time, but the measurement remained usable. Water tank quantity transducers have exhibited similar signatures in the past. The excursions are most probably due to corrosion in the potentiometer, which indicates the water tank bellows position for calculation of tank quantity. This condition had no impact on the mission.

The waste collection system performed satisfactorily throughout the mission.

Airlock System

Use of the airlock support components was not required because no extravehicular activity (EVA) was performed. The active system monitor parameters indicated normal outputs throughout the mission.

Smoke Detection and Fire Suppression Subsystem

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

Avionics and Software Support Systems

The integrated guidance, navigation and control (GNC) subsystem performed nominally throughout the mission. Two DTOs were performed using the GNC subsystem, and the results are reported in the Development Test Objective section of this report.

The flight control system performed satisfactorily. FCS checkout was completed at approximately 74:18:35:24 G.m.t. (13:11:57:11 MET) with nominal system performance. In support of the FCS checkout, APU 1 ran for approximately 3 minutes and 36 seconds.

The postlanding engine positioning to the rain-drain position was accomplished without the engine 1 pitch actuator oscillating at the hard stop as seen on previous flights. The OI-23 software was updated to correct this condition, and it performed properly. This was the last flight of the OI-23 software, and the OI-24 software has also been modified to correct this condition.

The inertial measurement unit (IMU) and star tracker both performed satisfactorily with no problems identified.

When the backup flight system (BFS) was brought out of halt during deorbit preparations, the crew was observed trying to assign BFS to a CRT; however, due to loss of signal, the condition could not be verified. After postflight discussions with the crew, it was confirmed that the condition described in a Discrepancy Report 109628 had occurred. After some initial difficulty, the crew was able to assign the BFS to GPC 5, and the condition did not recur during the remainder of the flight.

Displays and Controls Subsystem

The displays and controls subsystem performed nominally.

Communications and Tracking Subsystems

The communications and tracking subsystem performed nominally. Testing of a method to provide communications through the ZOE was successfully conducted on 19 of 21 orbits during the mission. Two orbits were lost because of an incorrect switch configuration. The tests were performed in support of the upcoming Mir docking mission, and the procedure used an existing spare TDRS in concert with the Canberra, Australia, ground station. The tests provided uninterrupted communications throughout a complete orbit of the Earth.

At 61:21:54 G.m.t. (00:15:16 MET), the crew reported no ICOM or air-to-ground (A/G) capability using the mid-deck ATU, and that the middeck speaker audio had failed (Flight Problem STS-67-V-04). It was also reported that the circuit breaker that powers the middeck ATU was open. A telemetry review showed a 15-ampere spike with a 1-second duration had occurred approximately 16 minutes after launch. It was reported by the crew that a HHM was being configured at that ATU at about the same time. They also stated that the same HHM did not work when used at the airlock ATU. For on-orbit operations, the crew used the airlock ATU with a headset, and for entry the payload station ATU was used. Later in the mission, the crew performed the ATU and HHM troubleshooting IFM procedure and called down the results. Although a failure was not evident from the data, the breaker was not reset during the remainder of the mission.

The PADM experienced intermittent lock-ups. The crew believed the problem was due to the PADM overheating. They changed out the PADM after one occurrence and power cycled the payload general support computer (PGSC); this recovered the PADM operational capability. All other occurrences were cleared with a power cycle.

Operational Instrumentation/Modular Auxiliary Data System

Performance of the operational instrumentation (OI) and the modular auxiliary data system (MADS) was satisfactory.

The left-hand outboard MLG tire pressure 1 measurement became erratic at 62:17:39 G.m.t. (01:11:01 MET) for approximately 40 minutes (Flight Problem STS-67-V-03). At 62:18:53 G.m.t. (01:12:15 MET), the erratic behavior resumed and seven minutes later, the measurement went off-scale low where it remained until 65:02:00 G.m.t. (03:19:22 MET), when the measurement returned to a normal reading. The measurement read correctly for the remainder of the mission. A redundant measurement was available, and this erratic behavior did not affect the mission.

During deorbit preparations, the MADS failed to turn on after the appropriate uplink command was sent. The problem was isolated to the master MADS power, which was in the off position. The switch was placed in the on position, and the MADS operated satisfactorily for the remainder of the mission.

Structures and Mechanical Subsystems

The structures and mechanical subsystems operated satisfactorily throughout the mission. The landing and braking parameters are shown in the table on the following page.

