

# **STS-62 SPACE SHUTTLE MISSION REPORT**

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**MAY 1994**

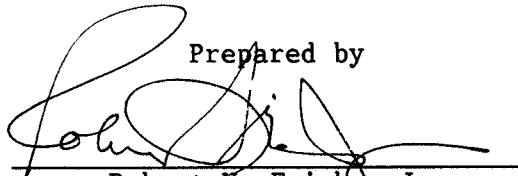


**National Aeronautics and  
Space Administration**

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

STS-62  
SPACE SHUTTLE  
MISSION REPORT

Prepared by

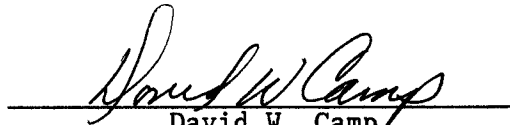


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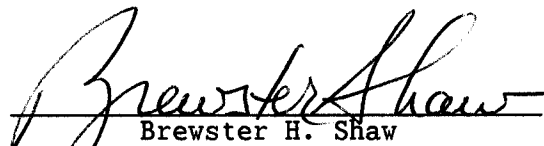
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May 1994

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## INTRODUCTION

The STS-62 Space Shuttle Program Mission Report summarizes the Payload activities as well as the Orbiter, External Tank (ET), Solid Rocket Booster (SRB), Redesigned Solid Rocket Motor (RSRM), and the Space Shuttle main engine (SSME) systems performance during the sixty-first flight of the Space Shuttle Program and sixteenth flight of the Orbiter vehicle Columbia (OV-102). In addition to the Orbiter, the flight vehicle consisted of an ET designated as ET-62; three SSME's which were designated as serial numbers 2031, 2109, and 2029 in positions 1, 2, and 3, respectively; and two SRB's which were designated BI-064. The RSRMs that were installed in each SRB were designated as 360L036A (lightweight) for the left SRB, and 360W036B (welterweight) for the right SRB.

This STS-62 Space Shuttle Program Mission Report fulfills the Space Shuttle Program requirement as documented in NSTS 07700, Volume VIII, Appendix E. That document requires that each major organizational element supporting the Program report the results of their hardware evaluation and mission performance plus identify all related in-flight anomalies.

The primary objectives of the STS-62 mission were to perform the operations of the United States Microgravity Payload-2 (USMP-2) and the Office of Aeronautics and Space Technology-2 (OAST-2) payload. The secondary objectives of this flight were to perform the operations of the Dexterous End Effector (DEE), the Shuttle Solar Backscatter Ultraviolet/A (SSBUV/A), the Limited Duration Space Environment Candidate Material Exposure (LDCE), the Advanced Protein Crystal Growth (APCG), the Physiological Systems Experiments (PSE), the Commercial Protein Crystal Growth (CPCG), the Commercial Generic Bioprocessing Apparatus (CGBA), the Middeck Zero-Gravity Dynamics Experiment (MODE), the Bioreactor Demonstration System (BDS), the Air Force Maui Optical Site Calibration Test (AMOS), and the Auroral Photography Experiment (APE-B).

The STS-62 mission was planned as a nominal 14-day mission with two contingency days available should Orbiter contingency operations or weather avoidance be required. The sequence of events for the STS-62 mission is shown in Table I. The official Orbiter Project Office Problem Tracking List is shown in Table II, and the official Government Furnished Equipment (GFE) Problem Tracking List is shown in Table III. The official MSFC Problem Tracking List is shown in table IV. In addition, the Integration and Payload in-flight anomalies are referenced in the applicable sections of the report. Appendix A lists the sources of data, both formal and informal, that were used in the preparation of this document. Appendix B provides the definition of acronyms and abbreviations used in this document. All times are given in Greenwich mean time (G.m.t.) as well as mission elapsed time (MET).

The five-person crew for this sixty-first flight of the Space Shuttle Program consisted of John H. Casper, Col., U. S. Air Force, Commander; Andrew M. Allen, Major, U. S. Marine Corps, Pilot; Pierre J. Thuot, Cmdr., U. S. Navy, Mission Specialist 1; Charles D. Gemar, Lt. Col., U. S. Army, Mission Specialist 2; and Marsha S. Ivins, Civilian, Mission Specialist 3. STS-62 was the third space flight for the Commander, Mission Specialist 1, Mission Specialist 2, and Mission Specialist 3; and the second space flight for the Pilot.

## MISSION SUMMARY

The STS-62 launch was planned for March 3, 1994, at 8:54 a.m. e.s.t. from launch complex 39B at Kennedy Space Center (KSC); however, the 24-hour weather forecast on March 2, 1994, indicated adverse weather conditions for the launch on March 3, and as a result the launch was delayed 24 hours.

The STS-62 vehicle was launched on time at 063:13:53:00.009 G.m.t. (8:53 a.m. e.s.t. on March 4, 1994). Main engine cutoff (MECO) occurred on time after a nominal ascent phase.

A total of 17 cycles of the SSME system 3 gaseous hydrogen (GH<sub>2</sub>) flow control valves (FCVs) occurred during the first 35 seconds of ascent (prior to the throttle bucket). A sluggish open response of 0.4 to 0.5 second (should be  $\leq$  0.3) was noted from approximately 6.3 seconds after liftoff to 30.5 seconds after liftoff. The sluggish response did not affect the ET ullage or SSME performance.

No orbital maneuvering subsystem (OMS) -1 maneuver was required as a direct ascent trajectory was flown. The OMS-2 maneuver was initiated at 063:14:35:20.0 G.m.t. (00:00:42:20.0 MET), the firing duration was 132.2 seconds, and the resultant differential velocity ( $\Delta V$ ) was 208.4 ft/sec. The orbit achieved was 163 by 160 nmi.

The auxiliary power unit (APU) 3 fuel-pump-inlet pressure measurement (V46P0310A) cycled normally for about 2.5 hours after APU shutdown following ascent. At approximately 063:16:32 G.m.t. (00:02:39 MET), the measurement began cycling with the upper end of the pressure cycle above the upper limit of 612 psi (off-scale high). The fuel isolation valve was opened for approximately 33 minutes at 063:18:59 G.m.t. (00:05:06 MET), but the fuel line pressure did not equalize with tank pressure, indicating an apparent blockage in the fuel-pump-inlet line. However, beginning with the cycle at 064:04:40 G.m.t. (00:14:47 MET), the upper end of some of the cycles was below the off-scale high point. The APU 3 fuel line heaters were switched to the B system at 064:11:43 G.m.t. (00:21:50 MET), and the APU fuel-pump-inlet pressure decreased below the fuel tank pressure and began cycling between 140 psi and 250 psi. At 064:20:54 G.m.t. (01:07:01 MET), when the fuel-pump-inlet pressure was at 182 psi, the fuel isolation valve was opened for the second of three times. An elapsed time of 14 seconds was required for fuel-pump-inlet pressure to increase from 181 psia and equalize with the tank pressure of 232 psia. The APU 3 fuel-tank isolation valve was opened a third time at 066:15:19:37 G.m.t. (03:01:26:37 MET), and pressure across the valve equalized immediately, indicating nominal conditions existed in the APU 3 fuel line.

It was concluded that during a rain storm which occurred 13 days prior to launch, water entered the aft fuselage through a Lexan door that covers the 50-2 access hatch. The water most likely entered the APU 3 fuel feed line insulation which covers the tubing and thermostats through either lead wire exit holes or through openings at the line support clamps. The water became entrapped between the insulation and tubing and froze during and following ascent, and in turn the hydrazine froze solid within the tube. Analysis has shown that only a small amount of water is required to freeze hydrazine within

the tube in a space vacuum due to the heat transferred during the water freezing and sublimation process. Additionally, thermal analysis and tests have shown that pooled water would freeze the hydrazine within the 2.5-hour time period after APU shutdown. Evidence of frozen hydrazine was indicated by the fuel-pump-inlet pressure rising until the transducer went off-scale high. After the water had sublimated, the hydrazine slowly thawed due to the heat input from the line heaters. Evidence of the thawing was seen when the fuel isolation valve opening response resulted in a sluggish pressure equalization between the APU fuel pump inlet pressure and the fuel tank pressure. Postflight inspection supported the conclusion that rain intrusion during the preflight time frame was the cause of this anomaly.

The OMS-3 and OMS-4 firings were completed nominally. The OMS-3 firing using the right orbital maneuvering engine (OME), began at 073:07:02:38.9 G.m.t. (09:17:09:38.9 MET), lasted for 42.0 seconds and imparted a total  $\Delta V$  of -33.6 ft/sec to the vehicle. This firing placed the Orbiter in an orbit of approximately 160 x 140 nmi. The OMS-4 firing, using the left OME, began at 073:07:43:29.0 G.m.t. (09:17:50:29.0 MET), lasted for 46.9 seconds and imparted a total  $\Delta V$  of -37.6 ft/sec to the vehicle. This firing placed the Orbiter in a circular orbit of 140 nmi.

The payload on-orbit low-frequency environment Detailed Supplementary Objective (DSO) 324 was performed in accordance with operational procedures at approximately 074:07:01 G.m.t. (10:17:08 MET). The purpose of DSO 324 was to obtain on-orbit low-frequency (0-50 Hertz) payload acceleration data from the primary reaction control subsystem (RCS) thruster firings. Seven thrusters were fired individually for specific durations of 80, 160, and 240 msec.

The flight control system (FCS) checkout was successfully completed using APU 3, which ran 7 minutes 40.85 seconds and consumed 18 lb of fuel. The APU was started at 075:06:50:56.49 G.m.t. (11:16:57:56.49 MET) and ran in hydraulic pump low-pressure mode for about 2 minutes 20 seconds before the normal pressure mode was selected. The APU 3 fuel-pump inlet-pressure was nominal during the run as well as after APU shutdown. The pressure first relieved back into the fuel tank at about 160 psid about 30 minutes after APU shutdown, and the fuel pump inlet pressure continued to relieve normally throughout the APU heat soakback periods.

Hydraulic system 3 performed nominally during the FCS checkout. Water spray boiler (WSB) cooling was required because of the long run-time of the APU. The maximum lubrication oil return temperature was 254.7 °F with spray cooling being initiated at 252 + 2 °F. During the activities prior to FCS checkout and APU operations, all three B system hydraulic steam vent heaters performed nominally. The vent heaters were turned on about 2 hours 18 minutes after the FCS checkout to perform a bake-out of WSB 3. The heaters were left on for approximately 4 hours.

The OMS-5 firing was performed at 075:08:08:33.1 G.m.t. (11:18:15:33.1 MET). The dual-engine firing lasted 37.6 seconds and imparted a total  $\Delta V$  to the vehicle of -61.3 ft/sec. All parameters were normal, and the Orbiter was placed in a 140 by 105 nmi. orbit.

The major activity of flight day 14 was the satisfactory performance of the RCS hot-fire. All primary thrusters were fired twice and operated as planned with no anomalies noted.

The remote manipulator system (RMS) was stowed at 076:10:31 G.m.t. (12:20:38 MET). All planned RMS operations were successfully completed for the mission. The RMS remained in the temperature monitoring mode until immediately prior to payload bay door closing.

All stowage activities in preparation for entry were completed. The payload bay doors were closed at 077:09:34:00 G.m.t. (13:19:41:00 MET) with dual-motor times noted for both doors and all latches.

The deorbit maneuver was initiated at 077:12:16:50.2 G.m.t. (13:22:23:50.2 MET). The maneuver was approximately 127.5 seconds in duration and the  $\Delta V$  was -214 ft/sec. Entry interface occurred at 077:12:38:06 G.m.t. (13:22:45:06 MET).