Landing and Braking Parameters

Parameter	From threshold, ft	Speed, keas	Sink rate, ft/sec	Pitch rate, deg/sec
Main gear touchdown	1716	210.0	~ 2.5	N/A
Nose gear touchdown	6182	150.6	N/A	~5.4

Brake initiation speed	141.6 knots
Brake-on time	42.8 seconds
Rollout distance	9,918 feet
Rollout time	60.9 seconds
Runway	22 (Concrete) EAFB
Orbiter weight at landing	217,450 lb

Brake sensor location	Peak pressure, psia	Brake assembly	Energy, million ft-lb
Left-hand inboard 1	1296	Left-hand outboard	12.31
Left-hand inboard 3	1428	Left-hand inboard	14.17
Left-hand outboard 2	1368	Right-hand inboard	14.90
Left-hand outboard 4	1404	Right-hand outboard	10.73
Right-hand inboard 1	1464		
Right-hand inboard 3	1404		
Right-hand outboard 2	1356		
Right-hand outboard 4	1416		

The drag chute performance was nominal. The drag chute DTO was not performed because an attempt was made to perform the crosswind DTO.

Integrated Aerodynamics, Heating and Thermal Interfaces

The ascent and entry aerodynamics were nominal. All five of the programmed test inputs (PTIs) required by DTO 251 were completed. Also, the manual maneuver required during final approach for DTO 254 was completed; however, the yaw rates were less than commanded.

The aerodynamic and plume heating during ascent was normal with no problems noted. Likewise, the aerodynamic heating during entry was also normal. All thermal interface temperatures were also nominal.

Thermal Control System

The performance of the thermal control system (TCS) was nominal during all phases of the mission, with all Orbiter subsystem temperatures maintained within acceptable limits.

Aerothermodynamics

The acreage heating during entry was nominal, and no unusual local heating areas were noted.

Thermal Protection Subsystem and Windows

The thermal protection subsystem (TPS) performed satisfactorily. Based on structural temperature response data (temperature rise), the entry heating was nominal. Data to determine boundary layer transition from laminar to turbulent flow were not available when this report was written.

Based on data from the debris inspection team, overall debris damage was well below average. The Orbiter sustained a total of 79 hits, of which 13 had a major dimension of one inch or greater. The number of impacts on the lower surface (50) of the vehicle was much lower than average (~90). The number of impacts on the lower surface with a major dimension of at least one inch or greater was 11, compared with the average of 14.. The overall TPS conditions was excellent.

This total does not include the numerous hits on the base heat shield attributed to the flame arrestment sparkler system. A comparison of these numbers to the statistics from 51 previous missions of similar configuration indicates that the number of hits, as well as the hits with a major dimension greater than one inch, were both less than average. The following table delineates the data on hits for the vehicle.

Orbiter Surfaces	Hits > 1 Inch	Total Hits
Lower Surface	11	50
Upper Surface	1	10
Right Side	0	1
Left Side	1	2
Right OMS Pod	0	4
Left OMS Pod	0	12
Total	13	79

The majority of the lower surface debris damage sites were confined to the aft center portion of the surface, with many of the damage sites showing signs of entry thermal erosion. No damage sites were found on the outboard elevons or the outboard wing areas. Also, there were no unusually large damage sites. All ET/Orbiter separation devices appeared to have functioned properly.

The number of tile damage sites on the base heat shield was less than usual. The dome-mounted heat shield closeout blankets on all three SSMEs were intact and in good condition with some minor fraying noted on SSME 1 at the 12, 4, and 6 o'clock positions. The experimental toughened unipiece surface insulation (TUFI) tiles that were located on the triangular carrier panel between and below SSMEs 2 and 3 sustained one small impact.

Orbiter windows 3 and 4 exhibited heavy hazing and streaks. Tile damage around the windows was less than usual. Window streaking and tile damage in this area are attributed to impacts from forward RCS paper covers and/or paper-covered room temperature vulcanizing (RTV) material.

A tile located on top of the fuselage immediately aft of window 1 had a missing corner piece that measured 2 1/2 inches by 2 inches by 2 inches. This damage did not appear to have resulted from a debris impact, but may have been the source of debris.

A brown discoloration was visible on the forward section of the left payload bay door. The area of discoloration extended from the door leading edge aft to a location on the door above the liquid dump vent nozzles on the left side of the Orbiter. After exposure to rain and the ferry flight, the discoloration was reported to have disappeared. In addition, a white residue was observed around the liquid waste dump vent nozzle, and exposed red RTV was observed along the forward edge of the payload bay door in this same area. An analysis is being made of the samples to determine their source.

A short section of inconel thermal barrier located on the lower aft inside edge of the left speedbrake was damaged. Two tiles adjacent to the thermal barrier were also damaged.

REMOTE MANIPULATOR SYSTEM

The remote manipulator system (RMS) was flown but was not used during this mission.

FLIGHT CREW EQUIPMENT/GOVERNMENT FURNISHED EQUIPMENT

The flight crew equipment/government furnished equipment (FCE/GFE) performed satisfactorily. Some minor problems occurred and these are discussed in the following paragraphs.

When the crew was loading the fourth Hasselblad film canister of the mission at approximately 66:08:13 G.m.t. (05:01:35 MET), the crewmember noted that the data module was missing the Hasselblad data recording system (HDRS) option (Flight Problem STS-67-F-04). The HDRS option prints data such as time and exposure number on the film. An IFM procedure, which included resecuring the battery and performing the initialization procedure, was completed successfully and proper operation was recovered.

The crew reported at 66:21:42 G.m.t. (05:16:04 MET) that the camcorder power interface (CCPI) failed while being used to power the compact portable light (CPL) (Flight Problem STS-67-F-01). The problem was traced to an intermittent contact at the CPL-to-battery-adapter connector. The problem was not previously apparent because an open deadface switch in this connector prevented reading a voltage at the CPL-to-battery-adapter contacts. During subsequent troubleshooting with the deadface switch depressed, the proper CCPI output of 8 volts was observed. An IFM restored the CPL to full operational capability.

During the troubleshooting of the ATU and HHM at 68:03:14 G.m.t. (06:20:36 MET), the crew reported that the digital voltmeter leads were not in the configuration that was specified in the IFM (Flight Problem STS-67-F-02). The multimeter lead tips were supposed to be removable, thereby allowing other connectors (found in the temperature probe kit) to be used with the multimeter. The IFM was performed, using the pin kit assembly to aid in obtaining the necessary measurements.

While the crew was downlinking video at 69:03:05 G.m.t. (07:20:27 MET), degradation in the video was noted with tearing at the top and bottom of the image. Troubleshooting isolated the problem to the commercial (TEAC) video tape recorder (Flight Problem STS-67-F-03).

CARGO INTEGRATION

Cargo integration hardware performance was nominal throughout the mission with no anomalies identified.

DEVELOPMENT TEST OBJECTIVES/DETAILED SUPPLEMENTARY OBJECTIVES

A total of 11 Development Test Objectives (DTOs) and 16 Detailed Supplementary Objectives (DSOs) was defined for the STS-67 mission. The preliminary results of the DTOs and DSOs are discussed in the following paragraphs.

DEVELOPMENT TEST OBJECTIVES

DTO 251 - Entry Aerodynamic Control Surfaces Test - Alternate Elevon Schedule (Part 9) - All five of the programmed test inputs (PTIs) maneuvers were executed during entry as scheduled. The data have been given to the sponsor for evaluation, and the results of the DTO will be reported in separate documentation.

DTO 254 - Subsonic Aerodynamics Verification (Part 2) - The crew performed the maneuver that fulfilled the requirements of this DTO during final approach to the runway. The preliminary results indicate that the yaw rates were less than expected. The data have been given to the sponsor for evaluation, and the results will be reported in separate documentation.

DTO 301D - Ascent Structural Capability Evaluation - Data were gathered for this data-only DTO during the ascent phase of the mission, and these data were recorded on the MADS recorder. The data have been given to the sponsor for evaluation, and the results will be published in separate documentation.

DTO 307D - Entry Structural Capability - Data were gathered for this data-only DTO during the entry phase of the mission, and these data were recorded on the MADS recorder. These data have been given to the sponsor for evaluation, and the results will be published in separate documentation.

DTO 312 - ET TPS Performance (Methods 1 and 3) - Photography of the ET (after separation) was acquired with the Nikon camera that used a 300 mm lens and a 2X extender (method 3). A total of 37 photographs were found on magazine 301 which was used for the photography. The exposure was good on all frames, and the focus was good on most of the frames. The first picture was taken approximately 23 minutes after liftoff, and the final picture was taken 8 minutes 35 seconds later.

All aspects of the ET were imaged. The ET appeared to be in good condition, and no anomalies were noted.

Two 16 mm umbilical well films (5 mm and 10 mm) of the SRB separation were screened and no anomalies were found. The 16 mm films of the ET were dark and unusable.

DTO 414 - APU Shutdown Test (Sequence A) - After ascent, the APUs were shut down in the order (APU 3, APU 1 and APU 2) prescribed. No back-driving of the power drive unit (PDU) was noted. The results of the DTO, which has been performed on numerous flights, will be published in separate documentation.

DTO 667 - Portable In-Flight Landing Operations Trainer - The portable in-flight landing operations trainer (PILOT) was used several times by the Commander and almost daily by the Pilot during the flight. The Commander noted during the debriefing that the PILOT does not incorporate the beep-trim function to bring the nose wheel down to the runway. During the actual landing, the Commander manually derotated the Orbiter, possibly because of the training received on PILOT.

DTO 674 - Thermo Electric Liquid Cooling System Evaluation (Less Omega Recorder) - This DTO was performed during ascent and entry. The data from the DTO have been given to the sponsor for evaluation. The results of the evaluation will be reported in separate documentation.