Main landing gear touchdown occurred at the Shuttle Landing Facility (SLF) on concrete runway 33 at 077:13:09:41 G.m.t. (13:23:16:41 MET) on March 18, 1994. The Orbiter drag chute was deployed satisfactorily at 077:13:09:54.7 G.m.t., and nose landing gear touchdown occurred 5.3 seconds after drag chute deployment. The drag chute was jettisoned at 077:13:10:21.6 G.m.t. with wheels stop occurring at 077:13:10:35 G.m.t. The rollout was normal in all respects. The flight duration was 13 days 23 hours 16 minutes 41 seconds.

APU 3 was shut down at 077:13:12:15.31 G.m.t., immediately after wheels stop as a protective measure in the unlikely event that the earlier APU 3 anomaly was due to a hydrazine leak. APU 1 and APU 2 were shutdown by 077:13:30:07 G.m.t. after a successful hydraulics load test on the two APUs. The crew completed the required postflight reconfigurations and departed the Orbiter landing area.

Review of the landing video from the infrared camera showed four pieces of debris falling from the vehicle at nose landing gear deployment. Two sources of the debris were identified. The first source was identified as a portion of the aft outboard corner tile on the starboard nose landing gear door (NLGD) that broke off during door opening. This event has occurred in the past. The second source was the forward section of the NLGD thermal barrier, which seals the interface between the NLGD and the reinforced carbon-carbon (RCC) chin panel. The thermal barrier is bonded to the chin panel. Apparently, the bond degraded and the thermal barrier fell out at nose landing gear deployment. No evidence of subsurface flow into the NLGD cavity was noted, indicating that the thermal barrier performed satisfactorily during entry.



## PAYLOADS

The crew conducted a large number of experiments that covered a wide range of space research activities from materials processing to biotechnology. During the 14-day Extended Duration Orbiter (EDO) flight, the crew gathered additional information for ongoing medical studies that will assess the impact of long-duration spaceflight (10 or more days) on astronaut health, as well as identify any operational medical concerns and test countermeasures for the adverse effects of weightlessness on human physiology. All payloads met or exceeded their minimum objectives for the flight.

### UNITED STATES MICROGRAVITY PAYLOAD-2

The United States Microgravity Payload-2 (USMP-2) was the second in a series of payloads that have been flown to study the effects of microgravity on materials and fundamental sciences. The USMP-2 consisted of five experiments which were all located in the payload bay. The five experiments were mounted on a Spacelab carrier, which performed satisfactorily during the mission. The carrier provided the required support to the experiments to allow the optimum gathering of scientific data.

The carrier-mounted environmental control system maintained the freon coolant loop at nominal temperatures in all varying Orbiter attitudes and activities. Likewise, the command and data management system (CDMS) provided control and overall visibility into the experiment activities by routing approximately 10,000 commands through the system control unit to experiments. The CDMS provided 27 billion bits of experiment data to the ground for real-time and postflight analysis.

The experiment tape recorder (ETR) performed nominally until just one hour prior to the completion of USMP-2 microgravity operations. Troubleshooting to reactivate the ETR was unsuccessful, and the unit was powered off. The ETR provided backup capability only, and scientific data were not impacted.

### Advanced Automated Directional Solidification Furnace

The Advanced Automated Directional Solidification Furnace (AASDF) was used to study the directional solidification of semiconductor materials in microgravity. Data from this experiment will be used to verify theories about the effect of gravity on the chemical composition of growing semiconductors, and also gravity's role in creating defects in semiconductor crystals.

The AASDF performed over 240 hours of directional solidification of the mercury-cadmium telluride sample. The temperature distribution in the furnace during growth was exactly as predicted. The AASDF Science Team was able to use "telescience" to create a demarcation, or reference point, on the crystal at a critical time in the growth process. The marker will provide an aid in determining the position and shape of the solid-liquid growth interface during postflight processing.

Postlanding operations consisted of slicing and polishing the crystal for study. The study findings will help scientists learn about the effect of convection -- movement of fluids caused by gravity -- during growth of crystals on Earth for advanced electronics use in the photo-electronics industry.

Material pour L'Etude des Phenomenes Interessant la Solidification  
sur Tere et en Orbite

The major scientific goal of the Material pour L'Etude des Phenomenes Interessant la Solidification sur Tere et en Orbite (MEPHISTO) experiment was to characterize the morphological transitions in faceted materials in the absence of gravity-induced thermosolutal convection. In accomplishing this goal, the MEPHISTO experiment on this flight was used to study the behavior of metals and semiconductors as they solidified. Results from this second flight of MEPHISTO will be compared with the results obtained from the first flight (October 1992).

Over 55 melting and solidification cycles with different thermal and velocity conditions were performed during the mission by issuing over 225 commands (each consisting of a series of operations). More than 45 signals were obtained during these cycles, together with continuous monitoring of the sample resistance, furnace translation, and thermal measurements. The large amount of data obtained in real-time as well as the large amount of sample grown in microgravity conditions will be used to improve the current understanding of solidification processing in general and the interfacial processes during crystal growth in particular. All major goals of MEPHISTO were satisfied.

Isothermal Dendritic Growth Experiment

Dendrites are crystalline forms that develop as materials solidify under certain conditions. The Isothermal Dendritic Growth Experiment (IDGE) used the material succinonitrile (SCN) to study dendritic solidification of molten metals in the microgravity environment of space.

The IDGE was a resounding success. Significant differences have been observed between dendritic growth rates on Earth and in orbit. These observations are based on the acquisition of 60 dendritic growth experiments conducted over a wide range of supercoolings between 0.05 °K and 2 °K. The IDGE instrument interrogated the dendritic solidification phenomenon over a wide range of growth conditions. Results showed virtually no difference between microgravity and unit gravity (at high supercoolings), and revealed significant effects that distinguish microgravity from unit gravity (at low supercoolings).

The IDGE team observed the tip splitting of dendrites at extremely small temperature differences below the freezing point that the IDGE team believes has never been observed on Earth. Far more data were acquired during the mission than was anticipated prior to the flight. This feat was only possible through the use of telepresence capabilities, which include remote monitoring, real-time data analysis, replanning, and commanding.

Critical Fluid Light Scattering Experiment-Zeno

The Critical Fluid Light Scattering Experiment-Zeno (CFLSE-Zeno) was used to study the behavior of xenon at its critical point. The critical point occurs at

conditions of temperature and pressure where a fluid is simultaneously a gas and a liquid with the same density. CFLSE-Zeno measured the properties of xenon much closer to its critical point than is possible on Earth.

All science requirements for CFLSE-Zeno were accomplished during the mission and the instrument operated satisfactorily throughout the mission. The remarkable behavior of the fluid xenon very near the critical temperature provided data exceeding the experimenter's expectations.

The most difficult part of the experiment was locating the critical temperature ( $T_c$ ) to the required precision. This was finally accomplished with the required precision of  $\pm 0.000010$  °K, at least 100 times closer than is possible on Earth.

Preliminary analyses show that the measured decay rates exhibit the required precision for temperatures within  $-0.000300$  °K of the  $T_c$ . Additional high quality measurements were made within a few  $\mu$  °K of the  $T_c$  and the density fluctuation correlation exhibited, as predicted, an ever slower rate of decay. Measurements below the  $T_c$ , in the two-phase region, were also made. All measurements closer than  $0.010$  °K from  $T_c$  reflect data unattainable on Earth at the required accuracy of 1 percent.

#### Space Acceleration Measurement System

The Space Acceleration Measurement System (SAMS) instruments monitored and recorded onboard accelerations and vibrations during the flight. The SAMS completed successful mission operations when the unit was deactivated for landing.

Both SAMS units provided downlink data from their corresponding 10 Hertz triaxial sensor heads (TSH). The data from these TSHs were displayed in near-real-time throughout the entire mission. The downlink data were rebroadcast over the video network. In addition to the downlink data, each unit recorded data. SAMS also recorded events that occurred after the dedicated microgravity period, such as the OMS firings and Development Test Objective (DTO) activities.

#### OFFICE OF AERONAUTICS AND SPACE TECHNOLOGY-2

The overall objective of the OAST-2 payload was to obtain technology data to support future needs for advanced satellites, sensors, microcircuits, and the international Space Station. The payload consisted of six In-Space Technology Program (INSTEP) experiments mounted on a Hitchhiker carrier. The following paragraphs discuss the OAST-2 experiments and their preliminary results.

#### Experimental Investigation of Spacecraft Glow Experiment

The Experimental Investigation of Spacecraft Glow (EISG) experiment investigated the phenomenon known as spacecraft glow, which is an aura of light created around the leading or front-facing surfaces of all spacecraft while in Earth orbit. Oxygen and nitrogen form molecules in excited states when the spacecraft rams into them at high velocity. The molecules give off light as they decay to their lower energy levels, thus causing the glow. Pressurized nitrogen gas was contained beneath the sample plate for release as a source of ionizing atoms for the tests.

The EISG experiment accomplished 100 percent of its objectives. Seven orbits of prime operations were performed, gathering information on the physical processes associated with spacecraft glow phenomenon in the far ultraviolet, visible, and infrared wavelengths. The nitrogen gas (N<sub>2</sub>) release events yielded surprising results in that the glow was extinguished rather than enhanced. Data were gathered to investigate the altitude effects on glow, surface temperatures, and materials. Atmospheric airglow observations over 87 night orbits were also acquired.

#### Spacecraft Kinetic Infrared Test Experiment

The Spacecraft Kinetic Infrared Test (SKIRT) experiment consisted of a circular variable filter infrared spectrometer that was contained in a Getaway Special (GAS) canister in the payload bay. The spectrometer was cooled by solid nitrogen to a temperature of 57 °K. As the spectrometer was rotated, spectral readings were taken every 5 seconds in the infrared range from 0.6 to 5.3 microns. Six dedicated maneuvers were performed during the mission for data taking; four involved Orbiter nose-down rolls and two involved lunar calibrations.

The SKIRT experiment was successfully completed with all of its objectives met, and an unprecedented set of infrared glow data collected. Observations were obtained during quiescent and non-quiescent orbital environments, roll maneuvers in and out of the velocity vector, day and night, and significantly different/varying altitudes. Experiment calibration data were acquired during two moon-viewing opportunities. Down-looking spectra taken will provide ground-truth infrared calibration data for earth-observing satellites. The SKIRT experiment also observed the diminished glow signal intensity during the EISG gaseous nitrogen releases.

#### Cryogenic Two Phase Experiment

The Cryogenic Two Phase (CRYOTP) experiment investigated the use of very cold liquids - cryogenics - for heat dissipation. Heat pipes are being tested as possible solutions to thermal control problems. In addition, the Brilliant Eyes Thermal Storage Unit (BETSU) investigated cryogenic heat dissipation not requiring internal fluid circulation like the heat pipes.

The BETSU experiment was an outstanding success. All experiment objectives were met and the BETSU phase-change material became the coldest (by 40 °C) in spaceflight history. The BETSU design performance, the off-design performance, the maximum storage capacity, and both the single- and two-phase supercooling phenomena were verified.

The Space Heat Pipe (SHP) was the first nitrogen heat pipe to fly in space. However, efforts were unsuccessful in priming or starting the heat pipe due to liquid buildup in the condenser. Valuable data were obtained regarding the formation of liquid slugs and liquid nitrogen behavior in zero-g that will be used in the design of future cryogenic heat pipes.

#### Solar Array Module Plasma Interaction Experiment

The Solar Array Module Plasma Interaction Experiment (SAMPIE) investigated the plasma interactions of high-voltage space power-systems with the space plasma in

low Earth orbit. Data were collected on arcing and current behavior of different materials and shapes for verification of data from ground-based plasma tests.