DTO 700-8 - Global Positioning System Development Flight Test (Configuration 1) - The Global Positioning System (GPS) performed nominally during all phases of the mission. A power cycle of the receiver assembly was performed to reinitialize system operation prior to OPS 3 transition because of a known software problem. Corrective action to modify this software is being implemented on future units.

DTO 700-9 - Orbiter Evaluation of TDRS Acquisition in Despread Bypass Mode - This DTO was performed 16 times during the mission. The objective of evaluating TDRS acquisition time variances for the transition from the Spaceflight Tracking and Data Network (STDN) to TDRS mode was successfully achieved. The time measured ranged from 2 to 10 seconds depending on actual Orbiter command sequence execution and initial network system configuration. This procedure was developed as an alternative to reduce the loss of command capability time during powered flight (for a roll-to-heads-up attitude) from the nominal 45 seconds to about 7 to 10 seconds. This procedure will also be evaluated by Mission Operations personnel prior to its implementation. The results of the DTO will be published in separate documentation.

DTO 805 - Crosswind Landing Performance - The wind conditions were predicted to be acceptable at landing time and the drag chute was deployed later than normal so that all the requirements of the DTO could be accomplished. However, the actual runway wind at landing was mainly a headwind, thus not meeting the requirements of this DTO. Consequently, the DTO was not accomplished.

DETAILED SUPPLEMENTARY OBJECTIVES

DSO 326 - Window Impact Observations - Observations were made by the crewmembers during the mission. The results of the observations have been given to the sponsor for evaluation. The results of the evaluation will be published in separate documentation.

DSO 328 - In-Flight Urine Collection Absorber Evaluation - Data were collected for this DSO during the flight. The DSO data have been given to the sponsor for evaluation, and the results of the sponsor's evaluation will be published in separate documentation.

DSO 484 - Assessment of Circadian Shifting in Astronauts by Bright Light (Configuration B) - This DSO was performed during the preflight and postflight periods only. The crew observations have been given to the sponsor for evaluation. The results of the sponsor's evaluation will be published in separate documentation.

DSO 487 - Immunological Assessment of Crewmembers - This DSO was performed during the preflight and postflight periods only. The data from this DSO have been given to the sponsor for evaluation. The results will be published in separate documentation.

DSO 488 - Measurement of Formaldehyde Using Passive Dosimetry - This DSO was performed as planned during the flight. The data from the DSO have been given to the sponsor for evaluation. The results will be published in separate documentation.

DSO 603C - Orthostatic Function During Entry, Landing and Egress - This DSO was performed during the latter stages of the flight, as well as after landing and egress. The data from this DSO were given to the sponsor for evaluation. The results of the evaluation will be published in separate documentation.

DSO 604 - OI-3C, Visual-Vestibular Integration as Function of Adaptation - Preflight, on-orbit, and postflight data were collected for this DSO. The data have been given to the sponsor for evaluation. The results of the evaluation will be published in separate documentation.

DSO 605 - Postural Equilibrium Control During Landing/Egress - Preflight and postflight data were collected for this DSO. The data have been given to the sponsor for evaluation. The results of the evaluation will be published in separate documentation.

DSO 608 - Effects of Space Flight on Aerobic and Anaerobic Metabolism During Exercise - Data were collected for this DSO during the flight. These data have been given to the sponsor for evaluation. The results of the evaluation will be published in separate documentation.

DSO 614 - The Effect of Prolonged Space Flight on Aerobic and Anaerobic Metabolism During Exercise (Protocol B) - The DSO measurements were taken during the preflight and postflight periods, and the data were given to the sponsor for evaluation. The results of the evaluation will be published in separate documentation.

DSO 621 - In-Flight Use of Florinef to Improve Orthostatic Intolerance Postflight - This DSO was performed during the mission, and the data have been given to the sponsor for evaluation. The results of the evaluation will be reported in separate documentation.

DSO 624 - Pre and Postflight Measurement of Cardiorespiratory Responses to Submaximal Exercise - This DSO was performed as planned, and the data have been given to the sponsor for evaluation. The results of the evaluation will be reported in separate documentation.

DSO 626 - Cardiovascular and Cerebrovascular Responses to Standing Before and After Space Flight - Measurement data were collected for this DSO, and the data have been given to the sponsor for evaluation. The results of the evaluation will be reported in separate documentation.

DSO 901 - Documentary Television - Onboard video was recorded and the tapes have been given to the sponsor for evaluation. The results of the evaluation will be reported in separate documentation.

DSO 902 - Documentary Motion Picture Photography - Onboard motion picture photography was performed by the crew, and the films have been given to the sponsor for evaluation. The results of the evaluation will be reported in separate documentation.

DSO 903 - Documentary Still Photography - Onboard still photography was conducted by the crew, and the photographs have been given to the sponsor for evaluation. The results of the evaluation will be reported in separate documentation.

PHOTOGRAPHY AND TELEVISION ANALYSIS

LAUNCH PHOTOGRAPHY AND VIDEO DATA ANALYSIS

On launch day, 24 videos were screened; and following launch day, 54 of the 55 expected 35 mm films of launch were received and reviewed. One camera, E-9, did not operate.

The review of the video as well as the 35-mm films did not reveal any anomalies.

ON-ORBIT PHOTOGRAPHY AND VIDEO DATA ANALYSIS

No requests were received to evaluate any of the on-orbit photography during the mission.

LANDING PHOTOGRAPHY AND VIDEO DATA ANALYSIS

Five videos of landing were reviewed and no anomalous conditions were found. In addition, the review of the landing day films also revealed no anomalies.

TABLE I.- STS-67 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	061:06:33:24.43 061:06:33:25.76 061:06:33:26.74
SRB HPU Activation[a]	LH HPU System A start command LH HPU System B start command RH HPU System A start command RH HPU System B start command	061:06:37:44.949 061:06:37:45.309 061:06:37:45.269 061:06:37:45.429
Main Propulsion System Start[a]	ME-3 Start command accepted ME-2 Start command accepted ME-1 Start command accepted	061:06:38:06.423 061:06:38:06.541 061:06:38:06.681
SRB Ignition Command (Liftoff)	Calculated SRB ignition command	061:06:38:12.989
Throttle up to 104 Percent Thrust[a]	ME-2 Command accepted ME-3 Command accepted ME-1 Command accepted	061:06:38:17.341 061:06:38:17.343 061:06:38:17.361
Throttle down to 67 Percent Thrust[a]	ME-2 Command accepted ME-1 Command accepted ME-3 Command accepted	061:06:38:44.381 061:06:38:44.384 061:06:38:44.402
Maximum Dynamic Pressure (q)	Derived ascent dynamic pressure	061:06:39:04
Throttle up to 104 Percent[a]	ME-2 Command accepted ME-3 Command accepted ME-1 Command accepted	061:06:39:09.342 061:06:39:09.344 061:06:39:09.362
Both SRM's Chamber Pressure at 50 psi[a]	RH SRM chamber pressure mid-range select LH SRM chamber pressure mid-range select	061:06:40:12.389 061:06:40:12.429
End SRM Action[a]	RH SRM chamber pressure mid-range select LH SRM chamber pressure mid-range select	061:06:40:14.909 061:06:40:15.369
SRB Physical Separation[a]	LH rate APU turbine speed - LOS RH rate APU turbine speed - LOS	061:06:40:18.029 061:06:40:18.029
SRB Separation Command	SRB separation command flag	061:06:40:19
Throttle Down for 3g Acceleration[a]	ME-2 command accepted ME-3 command accepted ME-1 command accepted	061:06:45:42.789 061:06:45:42.794 061:06:45:42.810
3g Acceleration	Total load factor	061:06:45:42.7
Throttle Down to 67 Percent Thrust[a]	ME-2 command accepted ME-3 command accepted ME-1 command accepted	061:06:46:33.670 061:06:46:33.675 061:06:46:33.691
SSME Shutdown[a]	ME-2 command accepted ME-3 command accepted ME-1 command accepted	061:06:46:39.990 061:06:46:39.990 061:06:46:40.011
MECO	MECO command flag MECO confirm flag	061:06:46:40 061:06:46:41
ET Separation	ET separation command flag	061:06:47:00