The SAMPIE completed all mission objectives in a comprehensive manner. The minimum success criteria and all planned plasma current collection measurements were completed in bay-to-ram and bay-to-Earth orientations. The bay-to-Earth measurements were taken in the wake of the EISG experiment, and the data should be representative of the bay-to-wake measurements. All planned low voltage and about three-quarters of the high voltage arcing measurements were completed in the ram orientation.

During the ram orientation high-voltage arcing operations on the Advanced Photovoltaic Solar Array (APSA) sample near the beginning of flight day 9, an anomalously large arc caused one of the two SAMPIE high-voltage power supplies to fail. In addition to the bay-to-ram data obtained prior to the anomaly, wake high-voltage data were collected for all samples connected to the remaining power supply.

#### Thermal Energy Stowage Experiment

The Thermal Energy Stowage (TES) experiment consisted of two components (TES-1 and TES-2) which provided data on the microgravity behavior of two thermal energy storage salts that underwent repeated cycles of freezing and melting.

The TES experiment autonomous operation was successfully started by the crew on flight day 2 and completed on flight day 3. Evaluation of the flight data was performed after the experiments were removed from the vehicle and returned to the experimenter.

#### Emulsion Chamber Technology Experiment

The Emulsion Chamber Technology (ECT) experiment tested the sensitivity of photographic materials as detectors for cosmic ray analysis, as well as the sensitivity to deterioration effects from heat, mechanical vibration, and unwanted background radiation.

The ECT experiment operated nominally throughout the mission. Analysis of the detector materials was performed after the experiment hardware was removed from the vehicle and returned to the experimenter.

#### SHUTTLE SOLAR BACKSCATTER ULTRAVIOLET/A EXPERIMENT

The SSBUV/A experiment was flown for the sixth time during the Space Shuttle Program on the STS-62 mission. This highly calibrated instrument collects ozone data for comparison with ozone data from free-flying satellites, and thereby provides the most accurate data for identifying atmospheric-ozone trends.

Following the planned outgassing period for the SSBUV/A instrument, the experiment operated nominally throughout the flight, obtaining data during 101 Earth-view orbits and three solar-view orbits. Data from at least 58 Earth-view orbits had good correlation with the data from the National Oceanographic and Atmospheric Administration (NOAA) ozone satellites. This exceeded the premission goal of 32 NOAA matches.

## DEXTEROUS END EFFECTOR

The DEE contains powerful electromagnets that generated an attraction force of 3,200 lb. The DEE was used with the RMS to grapple objects in the payload bay during this flight demonstration of the DEE. Three crew members operated the RMS with the DEE for a total of 24 hours.

The crew accomplished all payload objectives and were able to do more than required. The payload hardware performed nominally and was successfully secured for landing after payload operations were complete. The experiment data were stored on the payload general support computer (PGSC) and the Developmental Version Payload (DVP) computer. Postflight evaluation of the data, which included video recorded onboard, was performed. A more complete discussion of the DEE activities is contained in the Remote Manipulator System section of this report.

## LIMITED DURATION SPACE ENVIRONMENT CANDIDATE MATERIAL EXPOSURE EXPERIMENT

The LDCE experiment investigated candidate materials being considered for use in space structures. Three identical sets of materials, each comprised of 264 samples, were exposed to the space environment. One set (container) was opened soon after attaining orbit and was left open until preparations for entry were underway. A second set was opened at the same time, but it was closed during periods when the cargo bay was facing the direction of orbital motion (ram direction). The third set was opened only during those times when the vehicle cargo bay was facing the ram direction.

The three containers (LDCE 6, 7, and 9) doors were opened and closed in accordance with the preflight timeline. The sets gathered data on the combined effects of contamination and atomic oxygen.

## ADVANCED PROTEIN CRYSTAL GROWTH EXPERIMENTS

The APCG experiments consisted of two units: the Vapor Diffusion Apparatus (VDA) experiment, and the Protein Crystallization Apparatus for Microgravity (PCAM) experiment. Both experiments completed 100 percent of the assigned objectives for a very successful flight.

A new thermal enclosure system (TES) was used in place of two middeck lockers and housed four vapor diffusion trays (VDTs). Each of the four VDTs in the TES have 20 protein crystal growth chambers. All indications are that this hardware operated nominally, maintaining the internal temperature within 0.1 °C of the planned 22 °C. The internal fan experienced an anomaly on ascent, but the component was recovered after the crew ran a malfunction procedure. The crew experienced difficulty in activating one VDTs; however, the tray was eventually activated and loss of science is not expected as a result of the late activation.

The hand-held PCAM housed 96 samples, and the main purpose of flying this new hardware was for proof-of-concept. Video pictures taken at deactivation showed that crystals had grown. The Principal Investigator was pleased with these preliminary results.

## COMMERCIAL PROTEIN CRYSTAL GROWTH PAYLOAD

The CPCG payload was operated to provide data for better understanding and improving techniques for growth of protein crystals in space.

Mission operations were successfully completed on flight day 14 with the deactivation of the VDTs and the stowage of the ancillary support hardware. During the one-day weather delay of launch, proteins in 25 of the 60 CPCG VDA growth chambers were replaced. The remaining 35 growth chambers contained old protein material which may have compromised experiment science results had the CPCG activation not been accelerated from flight day 2 to flight day 1. With the one-day early activation, excellent science results are expected from the protein crystals.

## MIDDECK 0-GRAVITY DYNAMICS EXPERIMENT

The MODE was classified as a complex secondary payload that occupied four middeck lockers and was being flown for the second time in the Space Shuttle Program. More than 40 hours of tests were completed on the MODE Structural Test Article (STA) between flight day 3 and flight day 9.

All objectives of the MODE were completed, and MODE operations were excellent. All STA protocols, both required and desired, were successfully executed and the Dynamic Load Sensor (DLS) was activated earlier than scheduled, thereby providing more data collection time than planned.

## AIR FORCE MAUI OPTICAL CALIBRATION TEST

The AMOS is an electrical-optical facility on the Hawaiian island of Maui. No hardware is required onboard the Orbiter to support the experimental observations of thruster firings, water dumps, etc. The AMOS test opportunity on this flight involved viewing of an Orbiter thruster firing on flight day 14. However, the test could not be completed because of inclement weather at the site.

## AURORAL PHOTOGRAPHY EXPERIMENT-B

The APE-B photographic opportunities scheduled preflight were successfully completed, including an observation of the thruster firing that was to be performed for the AMOS test. All crew reports on the APE-B payload indicated nominal completion of objectives and hardware operation.

## BIOREACTOR DEMONSTRATION SYSTEM

STS-62 was the first of four flights during which BDS development tests were performed on a bioreactor, a cell-culture growth device. The cell-culture chambers of the bioreactor were loaded with colon carcinoma cells prior to launch.

From all indications, the BDS payload functioned as expected throughout the flight. Due to the numerous activities on flight day 1, activation was not originally planned for that day; however, an acceleration of the activation from flight day 2 to flight day 1 was accomplished in real-time, and adverse effects on the experimental results are not expected.

## PHYSIOLOGICAL SYSTEMS EXPERIMENT

STS-62 was the fourth mission for the PSE. The PSE investigated the complex interrelationship between the human body's immune and skeletal systems during exposure to microgravity. The flight operations support of the PSE payload was excellent. Daily temperature data were called down by the crew as planned, and the experiment operated as planned.



## VEHICLE PERFORMANCE

### SOLID ROCKET BOOSTERS

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

Analysis of the flight data shows that all SRB subsystems performed properly during prelaunch testing and countdown with the exception of the right-hand rock hydraulic power unit primary gas generator bed temperature measurement which was erratic throughout the countdown. Gas generator bed heater control was configured to use the right-hand rock secondary gas generator bed temperature measurement for controlling the heater prior to initial heater activation per the preplanned procedure.

Both SRBs were successfully separated from the ET at 126.1 seconds after liftoff. The retrieval ships were not sent to the recovery area until launch because of the unfavorable sea conditions; therefore, no report of the SRBs condition during descent and post-water impact is available. No adverse conditions were noted because of the extended subjection to the ocean conditions. The recovery ships recovered the SRBs in satisfactory condition, and returned them to Port Canaveral for transfer to Kennedy Space Center (KSC) for disassembly and refurbishment.

One in-flight anomaly was identified from the SRB postflight inspection. The Hypalon paint over the booster trowellable ablative (BTA) on the right SRB frustum was blistered (Flight Problem STS-62-B-1). The findings for the anomaly closure were that the blistering paint was not a debris concern.

### REDESIGNED SOLID ROCKET MOTORS

The RSRMs performance was nominal with no LCC or OMRSD violations. No in-flight anomalies have been identified from the data analysis or postflight inspection.

Power up and operation of the igniter-joint and field-joint heaters were accomplished routinely. All RSRM temperatures were maintained within acceptable limits throughout the countdown. The igniter-joint heaters operated for 17 hours 43 minutes, which is equivalent to 83 percent of the time during the LCC time frame; whereas the field-joint heaters were powered up for 11 hours 27 minutes, which is equivalent to 48 percent of the time during the LCC time frame.

For this flight, the aft skirt purge system was initiated later than expected for the cold temperatures experienced prior to ET propellant loading. The amount of heat supplied to the aft skirt was limited by a high temperature setting at the Mobile Launch Platform (MLP) gaseous nitrogen heater. The aft skirt purge was operated continuously at its maximum output setting during the entire LCC time-frame. This action was necessary because the set-point of the purge heater was misadjusted at a lower-than-normal level (was 110 °F, but should have been 119 °F), which reduced the total heater output capability. The

purge was, however, able to maintain the case/nozzle joint and flex bearing temperatures within the required LCC ranges, as well as provide the inert atmosphere in the SRB aft skirt from T-15 minutes through launch.

The motor performance parameters for this flight were within contract end item specification limits. The RSRM propulsion performance is shown in the following table based on the calculated propellant mean bulk temperature (PMBT) of 64 °F.

RSRM PROPULSION PERFORMANCE

Parameter	Left motor, 64 °F		Right motor, 64 °F	
	Predicted	Actual	Predicted	Actual
Impulse gates				
I-20, 10 <sup>6</sup> lbf-sec	64.94	64.90	65.03	64.72
I-60, 10 <sup>6</sup> lbf-sec	173.43	174.10	173.61	173.23
I-AT, 10 <sup>6</sup> lbf-sec	296.92	297.13	296.76	295.65
Vacuum Isp, lbf-sec/lbm	268.50	268.60	268.50	267.40
Burn rate, in/sec @ 60 °F at 625 psia	0.3676	0.3678	0.3681	0.3696
Burn rate, in/sec @ 64 °F at 625 psia	0.3687	0.3688	0.3692	0.3696
Event times, seconds				
Ignition interval	0.232	N/A	0.232	N/A
Web time <sup>a</sup>	110.9	111.0	110.7	110.7
Separation cue, 50 psia	120.7	121.1	120.5	120.3
Action time <sup>a</sup>	122.8	123.3	122.6	122.4
Separation command	125.6	126.3	125.6	126.3
PMBT, °F	64.00	64.00	64.00	64.00
Maximum ignition rise rate, psia/10 ms	90.4	N/A	90.4	N/A
Decay time, seconds (59.4 psia to 85 K)	2.8	3.0	2.8	2.8
Tailoff imbalance Impulse differential, KLBF-sec	Predicted N/A		Actual 423.9 <sup>b</sup>	

Notes:

<sup>a</sup> All times are referenced to ignition command time except where noted by the letter a. Those items are referenced to lift-off time (ignition interval).

<sup>b</sup> Impulse imbalance = left motor - right motor

All ground environment instrumentation (GEI) and operational flight instrumentation (OFI), with the exception of two field-joint heater LCC temperature sensors, performed within established requirements. All available data were recorded, transmitted, and analyzed.

Postflight inspection of the RSRMs revealed a gas path through the right-hand nozzle-to-case joint polysulfide at the 147.6-degree location. No soot was observed past the wiper O-ring. No heat effects were observed on the primary O-ring or steel components.

#### EXTERNAL TANK

All objectives and requirements associated with the ET propellant loading and flight operations were met. All ET electrical equipment and instrumentation operated satisfactorily. ET purge and heater operations were monitored and all performed properly. No ET LCC or OMRSD violations were identified, nor were any anomalies found during the data review.

Typical ice/frost formations were observed on the ET during the countdown. Normal quantities of ice or frost were present on the liquid oxygen (LO<sub>2</sub>) and liquid hydrogen (LH<sub>2</sub>) feedlines and on the pressurization line brackets, and some frost or ice was present along the LH<sub>2</sub> protuberance air load (PAL) ramps. These observations were acceptable per NSTS 08303. The Ice/Frost Red Team reported that there were no anomalous thermal protection system (TPS) conditions.

The nose cone purge heater and temperature control system operated successfully. However, unusually wide oscillations in heater outlet and nose cone compartment temperatures did occur until the controller required continuous maximum power from the heater.

The intertank purge heater and temperature control system operated successfully. Intertank temperatures were maintained within acceptable limits, all components within the intertank performed satisfactorily, and no hazardous gas violations were noted.

The ET pressurization system functioned properly throughout engine start and flight. The minimum LO<sub>2</sub> ullage pressure experienced during the ullage pressure slump was 13.7 psid.

ET separation was confirmed, and the ET was photographed after separation. Two findings were noted in the photography:

a. An approximately 14-inch long by 4-inch wide area of foam was missing from the intertank +Z area stringer top just forward of the -Y bleed ramp;

b. An approximately 6-inch diameter divot down to the substrate just outboard of the cable tray near station 1590 was noted.

ET separation, entry, and breakup all occurred nominally. The postflight predicted impact point was approximately 81 nmi. uprange of the preflight prediction.

#### SPACE SHUTTLE MAIN ENGINE

All SSME parameters were normal throughout the prelaunch countdown and were typical of prelaunch parameters observed on previous flights. Engine-ready was achieved at the proper time, and all LCC were met. All interface control document (ICD) start and shutdown transients requirements were met. Engine

performance during start, mainstage, and shutdown was nominal and as predicted with cutoff times of 516.77, 516.88, and 517.01 seconds (referenced to engine start command) for SSME 1, 2, and 3, respectively. The specific impulse (Isp) was rated as 452.4 seconds based on trajectory data. No SSME in-flight anomalies were identified in the data review.

Two significant observations were made concerning SSME operation after a review of the data:

a. SSME 1, 2, and 3 main injector hot gas injection pressures became static during mainstage operations because of frozen moisture in the pressure-sensing line. This condition was expected because of the cold weather during chill as well as having been experienced numerous times previously.

b. SSME 2 and 3 high pressure oxidizer turbopump (HPOTP) discharge pressures "dipped downward" during engine shutdown because of possible interstage seal rubbing. Although this has been seen before and is within the experience base, additional investigation is continuing to better understand the phenomenon.

#### SHUTTLE RANGE SAFETY SYSTEM

Shuttle Range Safety System (SRSS) closed-loop testing was completed as scheduled during the 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 system power was turned off prior to SRB separation. The ET system remained active until ET separation from the Orbiter.

#### ORBITER SUBSYSTEMS

##### Main Propulsion System

The overall performance of the main propulsion system (MPS) was as expected. LO<sub>2</sub> and LH<sub>2</sub> loadings were performed as planned with no stop-flows or reverts. There were no OMRSD or LCC violations.

The LH<sub>2</sub> loading operations were normal through chilldown, slow-fill, fast-fill, topping and replenish. The LH<sub>2</sub> load at the end of replenish was 231,862 lbm. Compared with the inventory (predicted) load of 231,853 lbm, the actual load difference was +0.004 percent, which is within the MPS loading accuracy.

The LO<sub>2</sub> loading operations were normal through chilldown, slow-fill, fast-fill, topping and replenish. The LO<sub>2</sub> load at the end of replenish was 1,388,428 lbm, which when compared with the inventory (predicted) load of 1,387,828 lbm reflects a difference of +0.04 percent that is within the 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 (which occurred shortly after the start of fast-fill) was approximately 152 ppm (corrected), which compares favorably with previous data for this vehicle.

Data indicate that the LO<sub>2</sub> and LH<sub>2</sub> pressurization systems performed as planned, and that all net positive suction pressure (NPSP) requirements were met throughout the flight. However, the SSME-3 GH<sub>2</sub> FCV indicated 17 cycles of slow opening responses (0.4 to 0.5 second versus 0.3 second requirement) from approximately 6.3 seconds after liftoff to 30.5 seconds after liftoff, as indicated by the FCV inlet pressure data (Flight Problem STS-62-V-01). These slow responses had no impact on GH<sub>2</sub> pressurization system performance. The FCV has been removed and is undergoing inspection and testing.

Helium usage was nominal with 55 lbm used during the purging of the engines.

#### Reaction Control Subsystem

The RCS operation was nominal throughout the mission with no problems or anomalies identified. Propellant consumption was 3995.2 lbm. In addition, the aft RCS used 3.88 percent of the left OMS propellants and 3.99 percent of the right OMS propellants during interconnect operations.

As a result of the cold-environment attitude, the forward RCS vernier thruster F5R oxidizer injector temperature fell below the redundancy management (RM) deselection limit of 130 °F. This temperature triggered a fault detection and annunciation (FDA) alarm during the crew sleep period at 070:23:48:47 G.m.t. (07:09:55:47 MET), and RM deselected the thruster. An attempt was made to tighten the digital autopilot (DAP) deadband to avoid waking the crew; however, the change was not made in time to prevent the alarm. Subsequently, the DAP deadband was tightened to force the thruster to fire more frequently, and thereby maintain the injector temperature above the 130 °F limit.

At 071:22:54:23 G.m.t. (08:09:01:23 MET), the forward RCS vernier thruster F5L oxidizer injector temperature went below its minimum FDA temperature limit of 130 °F and set off a crew alarm. To prevent future occurrences of this alarm, the Orbiter attitude was biased +5 degrees to cause the F5L thruster to fire more frequently to maintain the injector temperature above the minimum limit. The biased attitude was successful in causing the thruster to fire more frequently and the temperature to be maintained above 130 °F.

#### Orbital Maneuvering Subsystem

The OMS performed satisfactorily during the five OMS firings conducted during the mission. A total of 344.2 seconds of firing time was accumulated on the left OMS engine, and 339.3 seconds of firing time was accumulated on the right OMS engine. A total of 13,847.0 lbm of propellants was consumed during the five firings. The table on the following page reflects the firing data from the OMS maneuvers.

#### Power Reactant Storage and Distribution Subsystem

The PRSD subsystem performance was nominal throughout the mission. A total of 3877 lb of oxygen (138 lb for crew environmental usage and 3739 for fuel cell usage) and 471 lb of hydrogen was consumed during the mission. Consumables

OMS firing	Engine used	Time, G.m.t./MET	Firing duration, sec	$\Delta V$ ft/sec
2	Both	064:14:35:20.0 G.m.t. 00:00:42:20.0 MET	132.2	208.3
3	Right	073:07:02:38.9 G.m.t. 09:17:09:38.9	42.0	33.6
4	Left	073:07:43:29.0 G.m.t. 09:17:50:29.0 MET	46.9	37.6
5	Both	075:08:08:33.1 G.m.t. 11:18:15:33.1 MET	37.6	61.3
Deorbit	Both	077:12:16:50.2 G.m.t. 13:22:23:50.2 MET	127.5	214.2

remaining at touchdown could have provided an additional 155 hours of mission operations at the 16.1 kW power usage rate; however, at the extension-day average power level of 11.1 kW, a 229-hour mission extension was possible.

Boiloff data from the hydrogen tanks were collected for DT0 413 for use in determining the actual heat-leak rate of the tanks. Data were required to estimate support for a 90-day stay-time when docked to the Space Station.

The hydrogen (H<sub>2</sub>) tank 6 (EDO configuration) A heater failed off at approximately 065:22:02 G.m.t. (02:08:09 MET) (Flight Problem STS-62-V-04). The B Heater did energize at this time as well as both heaters (A and B) in hydrogen tank 7. The four heater switches for these two tanks were in the AUTO position. Three heater cycles occurred in this configuration with the failed-off heater. The pressure in tank 7 rose twice as fast as the pressure in tank 6, verifying that the heater did fail off, and that it was not just the heater ON indication that had failed. The switch for hydrogen tank 7 heater A was placed in the OFF position to allow for equal pressurization of and depletion from these tanks, using only the B heaters. Hydrogen tanks 6 and 7 continued to be used with only the B heaters throughout the remainder of the mission. During the same period, the hydrogen tank 6 A heater switch was set to manual, but the heater still did not activate. If the hydrogen tank 6 B heater had also failed off, 1 day 15 hours of unusable cryogenic hydrogen would have been left in tank 6 based on the average power level. At the time of the failure, the consumables analysis showed that enough cryogenics were available to support the planned mission and contingency days plus a three-day and five-hour mission extension. Postflight testing at KSC isolated the failure to a 5 ampere fuse in the cryogenic control box on the pallet. Failure analysis was being performed at the time of this writing to determine the cause of the fuse failure.

The PRSD oxygen tank 7 quantity measurement failed off-scale high at 075:08:09:46 G.m.t. (11:18:16:46 MET) (Flight Problem STS-62-V-06). The

measurement reading remained off-scale high for the remainder of the mission and throughout the tank deservicing period. The quantity in the tank at the time of the failure was 36.3 percent.

Fuel Cell Powerplant Subsystem

The fuel cell powerplant performance was nominal throughout the mission. The total energy generated by the fuel cells during the 335.3-hour mission was 5,408 kWh, and a total of 4,210 lbm of potable water was generated. The Orbiter electrical power level averaged 16.1 kW and the total electrical load reached 529 kWh. The fuel cells consumed 3739 lbm of oxygen and 471 lbm of hydrogen. Seven purges were performed, occurring at approximately 20, 66, 111, 161, 231, 303, and 327 hours mission elapsed time. The actual fuel cell voltages at the end of the mission were 0.05 V above predicted for fuel cell 1, 0.15 V above the level predicted for fuel cell 2, and 0.10 V above predicted for fuel cell 3.

Fuel cell 3 carried approximately 40 to 45 percent of the total electrical load throughout much of the mission, but fuel cell 3 did not show a significantly different performance degradation than fuel cells 1 and 2. Purge intervals of up to 72 hours were achieved without reaching the 0.2-volt decay limit.

Auxiliary Power Unit Subsystem

The APUs operated acceptably during the STS-62 mission. The following table shows APU run-times and propellant consumption. A number of minor problems were noted, and these are discussed in the following paragraphs.

Flight Phase	APU 1 (S/N 409)		APU 2 (S/N 308)		APU 3 (S/N 408)	
	Time, min:sec	Fuel consumption, lb	Time, min:sec	Fuel consumption, lb	Time, min:sec	Fuel consumption, lb
Ascent	21:13	51	21:28	59	20:56	55
FCS checkout					07:40	18
Entry <sup>a</sup>	64:48	138	78:08	179	09:00	42
Total <sup>a,b</sup>	86:01	189	99:36	238	37:36	115

Notes:

- <sup>a</sup> APU's 1 and 2 ran for 20 minutes, 25 seconds after landing. APU 3 ran about 2 minutes 34 seconds after landing.
- <sup>b</sup> Totals include ascent, FCS checkout, and entry.