[a] MSFC supplied data

TABLE I.- STS-67 SEQUENCE OF EVENTS

Event	Description	Actual time, G.m.t.
APU Deactivation	APU-3 GG chamber pressure APU 1 GG chamber pressure APU 2 GG chamber pressure	061:06:52:46.95 061:06:52:53.34 061:06:52:58.62
OMS-1 Ignition	Left engine bi-prop valve position Right engine bi-prop valve position	Not performed - direct insertion trajectory flown
OMS-1 Cutoff	Left engine bi-prop valve position Right engine bi-prop valve position	
OMS-2 Ignition	Left engine bi-prop valve position Right engine bi-prop valve position	061:07:18:34.5 061:07:18:34.5
OMS-2 Cutoff	Left engine bi-prop valve position Right engine bi-prop valve position	061:07:21:32.1 061:07:21:32.1
Payload Bay Doors (PLBDs) Open	PLBD right open 1 PLBD left open 1	061:08:15:13 061:08:16:33
Flight Control System Checkout		
APU Start	APU-1 GG chamber pressure	074:18:35:24.87
APU Stop	APU-1 GG chamber pressure	074:18:38:59.99
Payload Bay Doors Close	PLBD left close 1 PLBD right close 1	077:18:04:13 077:18:06:33
APU Activation for Entry	APU-2 GG chamber pressure APU-1 GG chamber pressure APU-3 GG chamber pressure	077:20:35:06.29 077:21:02:50.48 077:21:02:57.78
Deorbit Burn Ignition	Right engine bi-prop valve position Left engine bi-prop valve position	077:20:39:13.1 077:20:39:13.1
Deorbit Burn Cutoff	Right engine bi-prop valve position Left engine bi-prop valve position	077:20:44:12.5 077:20:44:12.5
Entry Interface (400K feet)	Current orbital altitude above	077:21:15:50
Blackout end	Data locked (high sample rate)	No blackout
Terminal Area Energy	Major mode change (305)	077:21:40:44
Main Landing Gear Contact	RH main landing gear tire pressure 1 LH main landing gear tire pressure 2	077:21:46:59 077:21:47:01
Main Landing Gear Weight on Wheels	LH main landing gear weight on wheels RH main landing gear weight on wheels	077:21:47:01 077:21:47:02
Nose Landing Gear Contact	NLG LH tire pressure 1	077:21:47:14
Nose Landing Gear Weight On Wheels	NLG weight on wheels 1	077:21:47:15
Drag Chute Deployment	Drag chute deploy 1 CP Volts	077:21:47:16.0
Drag Chute Jettison	Drag chute jettison 1 CP Volts	077:21:47:43.0
Wheel Stop	Velocity with respect to runway	077:21:48:00
APU Deactivation	APU-3 GG chamber pressure APU-1 GG chamber pressure APU-2 GG chamber pressure	077:22:05:33.616 077:22:05:39.847 077:22:05:45.503

TABLE II.- ORBITER PROBLEM TRACKING LIST

No.	Title	Time	Comments
STS-67-V-01	RCS Vernier Thruster L5D Oxidizer Temperature Erratic	061:08:54 G.m.t. 00:02:16 MET	At 061:08:54 G.m.t. (00:02:16 MET), RCS vernier thruster L5D oxidizer injector temperature began behaving erratically. The temperature dropped below the 130 °F leak detection limit and the RM declared it fail-leak. The fuel injector temperature for this thruster was stable, confirming that there was no leak, and that the problem appears to be due to instrumentation. This same behavior occurred on the last flight of this vehicle (Flight Problem STS-68-V-02). This thruster was changed out during the STS-67 flow. A GMEM was performed to recover the vehicle control with the vernier thrusters. KSC: Instrumentation troubleshooting (connector Hi-Pot) completed. No anomaly noted (will probably be a UA).
STS-67-V-02	Primary Thruster R4R Fail Leak Level III Closure	061:18:56 G.m.t. 00:12:18 MET CAR 67RF01 PR RP01-22-0764	At 061:18:56 G.m.t. (000:12:18 MET), the RM software declared primary thruster R4R fail-leak. The oxidizer injector temperature and the fuel temperatures were both decreasing, confirming a real leak through the oxidizer valve. This thruster had not been fired during this mission. Wet butcher paper was noted on the thruster preflight. At 061:19:18 G.m.t. (000:12:40 MET), the right manifold 4 isolation valves were closed because the fuel injector temperature fell below 40 °F. KSC: Thruster removal and replacement on May 13, 1995.
STS-67-V-03	Left-Hand MLG Outboard Tire Pressure 1 (V51P0570A) Off-Scale Low Level III Closure	062:17:39 G.m.t. 001:11:01 MET CAR 67RF02 IPR 69V-0008	The left-hand outboard MLG tire pressure 1 measurement became erratic at 062:17:39 G.m.t. for approximately 40 minutes. At 062:18:53 G.m.t. (001:12:15 MET), the erratic behavior resumed and the measurement went off-scale low 7 minutes later. The redundant pressure measurement showed a nominal signature. At 065:02:00 G.m.t. (03:19:22 MET), the tire pressure 1 measurement returned to a normal reading. KSC: Troubleshooting is complete. Attempts to recreate the anomaly were unsuccessful. Signal conditioner troubleshooting continuing (probably a UA).
STS-67-V-04	Loss of Middeck Audio, ICOM, and Air-to-Ground Communications	061:06:54 G.m.t. 000:00:15 MET IPR 69V-0009	At 061:21:54 G.m.t. (00:15:16 MET), the crew reported that the middeck audio terminal unit and hand-held microphone were not functioning on both A/G and ICOM. The crew also reported an open circuit breaker corresponding to the non-functioning equipment. A data review revealed a 15-ampere spike that was 1 second in duration at approximately 16 minutes MET. The crew reported that the same hand-held microphone did not work when used at the airlock ATU. An IFM procedure to troubleshoot the failure produced roughly the results expected for nominal hardware. The IFM did not reveal a cause for the open circuit breaker KSC: Troubleshooting is continuing. Orbiter audio system is operating properly. Investigation of hand-held microphone used during the on-orbit anomaly revealed no problem. Troubleshooting of speaker box will be