DTO 414 was performed at APU shutdown, and the APU shutdown order was APU 3, APU 1, and APU 2. No power drive unit (PDU) motor back-driving was noted; all pressure slope changes correspond to switching valve changes-of-state.

After MECO, the APU 3 lube oil temperature reached 281 °F before WSB 3 began cooling to correct the under-cooling condition. The system was then over-cooled until the temperature decreased to 229 °F, which was expected after the under-cooling condition. Following the over-cooling to 229 °F, the

temperature then stabilized at the nominal level of 253 °F. This under-cooling and subsequent over-cooling condition followed by nominal temperatures is believed to be caused by a WSB spray-bar freeze-up and subsequent thawing.

The APU 3 fuel-pump-inlet pressure measurement (V46P0310A) cycled normally for about 2.5 hours after APU shutdown following ascent. At approximately 063:16:32 G.m.t. (00:02:39 MET), the measurement began cycling with the upper end of the pressure cycle above the upper limit (off-scale high) (Flight Problem STS-62-V-02). This is the first time that this anomaly has been observed in the Space Shuttle Program. The fuel isolation valve was opened for approximately 33 minutes at 063:18:59 G.m.t. (00:05:06 MET), but the fuel-line pressure did not equalize with tank pressure, indicating an apparent blockage (frozen hydrazine) in the fuel-pump-inlet line. However, beginning with the cycle at 064:04:40 G.m.t. (00:14:47 MET), the upper end of some of the cycles was below the off-scale high point.

The APU 3 fuel-line heaters were switched to the B system at 064:11:43 G.m.t. (00:21:50 MET), and the APU fuel-pump-inlet pressure decreased below the fuel tank pressure and began cycling between 140 psi and 250 psi. At 064:20:54 G.m.t. (01:07:01 MET), when the fuel-pump-inlet pressure was at 182 psi, the fuel isolation valve was opened for the second time. An elapsed time of 14 seconds was required for fuel-pump-inlet pressure to increase from 181 psia to the tank pressure of 232 psia.

The APU 3 fuel-tank isolation valve was opened a third time at 066:15:19:37 G.m.t. (03:01:26:37 MET). Pressure across the valve equalized immediately, indicating no anomalous conditions existed in the APU 3 fuel line and the valve was then closed. Several minutes after the fuel-pump-inlet line heaters cycled on, nominal operation of the back-pressure relief valve was observed.

The APU 3 fuel-pump-inlet pressure continued to cycle nominally between 140 and 320 psia while operating on the B system heaters. At 069:08:19:12.7 G.m.t. (05:18:26:12.7 MET), the APU 3 fuel isolation valve was opened to verify system performance with the pump-inlet pressure above the tank pressure. The valve was opened at a pump-inlet pressure of 295 psia, and the tank-outlet pressure was 224 psia. With a data rate of one sample per second, the pump-inlet pressure fell to 238 psia on the first sample and to 230 psia on the second sample where it stabilized. This performance was normal.

It was concluded that during a rain storm which occurred 13 days prior to launch, water entered the aft fuselage through a Lexan door that covers the 50-2 access hatch. The water most likely entered the APU 3 fuel feed line insulation which covers the tubing and/or thermostats through either lead wire exit holes or through openings at the line support clamps. The water became entrapped between the insulation and tubing and froze during and following ascent, and in turn the hydrazine froze solid within the tube. Analysis has shown that only a small amount of water is required to freeze hydrazine within the tube in a space vacuum due to the heat transferred during the water freezing and sublimation process. Additionally, thermal analysis and tests have shown that pooled water would freeze the hydrazine within the 2.5-hour time period after APU shutdown. Evidence of frozen hydrazine was indicated by the fuel-pump-inlet pressure rising until the transducer went off-scale high. After



the water had sublimated, the hydrazine slowly thawed due to the heat input from the line heaters. Evidence of the thawing was seen when the fuel isolation valve opening response resulted in a sluggish pressure equalization between the APU fuel pump inlet pressure and the fuel tank pressure.

APU 3 was shut down at 077:13:12:15.31 G.m.t., immediately after wheels stop, because of the potential leak concern as a result the APU 3 anomaly earlier in the mission. APU 1 and 2 were shut down by 077:13:30:06.49 G.m.t. after a successful hydraulics load test on the two APUs. No leak in the APU propellant feed lines was found during postflight testing.

At 064:01:17:35 G.m.t. (00:11:24:35 MET), the APU 1 fuel-pump drain-line temperature 2 failed off-scale low, the APU 2 isolation valve B temperature 1 failed off-scale low, and the APU 3 GGVM heat sink temperature dropped 20 °F in two seconds (Flight Problem STS-62-V-03). The measurements returned to normal operation prior to landing. A discussion of this problem is contained in the Instrumentation Subsystems section of this report.

The APU 2 gearbox lube oil return and outlet temperatures indicated the B heater did not turn on as expected at 072:00:00 G.m.t. (08:10:07 MET). However, the measurements did show that the heater turned on 3.5 hours later but at a thermostat reading that was 14 °F lower than previous cycles. Subsequent cycles appeared nominal and no action was taken.

The FCS checkout was successfully completed using APU 3, which ran 7 minutes 40 seconds and consumed 18 lb of fuel. The APU was started at 075:06:50:56 G.m.t. (11:16:57:56 MET) and ran in hydraulic pump low-pressure mode for about 2 minutes 20 seconds before the normal pressure mode was selected. The APU 3 fuel-pump-inlet pressure was nominal during the run as well as after APU shutdown. The pressure first relieved back into the fuel tank at approximately 160 psid about 30 minutes after APU shutdown, and the fuel-pump-inlet pressure continued to relieve normally throughout the APU-soakback periods.

#### Hydraulics/Water Spray Boiler Subsystem

Overall subsystem performance was nominal throughout the mission. Likewise, the WSB also performed satisfactorily except WSB 3 caused an under-cooling condition after ascent on the APU 3 lubrication oil when the oil temperature reached 281 °F before cooling was initiated. As a result of the delayed cooling, an over-cooling condition occurred when the lubrication oil reached 229 °F before stabilizing at 253 °F. No other WSB problems were noted during the mission.

DTO 414 - APU Shutdown Sequence results are presented in the Development Test Objective section of this report.

Hydraulic system 3 performed nominally during the FCS checkout. WSB cooling was required because of the long run-time of the APU. The maximum lubrication oil return temperature was 254.7 °F with spray cooling being initiated at 252 ± 2 °F. During the activities prior to FCS checkout and APU operations, all three B system hydraulic steam vent heaters performed nominally. The vent heaters were turned back on about 2 hours 18 minutes after the FCS checkout to perform a bake-out. The heaters were left on for approximately 4 hours.

## Electrical Power Distribution and Control Subsystem

The electrical power distribution and control (EPDC) subsystem performed satisfactorily throughout the mission. Two problems were noted with the floodlights. These are discussed in the Avionics and Software Systems section as a part of the Displays and Controls discussion.

The discussion of the EDO cryogen pallet hydrogen tank 6 heater A failure is contained in the Power Reactant Storage and Distribution section of this report.

## Environmental Control and Life Support System

The environmental control and life support system (ECLSS) met all requirements placed on it during the mission and operated satisfactorily.

The atmospheric revitalization system (ARS) operated satisfactorily throughout the flight. The cabin air temperature was maintained below 80.2 °F, and the humidity peaked at 49.3 percent. The partial pressure of carbon dioxide (PPCO<sub>2</sub>) varied between nominal values of 3.92 mmHg maximum and 1.12 mmHg minimum. The avionics bay air outlet temperatures peaked at nominal values of 97.8 °F for bay 1, 80.2 °F for bay 2, and 77.5 °F for bay 3. The avionics bay water coldplate outlet temperatures were also nominal and peaked at 87.0 °F for bay 1, 79.9 °F for bay 2, and 79.5 °F for bay 3.

At 064:10:14 G.m.t. (00:20:21 MET), the water coolant loop (WCL) 1 accumulator quantity measurement dropped from 44.9 percent to 19.5 percent in 56 seconds (Flight Problem STS-62-V-05). The quantity measurement recovered in approximately 10 seconds with the final value toggling between 44.4 percent and 44.9 percent. High rate data showed no transients by the WCL 1 pump ΔP transducer, the pump-outlet pressure transducer, or the WCL 1 interchanger flow-rate transducer, thus indicating an instrumentation anomaly in the quantity transducer. The anomaly subsequently recurred at 065:13:54 G.m.t. (01:23:41 MET) when the quantity measurement stepped down from 44.4 percent to 40.8 percent in six steps over the course of 6 seconds. Two seconds later, the measurement recovered, then dropped in one second and recovered to 44.4 percent after one second. This anomaly did not affect the operation of WCL 1 as the other measurements were used to verify the operation of the loop.

The active thermal control subsystem (ATCS) operation was satisfactory throughout the mission. The flow proportioning valve on Freon coolant loop (FCL) 2 was switched to the payload position at 063:16:24 G.m.t. (00:02:21 MET) to support payload cooling requirements. At 063:17:06 G.m.t. (00:03:13 MET), the port radiator panels were deployed to provide improved heat rejection by the radiators during the times the flash evaporator system (FES) was inhibited. The starboard radiator panels remained stowed to prevent blockage of the Ku-band antenna.

The radiator cold soak provided cooling during entry through landing plus 14 minutes when ammonia system A, using the primary/general purpose computer (GPC) controller was activated. Ammonia system A controlled the Freon evaporator outlet temperatures to 35 °F using unique procedures that prevent under-temperature operation of this ammonia system. System A operated for 30 minutes before depletion, after which system B operated for 3 minutes, maintaining temperatures to 36 °F, before ground cooling was established.

The supply water and waste management systems performed nominally. By the completion of the mission, all of the associated supply and waste water in-flight checkout requirements were performed and satisfied. Supply water was managed through the use of the FES and overboard dump systems. Four supply water dumps were performed at an average rate of 1.51 percent/minute (2.49 lb/min). The supply water dump line temperature was maintained between 77 and 107 °F throughout the mission with the operation of the line heater.

At 066:23:16 G.m.t. (03:09:23 MET), the supply water tank B quantity measurement experienced several transients from a nominal value of 3.5 percent to off-scale low. The symptoms match a known phenomenon that is caused by corrosion on the measurement potentiometer. The measurement experienced additional transients throughout the remainder of the mission. The quantity measurement will be repaired during the Orbiter Maintenance Down Period (OMDP).

Waste water was gathered at approximately the predicted rate. Four waste water dumps were made at an average rate of 1.88 percent/minute (3.09 lb/min). The waste-water dump-line temperature was maintained between 54 and 82 °F throughout the mission while the vacuum vent line temperature was between 59 and 75 °F.

The waste collection system (WCS) performed adequately throughout the mission. At 073:18:19 G.m.t. (10:04:26 MET), WCS fan separator 1 exhibited a long (10.162 second) startup signature. There was no indication of liquid in the bowl at that time. Cycles before and after that time exhibited normal startup spikes of 3 to 4 seconds.

At 077:06:29 G.m.t. (13:16:36 MET), fan separator 1 of the WCS exhibited stall currents that tripped the circuit breaker (Flight Problem STS-62-V-08). Again, there was no indication of liquid in the bowl. The crew reconfigured to use fan separator 2 three minutes later. Fan separator 2 operated properly for the remainder of the mission.

The atmospheric revitalization pressure control system (ARPCS) performed normally throughout the flight. During the redundant component check, the pressure control configuration was switched to the alternate system. Both systems exhibited normal operation.

The regenerable carbon dioxide (CO<sub>2</sub>) removal system (RCRS) controller 2 bed B pressure sensor was biased about 1<sup>2</sup> psia from actual cabin pressure (Flight Problem STS-62-V-11). The RCRS operated on controller 2 throughout the last half of the flight, and no shut downs occurred. Postflight evaluation into the sensor's history shows that this sensor was biased 0.55 psia during the acceptance test procedure (ATP) two years earlier. Since that time, the sensor has drifted an additional 0.45 psia. The trip limit for the controller to shut down the RCRS, based on the sensors, is  $\geq 1.8$  psia above actual pressure. To prevent an unnecessary shut down, the sensor will be changed prior to the next flight of the RCRS.

#### Smoke Detection and Fire Suppression System

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

## Airlock Support System

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

## Avionics and Software Support System

The integrated guidance, navigation and control system performance was nominal for all ascent and descent operations. Also, the system performed normally when the requirements of DSO 324 (SKIRT roll) were completed.

The FCS performance was nominal throughout the mission. The FCS checkout was successfully completed with no problems or anomalies identified.

The inertial measurement unit (IMU) ship set, made up of two KT-70 IMUs and one high accuracy inertial navigation system (HAINS) IMU, operated nominally throughout the mission.

Star tracker performance was nominal throughout the mission with no problems or anomalies identified.

During the loading of the systems management (SM) GPC [data processing system (DPS) post-insertion GPC reconfiguration], an input/output (I/O) error was annunciated against mass memory unit (MMU) 1 at 063:14:52:31 G.m.t. (00:00:59:31 MET). A V-bit, indicating in this case that the MMU data word was invalid, was set in the downlist and the SM software was successfully loaded during the "retry" of MMU 1. No data were retrievable from the MMU status registers because the commanding GPC (GPC 4) was in OPS 0, which was not a supported downlist mode at the time. A tape access error also occurred against this MMU during the preflight final software load for STS-62. It is believed that the error that occurred during the on-orbit SM load is most probably the same type as occurred during prelaunch final software load. MMU 1 functioned normally for the remainder of the mission.

The displays and controls subsystem performed nominally; however, two floodlight problems were noted. Payload bay floodlights were powered on by the crew at approximately 066:11:00 G.m.t. (02:21:07 MET). Spikes which indicate arcing and/or flickering were seen on the mid main B bus current data. The crew reported that the mid-port payload bay floodlight was flickering. The light was powered off for the remainder of the mission. Later in the mission at 074:10:07:55 G.m.t. (10:20:14:55 MET), the mid starboard floodlight failed. Main bus C current data indicated a flickering signature and a current spike. The light was powered off for the remainder of the mission.

## Communications and Tracking Subsystems

The communications and tracking subsystems operated acceptably. A number of problems were noted and these are discussed in the following paragraphs.

The Ku-band self-test was performed at 063:16:35:10 G.m.t. (00:02:42:10 MET). The EA-2 portion of the test, which covers the radar mode of operation, caused the self-test to fail. Since this mission did not require the Ku-band system to operate in the radar mode, this self-test failure did not impact the mission.

Three Ku-band self-tests were performed at 076:16:08 G.m.t. (13:02:15 MET) prior to stowing the Ku-band antenna, and all three self-tests were successful. The Ku-band will not be scheduled for use in the radar mode during the next flight of OV-102. Ground troubleshooting of the vehicle will be performed in an effort to determine the cause of the problem. If the problem cannot be resolved, the Ku-band hardware will be removed and sent to the vendor for repair during the next OMDP for OV-102.

Early in the mission, several successful downlink and uplink file transfers were accomplished using the Ku-band Communications Adapter (KCA). Following a payload data interface panel (PDIP) utility power outlet failure, only the uplink capability could be restored after a ground software change. After the completion of payload requirements for the Ku-band, an IFM procedure was performed on the PDIP and the downlink file transfer function was re-enabled. The total file-transfer activity for the mission (both uplink and downlink) consisted of 102 Mb (283 files) transferred in 86 minutes. A more detailed discussion of the KCA is found under DT0 679 in the Development Test Objective section of this report.

### Instrumentation Subsystems

The instrumentation subsystems (operational instrumentation and modular auxiliary data system) operated nominally throughout the mission. Initial evaluation indicates two anomalies in the instrumentation subsystems and they are discussed in the following paragraphs.

At 064:01:17:35 G.m.t. (00:11:24:35 MET), the APU 1 fuel-pump drain-line temperature 2 failed off-scale low, the APU 2 isolation valve B temperature 1 failed off-scale low, and the APU 3 gas generator valve module (GGVM) heat sink temperature dropped 20 °F in two seconds (Flight Problem STS-62-V-03). These measurements are loaded on dedicated signal conditioner (DSC) operational mid (OM) 1, card 21. The fourth measurement on the DSC card appeared nominal at all times and is processed by MDM OF3. The three anomalous measurements are processed by multiplexer/demultiplexer (MDM) OF4, card 9, channels 12, 13, and 14. Each of the failed measurements uses output channel A on the DSC card, whereas the fourth DSC measurement uses output channel B. No other measurements on the MDM card exhibited similar behavior during this time frame. At 070:16:31:37 G.m.t. (07:02:38:37 MET), the three failed measurements returned to nominal readings. The nominal readings continued until 070:21:26:14 G.m.t. (07:07:33:14 MET) when the measurements again failed. The three anomalous temperature measurements were isolated to the DSC OM1, card 21. The faulty card was removed for repair.

Beginning at 075:00:00 G.m.t. (11:10:07 MET), dump data from part of track 6 and all of track 7 on operations (OPS) recorder 2 was of poor quality because of excessive noise (Flight Problem STS-62-V-07). The poor-quality dump data persisted regardless of tape direction during the dump. OPS recorder 2 continued to degrade with tracks 5, 6, 7, 8, and 10 being unusable because of excessive dropouts when recorded data were played back. OPS recorder 2 was only used during acquisition of signal (AOS) periods for the remainder of the mission, minimizing the number of playbacks required. The OPS recorder 2 noise problems were verified during the postflight dump. The recorder was removed from the vehicle and sent to the NASA Shuttle Logistics Depot (NSLD) for testing.



Data reflect nominal aerodynamic and plume heating during ascent and entry. Nominal thermal interface temperatures were noted during all phases of the prelaunch operations and flight.

#### Thermal Control Subsystem

The performance of the thermal control subsystem was nominal during all phases of the flight, and all subsystem temperatures were maintained within acceptable limits.

During the flight, three temperature measurements were lost, all of which used the same DSC and MDM cards. This anomaly is discussed in more detail in the Instrumentation Subsystems section of this report.

#### Aerothermodynamics

The acreage heating was nominal as was local heating. All structural temperatures were within limits. One area of concern existed because of the large damage area that measured 8 in. by 3 in. by 0.675 in. deep, and was located five feet forward and five feet inboard of the right main landing gear wheel well leading edge. This level of damage could cause an early as well as asymmetric boundary layer transition during entry.

#### Thermal Protection Subsystem

The thermal protection subsystem (TPS) performed satisfactorily throughout the mission based on structural temperature response data, which indicates slightly below average heating, especially on the lower surface. The overall boundary layer transition from laminar flow to turbulent flow occurred 1220 seconds after entry interface on the forward centerline of the vehicle and 1210 seconds after entry interface on the aft centerline of the vehicle. Data were not available to determine if the transition was symmetric from the right side of the vehicle to the left side of the vehicle.

Based on data from the runway inspection of the vehicle, overall debris damage to the TPS was below average based on a comparison of total hits on this mission to previous missions of this same configuration. The TPS sustained a total of 97 hits of which 16 had a major dimension of one inch or greater. This total does not include the numerous hits on the base heat shield attributed to the flame arrestment sparkler system.

The Orbiter lower surface had a total of 39 hits (average is 93) of which 7 had a major dimension of one inch or greater (average is 15). The largest tile damage site measured 8 in. by 3 in. by 0.675 in. deep, involved four tiles, and was located about five feet forward and five feet inboard of the right main gear wheel well leading edge. The damage site appears to have originated from four distinct impacts that were enlarged by erosion during entry. The remaining tile material in the damage site showed no significant glazing.

Review of the landing video from the infrared camera showed that at NLGD opening, the forward three sections of the outer mold line (OML) and primary thermal barrier fell from the vehicle (Flight Problem STS-62-V-10). These thermal barriers are bonded to the RCC chin panel using ceramic cement and are

captive once the NLGD is closed. The debonded condition has been attributed to a process step that was not performed when the chin panel was repaired at the vendor prior to STS-62. The requirement to sand the bonding surface after application of the Type A coating was not satisfied. To verify this resolution, a test was performed on the vehicle to compare bonds to the sanded surface versus the unsanded surface. Adequate bonds were attained on both surfaces; however, it was more difficult to wet the unsanded surface during the surface priming operation. An inadequate priming of the surface would account for the bonding failure. Softening of the Type A coating at higher temperatures also contributed to the failure. Thus, the STS-62 anomaly can be attributed to both of these described conditions.

The nose cap and chin panel tile areas were in good condition with some fraying of the nose-cap-to-chin-panel gap filler noted. The right-hand aft outboard corner tile was cracked during NLGD opening, and it will be replaced.

Orbiter windows 3 and 4 exhibited moderate hazing. Only a very light haze was present on the other windows. Surface wipes were taken from all windows for laboratory analysis. Tile damage on the window perimeter tiles was typical.

The left-hand main landing gear door (MLGD) thermal barriers (old bonded design) were in good condition; however, the right-hand MLGD thermal barriers (new mechanically attached design) were breached in three locations. The left-hand elevon-to-elevon gap tiles (old design) were in marginal condition whereas, the new design gap tiles were in good condition. Several broken low-temperature reusable surface insulation (LRSI) tiles were noted on the right-hand upper wing.

The ET door thermal barriers were in nominal condition overall with no related tile damage. Tile damage on the base heat shield was also typical. The dome-mounted heat shield (DMHS) closeout blankets on all three SSMEs were in excellent condition and no material was missing. Tiles on the vertical stabilizer "stinger" and around the drag chute door were intact and undamaged with the exception of one 7/8 in. diameter damage site on the +Y edge of the stinger.

An unusual number of debris hits was noted on the vertical tail, especially on the right-hand leading edge below the split line thermal barrier. The split line thermal barrier itself was breached on the left-hand forward area. Three cracked TPS tiles were found on the vertical tail at the point where the vertical tile meets the Shuttle Infrared Leeside Temperature Sensing (SILTS) pod (Flight Problem STS-62-V-12). Two of the cracked tiles were located on the right-hand side of the vertical tail and the third cracked tile was located on the left-hand side of the tail. All three of the cracked tiles were found near the tip trailing edge above the rudder speedbrake. The damage locations follow the horizontal stiffener in that area. An inspection showed no structural damage beneath the tiles. This vehicle (OV-102) is the only one in the fleet that uses these type of tiles in the vertical tail area; the other vehicles use advanced flexible reusable surface insulation (AFRSI) blankets. The cause of the cracked tiles has not been determined at this writing.

A cluster of 29 damage sites spanned three tiles on the rudder black-edge tiles, located on the SILTS pod. One damage site was located on the left side and two



directly opposite on the right side, just above the rudder speedbrake (RSB). Six of the damage sites had a major dimension of one inch or larger while three of the damage sites were deep enough to expose the substrate. The tiles were cracked forward to aft, along a structural seam. The cracks were apparently caused by structural deflection, although X-rays have shown no damage to the Orbiter structure. Analysis of data shows that the ascent loads were larger than entry, indicating that the damage may have occurred during ascent. The three tiles were subsequently replaced by three identical tiles. There is no safety-of-flight issue with the tiles cracking through the thickness, especially in this thermally benign area.

The potential identification of debris damage sources for STS-62 will be based on the laboratory analysis of Orbiter postlanding microchemical samples, inspection of the recovered SRB components, and film analysis (including on-orbit photography of the ET). The results of these analyses will be reported in the STS-62 Ice/Debris/TPS Assessment and integrated photographic analysis report (NASA Technical Memorandum 109201).