TABLE II.- ORBITER PROBLEM TRACKING LIST

			performed after test hardware are available.
STS-67-V-05	RCS Primary Thruster R1A Fail-OFF Level III Closure	076:14:17 G.m.t. 015:07:39 MET PR RP01-22-0765 CAR 67RF03	During the RCS hot-fire, primary RCS thruster R1A deselected after a 320 msec firing. Peak chamber pressure reached approximately 8 psia. Both oxidizer and fuel flow occurred. Low heat soak-back confirmed low performance. KSC: Thruster will be removed and replaced on April 29, 1995.
STS-67-V-06	PCS System 2 Nitrogen High Flow Transients After Switches from Oxygen to Nitrogen	074:21:49 G.m.t. 013:15:10 MET IPR 69V-0015 PR-ECL-0418	After the mid-mission change-over from pressure control system (PCS) 1 to PCS 2, several occurrences of transient high nitrogen flow were observed. The transients occurred at the beginning of the nitrogen flow cycle upon switchover from oxygen to nitrogen. Higher than normal initial nitrogen flow has been observed on six of the 11 oxygen/nitrogen switchover cycles that have occurred and range from 2.75 to 5.0 lbm/hr and last up to several minutes. Normal nitrogen flow profiles sustain an initial peak of 1.5 for a few seconds. During one event, the flow went off-scale high (>5.0 lbm/hr) for about 1.5 minutes, tripping the caution and warning alarm for exceeding nitrogen flow rate FD limit of 4.9 lbm/hr. None of the high-flow transients were explainable by events known to produce high nitrogen flow, such as low cabin pressure or decreasing cabin temperature. Data from prior flights of OV-105 reveal similar transient high PCS 2 nitrogen flow behavior; however, this behavior typically only occurs on the first two or three switchover cycles. Data review complete at the vendor, Carlton. No OMRSD violations exist. KSC: PR disposition is in work to close.
STS-67-V-07	FES Supply B Accumulator/Hi-Load Line System 2 Heater Performance During Prelaunch	061:06:17 G.m.t. IPR 69V-0004	The FES supply B accumulator/hi-load line system 2 heater is used during prelaunch operations. When ET cryogenic loading began, the accumulator line temperature began decreasing from approximately 80 °F. The temperature decreased to 56.6 °F before the heater was reconfigured to system 1. The LCC limit is 56 °F. After the heater reconfiguration, the accumulator line temperature began to increase. The high-load line is heated by this same heater and its temperature remained above 100 °F . The heater thermostat, which is located on the accumulator line, was closed (heater on) throughout the prelaunch period following the start of ET cryogenic loading. Nominal heater performance was observed prior to ET cryogenic loading. The FES feedline heaters were reconfigured from system 1 to system 2 at 069:05:22 G.m.t. (007:22:44 MET). Nominal heater cycles were seen on the FES supply B accumulator/high-load line system 2 heater. KSC: Detailed inspection of insulation found gap in insulation that may have contributed to prelaunch problem. Insulation repair in work. Heater performance was nominal. LCC revision in progress to clarify heater switching process.

TABLE III.- GOVERNMENT FURNISHED EQUIPMENT PROBLEM TRACKING LIST

No.	Title	Time	Comments
STS-67-F-01	Intermittent Power Connection Between CCPI Battery Adapter and CPL Level III Closure	066:22:43 G.m.t. 05:16:05 MET	The crew reported a failure of the Camcorder Power Interface (CCPI) to power the Compact Portable Light (CPL)> Subsequent troubleshooting isolated the problem to an intermittent contact at the CPL-to-battery-adapter connector. An IFM successfully restored CPL operation. Repair of the intermittent condition will be required postflight.
STS-67-F-02	Incorrect Digital Multimeter Leads Level III Closure	067:03:06 G.m.t. 05:20:24 MET	The crew determined that the Digital Multimeter (DMM) kit contained probes with fixed tips instead of the required probes with interchangeable tips.
STS-67-F-03	TEAC Video Tape Recorder Failure	069:03:06 G.m.t. 007:20:27 MET	At 069:03:05 G.m.t. (07:20:27 MET), the crew attempted to playback video to the ground using the TEAC video tape recorder. The video received was "tearing" with noise at the top and bottom of the screen. To troubleshoot the problem, fresh recordings were made on both the TEAC and the camcorders. The TEAC could not play either its own or the camcorder tapes. The camcorders could play their own tapes, but not the tapes recorded on the TEAC recorder. The camcorders could play their own tapes, but not the tapes recorded on the TEAC recorder. The TEAC recorder appears to have failed. A tape of the video has recorded for analysis
STS-67-F-04	Hasselblad Data Module Programmer Fault Level III Closure	066:08:13 G.m.t. 005:01:35 MET	When loading the fourth film canister of the mission, at approximately 66:08:13 G.m.t. (05:01:35 MET), the crewmember noted that the data module programmer was missing the HDRS option. The HDRS option prints data such as time, data, and number on the film. An IFM was worked to recover proper operation. The battery was removed and replaced and an initialization procedure was performed. This procedure was successful and no further problems were reported.