No tile damage from micrometeorites or on-orbit debris was identified during the inspection. Also, no TPS damage was attributed to material from the wheels, tires, or brakes. The tires were in good condition after landing on the KSC runway.

The Shuttle thermal imager (STI) was used to measure the surface temperatures of several areas on the vehicle following landing in accordance with the OMRSD requirements. Eight minutes after landing, the Orbiter nose cap RCC temperature was 224 °F. About 16 minutes after the first measurement, the right-hand wing leading edge RCC panel was 108 °F and panel 17 was 100 °F.

FLIGHT CREW EQUIPMENT/GOVERNMENT FURNISHED EQUIPMENT

All flight crew equipment(FCE)/GFE performed nominally.

The crew reported noting a closeout panel floating around the middeck after MECO. This panel was identified as the starboard side closeout panel for the volume B stowage area, and the panel was reinstalled by the crew. The Velcro holding the panel in place had apparently come loose.

At 064:15:23 G.m.t. (01:01:30 MET), the crew reported that when dispensing hot water, the galley dispensed up to twice as much as requested (Flight Problem STS-62-F-01). The crew also reported that the dispensed volume of hot water had been varying randomly throughout the mission; this condition cleared later in the flight. The galley flow regulators cannot be adjusted on-orbit. The cold water was being dispensed accurately.

Beginning at 065:07:55 G.m.t. (01:18:02 MET), static noise was noted on the forward and return links on air-to-ground 1 (Flight Problem STS-62-F-02). At the time of the problem, the crew was using audio interface unit (AIU)-C channel 1. When AIU-C channel 2 was selected by the crew, the static was no longer noted. This problem could be a faulty crew remote unit; however, the more likely cause was an AIU-C channel 1 failure.

At approximately 075:04:17 G.m.t. (11:14:24 MET), the crew reported that a wireless crew communications system (WCCS) headset had failed (Flight Problem STS-62-F-05). The crew reported during the postflight debriefings that the battery was replaced in the WCCS and it operated properly thereafter.

The crew reported that the third (extra) manifested multiple headset adapter (MHA) was not stowed in locker MF430 (Flight Problem STS-62-F-04), even though the cushion within the locker was configured for a MHA. The locker was shipped to KSC short of this MHA; however, the necessary documentation was shipped with the locker so that KSC should have placed the MHA into the locker before loading the locker onto the Orbiter.

Closed circuit television (CCTV) camera D exhibited a loss of low-light-level capability at 065:16:40 G.m.t. (02:02:47 MET) (Flight Problem STS-62-F-03). Power cycling of the camera did not correct the problem. The camera operated properly at the next sunrise. Later while using camera D for testing of this problem, the camera would not focus and the image looked as if there was a film on the lens. The power was cycled, but this did not correct the problem. While troubleshooting, the iris was commanded to full open, but no difference was noted. When the iris was taken to close, the picture immediately disappeared. This indicated that the iris was not opening the correct amount.

Camera A was pointed at camera D in an attempt to see the iris move and note any anomalous conditions. This test was inconclusive. A troubleshooting procedure was performed on camera D in an attempt to open the iris and make the camera usable for documenting the OAST-2 operations. Video was received from camera D, and it showed that the camera was operating nominally in the low-light conditions.

The camera D iris again became stuck partially open and did not respond to the iris open and close commands at 073:12:40 G.m.t. (09:22:47 MET). The camera's power was cycled, but the problem was not corrected. The RMS wrist camera was used for the EISG payload low-light camera requirements for the remainder of the mission.

At 076:12:29 G.m.t. (12:22:36 MET), the downlink from the camcorder (s/n 1002) displayed numerous colored spots during low-light level operations (Flight Problem STS-62-F-07).

At 076:16:03 G.m.t. (13:02:10 MET), the end effector (EE) CCTV camera video contained two vertical lines floating across the image horizontally (Flight Problem STS-62-F-06). The same pattern was seen on downlinks from the DEE right-angle and magnetic end effector (MEE) cameras. No DEE operations were in progress during this time period.

At various times in the mission, CCTV camera A exhibited image instability (Flight Problem STS-62-F-08). Occasional jerking, flashes of color patches, and image tearing were noted in the downlinked video. The camera will be repaired when returned to JSC for testing.

## REMOTE MANIPULATOR SYSTEM

The RMS was flown on STS-62 to support the Dexterous End Effector Demonstration (DEED), and the RMS performed satisfactorily. This was the thirty-fifth flight of the RMS, and there were no RMS anomalies. The DEED hardware consisted of a magnetic attachment tool (MAT) and task bar carried on an Orbiter longeron-mounted experiment support and activities plate (ESAP). The MAT is comprised of a MEE that is capable of grappling its associated grapple plate using electromagnets, a force/torque sensor (FTS) capable of measuring and displaying forces and moments existing at the RMS-end-effector-MAT interface, and a targeting and reflective alignment concept (TRAC) mirror. TRAC used the CCTV view of a camera's own reflection to accurately align an object with the camera's viewing axis. All DEED objectives were met to the satisfaction of the payload developers. There were not hardware anomalies; however, DEED cameras exhibited significant washout in daylight, making some tasks difficult to perform.

The RMS checkout was performed in accordance with nominal procedures at 063:18:43 G.m.t. (00:04:50 MET), and all signatures were normal. At the end of the checkout, the arm remained in use to perform the first DEED test. The MAT was grappled by the RMS end effector (EE) at 063:20:18 G.m.t. (00:06:25 MET). The MAT was then released from the ESAP and positioned by the arm at about 30 feet above an Orbiter keel camera. For about one hour, arm positioning accuracy tests were performed using an Orbiter keel camera and a TRAC mirror mounted on the MAT. Prior to restowing the MAT, FTS calibration was performed by pressing two MAT-mounted springs of known force against the MAT's ESAP cradle. The arm was cradled and latched at 063:21:38 G.m.t. (00:07:45 MET).

For this mission, the maximum RMS rates when maneuvering the MAT were limited in software to the very slow rates used during the Hubble Space Telescope (HST) repair when moving a 24,000-lb payload. This was done to give the operator more controllability during the dexterous tasks planned for the DEED. Because the low rates allowed the operator sufficient response time to compensate for unwanted RMS motion, all RMS manual mode positioning and tracking accuracy tasks performed during the mission demonstrated excellent capability for the RMS/operator to perform fine precision maneuvers. The crew felt that the incorporation of Position and Orientation Hold Submode (POHS) in the RMS will only enhance precise operations.

Because of the USMP-2 low tolerance to disturbances, the RMS operations were restricted for the next seven flight days.

Unplanned RMS activity occurred on flight day 9. Orbiter CCTV camera D was required for the mission success of the EISG payload. When this camera failed, the mission objective of monitoring the EISG glow plate during Orbiter night passes was met by using the RMS wrist camera. An appropriate arm position for the camera was developed by the ground controllers and used during several night passes. The first RMS CCTV survey began at 071:14:53 G.m.t. (08:01:00 MET), and the arm was cradled and latched by 071:15:40 G.m.t. (08:01:47 MET).

DEED activities were resumed at 073:08:37 G.m.t. (09:18:44 MET). The RMS was maneuvered to the MAT which was then grappled at 073:08:55 G.m.t. (09:19:02 MET). The same arm positioning accuracy tests and FTS calibration

performed on flight day 1 were continued with each of the three mission specialists performing each task. Activities were interrupted, however, at 073:12:35 G.m.t. (09:22:42 MET) and then terminated at 073:14:53 G.m.t. (010:01:00 MET) to perform EISG monitoring using the RMS CCTV. After the second monitor exercise, the FTS was used to measure the strength of loads that the arm can apply. With the MAT grappled and constrained in its ESAP cradle, RMS hand controller commands were issued along each EE axis. The MAT was released at 073:16:20 G.m.t. (10:02:27 MET), and the arm was cradled and latched by 073:17:27 G.m.t. (10:03:34 MET).

The next day's activity began with an arm power-up at 074:07:14 G.m.t. (10:17:21 MET), and the MAT was grappled at 074:07:32 G.m.t. (10:17:39 MET). After the FTS calibration procedure was performed, constrained MAT FTS measurements were continued until 074:08:42 G.m.t. (10:18:49 MET) when the DEED task bar was grappled using the MEE. Dexterous operations were performed with each of the three operators inserting the pin end of the task bar into holes of three different sizes in the ESAP. Operators successfully performed multiple insertions into all but the smallest hole (0.030-inch clearance). Insertion into the smallest hole was successfully performed only once.

Analyzing the video data after the mission, the crew felt that the width of the green crosshairs displayed on the Orbiter CCTV monitors masked the alignment accuracy needed to perform the 0.030-inch tolerance insertion. Without the crosshairs displayed, misalignments were visible during the postflight review of the video tape that the crew was not aware of during the mission. The crew also reported that the crosshairs seemed to "jump-around" occasionally on the display. A thinner crosshair display would have been desirable, preferably generated at the MAT centerline camera.

The crosshairs on the TRAC mirror as viewed by the MAT center-line camera were the primary cues used for all alignment and insertion tasks. The crew was complimentary of the TRAC mirror targeting system because it decoupled the translational and rotational alignment errors. When the center of the TRAC mirror was at the center of the MAT center-line camera view, translational alignment was achieved. When the MAT camera was reflected in the center of the TRAC mirror, pitch and yaw misalignments were removed. Roll alignment was achieved by overlaying the CCTV crosshairs on the TRAC mirror crosshairs. During the mission, however, finding the intersection of the TRAC crosshairs was sometimes made difficult by lighting conditions. DEED-supplied cameras often washed out views during daylight passes, probably because of their fixed iris settings.

The crew stated that during the insertion tasks, TRAC continued to serve as the primary alignment cue with FTS data being used only as a cross-check. The FTS proved to be most useful in finding the point of initial insertion into a hole. Once started into the two larger holes, force/torque build-ups during insertion never reached a level that required operator corrections. However, given the non-linear behavior of the arm in a constrained situation and that POHS will be turned off when constrained conditions are met, the crew believed that insertion tasks like those on STS-62 should never be attempted without some type of force/torque feedback.

The task bar was then restowed and the MAT rotated 180 degrees on the arm to grapple the paddle end of the task bar for additional insertion tests into a slotted opening on the top of the ESAP. Beginning at 074:13:21 G.m.t. (10:23:28 MET), three operator commanded automatic sequence (OCAS) maneuvers were performed from a point 5 feet away from the ESAP to 30 feet above the Orbiter keel camera and back. The intent of the test was to determine the repeatability of OCAS termination points using the measuring accuracy of the TRAC targeting system. After the last OCAS maneuver at 074:14:16 G.m.t. (11:00:23 MET), the arm was positioned for one of the day's two EISG CCTV monitoring sessions. Between the EIGS viewings, arm positioning accuracy tests similar to those performed on flight day 1 were again performed, but with the MAT's TRAC target reflecting a camera on the ESAP from only about 1-foot distance. The second EISG monitoring session occurred at 074:15:30 G.m.t. (11:01:37 MET), immediately following the stowing of the MAT in its ESAP cradle. After the EISG monitoring session, the arm was placed in an overnight park position to prevent interference with the field-of-view of the SSBUV payload instrument.