DOCUMENT SOURCES

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

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

ACRONYMS AND ABBREVIATIONS

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

A/G	Air-to-ground
APU	auxiliary power unit
ARPCS	atmospheric revitalization pressure control system
ARS	atmospheric revitalization system
ASTRO-2	Ultraviolet Astronomy -2 payload
ATCS	active thermal control system
ATU	audio terminal unit
BFS	backup flight system
BITE	built-in test equipment
CCPI	camcorder power interface
CEI	contract end item
CMIX	Commercial Materials Dispersion Apparatus ITA Experiments
CPL	compact portable light
CRIM	commercial refrigerator module
DSO	Detailed Supplementary Objective
DTO	Developmental Test Objective
ΔP	differential pressure
ΔV	differential velocity
deg/hr	degree per hour
EAFB	Edwards Air Force Base
EDO	Extended Duration Orbiter
EI	entry interface
EPDC	electrical power distribution and control subsystem
ET	External Tank
EVA	extravehicular activity
FCE	flight crew equipment
FCL	Freon coolant loop
FCP	fuel cell powerplant
FCS	flight control system
FES	flash evaporator system
ft/sec	feet per second
g	gravity
GAS	Getaway Special
GFE	Government furnished equipment
GH_2	gaseous hydrogen
GLS	ground launch sequencer
GMEM	general purpose computer memory
G.m.t.	Greenwich mean time
GPC	general purpose computer
GPS	Global Positioning System
HAINS	high accuracy inertial navigation system
HDRR	high data rate recorder
HDRS	Hasselblad Data Recording System

HHM	hand-held microphone
HPFT	high pressure fuel turbine
HPFTP	high pressure fuel turbopump
HPOTP	high pressure oxidizer turbopump
HUT	Hopkins Ultraviolet Telescope
ICOM	intercommunications
IFM	in-flight maintenance
IMU	inertial measurement unit
IPS	Instrument Pointing System
Isp	specific impulse
KIS	Ku-band Interface System
KSC	Kennedy Space Center
kW	kilowatt
kWh	kilowatt hour
LCC	Launch Commit Criteria
LESC	Lockheed Engineering and Science Company
LH_2	liquid hydrogen
LO_2	liquid oxygen
MACE	Middeck Active Control Experiment
MADS	modular auxiliary data system
MCC	main combustion chamber
MDA	Materials Dispersion Apparatus
MDM	multiplexer/demultiplexer
MECO	main engine cutoff
MET	mission elapsed time
MLG	main landing gear
MPS	main propulsion system
MSFC	Marshall Space Flight Center
N_2	nitrogen
NASA	National Aeronautics and Space Administration
nmi.	nautical mile
NSTS	National Space Transportation System (i.e., Space Shuttle Program)
O_2	oxygen
OI	operational instrumentation subsystem
OMRSD	Operations and Maintenance Requirements and Specifications Document
OMS	orbital maneuvering subsystem
OPF	Orbiter Processing Facility
PADM	portable audio data modem
PAL	protuberance air load
PCG	Protein Crystal Growth
PCG-STES	Protein Crystal Growth-Single Locker Thermal Enclosure System
PCG-TES	Protein Crystal Growth-Thermal Enclosure System
PCS	pressure control system
PGSC	payload and ground support computer
PI	Principal Investigator
PILOT	Portable In-Flight Landing Operations Trainer
PLBD	payload bay door
PMBT	propellant mean bulk temperature
PRSD	power reactant storage and distribution

PTI	programmed test input
RCS	reaction control subsystem
RM	redundancy management
RMS	remote manipulator system
RSRM	Reusable Solid Rocket Motor
RTV	room temperature vulcanizing
S&A	safe and arm
SAREX-II	Shuttle Amateur Radio Experiment-II
SLF	Shuttle Landing Facility
S/N	serial number
SRB	Solid Rocket Booster
SRSS	Shuttle range safety system
SSME	Space Shuttle main engine
STDN	Spaceflight Tracking and Data Network
TCS	thermal control system
TDRS	Tracking and Data Relay Satellite
TEAC	Brand name of recorder
TMBU	table maintenance block update
TPS	thermal protection subsystem
TUFI	toughened unipiece surface insulation
TVC	thrust vector control
UIT	Ultraviolet Imaging Telescope
Vdc	Volts, direct current
WSB	water spray boiler
WSTF	White Sands Test Facility
WUPPE	Wisconsin Ultraviolet Photo-Polarimeter Experiment
ZOE	zone of exclusion

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