On the final day of DEED operations, the arm was first maneuvered to the pre-cradle position at 075:06:47 G.m.t. (11:16:54 MET) to avoid unwanted RMS motion during an Orbiter OMS firing. Also at 075:09:30 G.m.t. (11:19:37 MET), the day's only EISG monitoring session was performed using the RMS wrist CCTV. At 075:10:43 G.m.t. (11:20:50 MET), the MAT was grappled by the RMS EE and the FTS was calibrated. To characterize the MEE capture envelope, a series of magnetic grapples were attempted with the MAT at varying distances above its ESAP cradle. The MEE had to be closer than 2 inches to the grapple fixture for an effective magnetic grapple to occur. This grapple test was followed by additional task bar insertion tests, performed this time without the operator using FTS data for dexterity cues. On completion of this activity, the task bar and MAT were stowed for the final time and DEED operations were completed. The arm was again placed in an extended park position overnight.

At 076:07:44 G.m.t. (12:17:51 MET), the final EISG monitoring session was performed using the RMS. Afterwards, the arm was cradled and latched and the manipulator positioning mechanisms (MPMs) were rolled in at 076:10:32 G.m.t (12:20:39 MET).

The RMS was stowed at 076:10:31 G.m.t. (12:20:38 MET). All planned RMS operations were successfully completed for the mission. The RMS remained in the temperature monitoring mode until immediately prior to payload bay door closing.

## CARGO INTEGRATION

The cargo integration hardware performance was nominal except for the anomaly in the PDIP. When the PDIP dc outlet ceased functioning during flight day 3 activities, power to operate the data path switching relays enable the KCA to operate both in the uplink and downlink modes in support of DTO 679 were lost. A ground software change was made to allow one-way uplink communication using the KCA.

An in-flight maintenance (IFM) procedure was performed at 076:13:59 G.m.t. (013:00:06 MET) using a breakout box and KCA two-way operations were restored. Operation in this mode was excellent, and the crew satisfactorily downlinked 41 files for a total of 9 Mb of data. A more detailed discussion of this KCA problem is presented in the Development Test Objectives section of the report.

## DEVELOPMENT TEST OBJECTIVES AND DETAILED SUPPLEMENTARY OBJECTIVES

The STS-62 flight had 17 development test objectives (DTOs) and 20 detailed supplementary objectives (DSOs) assigned to the manifest. Data were not collected on one DTO - Crosswind Landing Performance (DTO 805). The following paragraphs provide a short summary about the DTOs and DSOs that were accomplished.

### DEVELOPMENT TEST OBJECTIVES

DTO 254 - Subsonic Aerodynamics Verification - The crew reported that all the requirements of this DTO were met. The data from the crew as well as all recorded data have been given to the DTO sponsor for evaluation, and the results of the evaluation will be published in a separate report.

DTO 301D - Ascent Wing Structural Capability Evaluation - Data were recorded on the MADS recorder for this DTO, and these data have been given to the sponsor for evaluation. The results of that evaluation will be documented in a separate report.

DTO 307D - Entry Structural Capability Evaluation - Data were recorded on the MADS recorder for this DTO, and these data have been given to the sponsor for evaluation. The results of that evaluation will be documented in a separate report.

DTO 312 - External Tank Thermal Protection System Performance (Methods 1 and 3) - The DTO 312 photography of the ET after separation was acquired using the Nikon 35 mm camera and the 300 mm lens and a 2X extender (Method 3). Thirty-six exposures were made of the ET, all of which had good exposure but variable focus. The first frame was taken at 063:14:08:31 G.m.t. (00:00:15:31 MET), and the thirty-sixth frame was exposed at 063:14:13:11 G.m.t. (00:00:20:11 MET). The frames were evenly spaced with approximately 8 seconds between exposures. One possible divot was noted on the LH<sub>2</sub> intertank interface of the -Z axis (toward Orbiter side as the ET rests on the MLP) on frame 17. Two light areas were noted in the intertank area above and to the left of the forward bipod on frame 1. The light areas are possible repairs to the ET insulation. A single light area was noted on the +Y axis of the LH<sub>2</sub> intertank interface on frame 13. This light area could not be confirmed as a divot.

In addition to the 35 mm photography, the camcorder was used to obtain extensive video of the ET. The video had good focus and exposure. The photographer sighted the ET in the field of view (FOV), and then zoomed in, effectively enlarging the ET in the view. The ET was well tracked, and an average tumble rate of 0.85 deg/sec was computed from the video. Possible divots were noted on the LH<sub>2</sub> intertank interface, and a more detailed review of this area was made using the 35 mm photographs.

Two pieces of debris were noted in the FOV. The first appeared to originate from the LH<sub>2</sub> umbilical disconnect, and the second appeared from behind the aft portion of the ET at the LH<sub>2</sub>/aft dome interface. The debris had the appearance of umbilical ice; however, a positive identification could not be made. The debris separated slowly from the ET and departed the FOV about 34 seconds after the initial appearance.



DTO 319D - Orbiter/Payload Acceleration and Acoustics Environment Data - Data were collected for this data-only DTO, and these data have been given to the sponsor for evaluation. The results of that evaluation will be reported in a separate document.

DTO 413 - On-Orbit PRSD Cryogenic Boiloff - All scheduled DTO operations were performed by the crew and ground controllers to measure the pressure rise in the tanks on-orbit when the tanks were not supplying reactant. This was accomplished by operating one or two tanks between 240 and 275 psia and allowing the other tanks to increase in pressure due to heat leak over several hours. The measured heat-leak range in each of the tanks was 4 to 6 Btu/hr. While performing the DTO, each of the hydrogen supply-line check valves, except for tanks 3 and 9, experienced slight leakage as evidenced by the pressure rise in these tanks being higher than expected during portions of the pressure-rise cycle. When this condition would occur, the tank that was being operated manually at the higher pressure range would be allowed to decrease to the pressure of the tank with a leaking check valve. This would allow flow out of that tank, and in turn the check valve would then reseal properly when the controlling tank was pressurized. Data analysis is continuing.

DTO 414 - APU Shutdown Test (Sequence A) - The APUs were shut down in the planned sequence (APU 3, APU 1, and APU 2) with at least 5 seconds between individual APU shutdowns. No unusual APU spindown pressures were observed, nor was any back-driving of the PDU motor observed. The DTO will continue to be performed on upcoming flights. After the flight tests are complete, the detailed results of this DTO will be reported in separate documentation.

DTO 521 - Orbiter Drag Chute System - A special test condition for this flight was deployment of the drag chute at the initiation of derotation. This special test condition was met and data from this test will be reported in separate documentation. The initial results indicate that the next drag chute test will deploy the drag chute at a higher speed (approximately 185 knots).

DTO 656 - PGSC Single Event Upset Monitoring (Configuration 1 and 2) - Data were collected for this DTO. The data have been given to the sponsor for evaluation. The results of that evaluation will be reported in separate documentation.

DTO 664 - Cabin Temperature Survey - Temperature data were collected by the crew, and these data have been given to the sponsor for evaluation. The results of this evaluation will be reported in a separate document.

DTO 667 - Portable In-Flight Landing Operations Trainer - The Commander and Pilot performed the preflight planned sessions plus several additional runs on the Portable In-Flight Landing Operations Trainer (PILOT).

DTO 670 - Passive Cycle Isolation System - Several configurations for isolating the Passive Cycle Isolation System (PCIS) ergometer for microgravity enhancement were exercised during the mission. Data concerning the enhancement will be evaluated by the sponsor, and the results of that evaluation will be reported in a separate document.

DTO 674 - Thermoelectric Liquid Cooling System Evaluation - The crew reported that the Thermoelectric Liquid Cooling System performed well during ascent, entry and landing. The subjective results of the crewmembers were given to the sponsor for evaluation. The results of the evaluation will be reported in a separate document.

DTO 678 - Infrared Survey of Orbiter Crew Compartment, Spacelab, and Spacehab Module - Prerecorded infrared (IR) scanner video downlink was received and recorded. These videos included IR images of the CGBA and CPCG payloads, as well as the galley and flight deck. Because the KCA downlink capability was not available for the majority of the flight (see DTO 679), digital IR images were not downlinked until flight day 14. Additional IR images stored on disk have been evaluated. The data are being evaluated by the sponsor and the results of that evaluation will be reported in separate documentation.

DTO 679 - Ku-band Communications Adapter Demonstration - Early in the mission, several successful downlink and uplink file transfers were accomplished. However, when the Linhof camera was plugged into the dc power 2 connector of the PDIP, the camera did not function. The camera was subsequently plugged into a utility outlet, and the camera functioned properly. Although the Ku-band function of the PDIP was previously operating properly, this function also stopped operating. Both of the dc power 2 connectors and the PDIP relays are on the same circuit. The PDIP is powered from the standard switch panel (SSP) on a separate power feed. This power was used by the PDIP for the two power connectors and the relays that are used for the Ku-band switching functions. The Ku-band function was required for the the OAST-2 payload, and this DTO 679. The crew performed the utility output power check IFM procedure and verified no power was being supplied to the dc power 2 outlet.

A ground software change was made to allow one-way uplink communication using the KCA. The verification of the downlink response signal was deleted as that signal was no longer available as a result of the dc problem with the PDIP. Subsequently at 071:05:26 G.m.t. (07:15:33 MET), one-way communication was established and 17 files containing 12 Mb of data were uplinked to the Orbiter in approximately 25 minutes. The uplink time was somewhat lengthened because a manual verification step was required when using the one-way protocol. However, using the portable audio data modem (PADM), the equivalent data transfer would have required between 9 and 10 hours.

The KCA was used again successfully at 072:07:36 G.m.t. (08:17:43 MET) to uplink 6 Mb of data that were stored in four files in 7 1/2 minutes. Uplinking these data through the PADM would have taken 5 3/4 hours. Although the first file was not received using this one-way uplink configuration, a successful onboard workaroud was developed to receive the data satisfactorily.

The IFM procedure was performed using a breakout box at 076:13:59 G.m.t. (13:00:06 MET) and KCA two-way operations were restored. Operation in this mode was excellent, and the crew satisfactorily downlinked 41 files for a total of 9 Mb of data. A total of 102 Mb of data were transferred and this is equivalent to approximately 3 days 22 hours of PADM file transfer time. Additional details on the results of this DTO will be reported in separate documentation.

DTO 805 - Crosswind Landing Performance - The minimum crosswind magnitude (10 to 15 knots steady-state) required for this DTO was not present for the KSC landing.

DTO 910 - Orbital Acceleration Research Experiment - The Orbital Acceleration Research Experiment (OARE) operated successfully throughout the mission acquiring quasi-steady-state microgravity data in support of the microgravity payloads. These data have been given to the sponsor for evaluation, and the results of that evaluation will be reported separately.

#### DETAILED SUPPLEMENTARY OBJECTIVES

DSO 324 - Payload On-Orbit Low Frequency Environment - The payload on-orbit low-frequency environment DSO objectives were performed on flight day 12 in accordance with operational procedures at approximately 074:07:01 G.m.t. (10:17:08 MET). The purpose of DSO 324 was to obtain on-orbit low-frequency (0-50 Hertz) payload acceleration data from the primary reaction control subsystem thruster firings. Seven thrusters were fired individually for specific durations of 80, 160, and 240 msec. The results were as expected. The data have been given to the sponsor for evaluation, and the results will be published separately.

DSO 326 - Window Impact Observations - Window observations were made by the crew, and their findings have been given to the sponsor. The results of these findings will be reported separately.

DSO 485 - Inter Mars Tissue Equivalent Proportional Counter - The Inter Mars Tissue Equivalent Proportional Counter (ITEPC) activation and deactivation (aft main bus B power) were accomplished after orbital insertion and during deorbit preparations. The data have been given to the sponsor for evaluation, and the results of that evaluation will be reported separately.

DSO 487 - Immunological Assessment of Crewmembers - All preflight and postflight requirements of this DSO were met. The data have been given to the sponsor for analysis, the results of which will be reported separately.

DSO 492 - In-Flight Evaluation of a Portable Clinical Blood Analyzer - All sessions were completed as scheduled. No anomalies were reported on the blood analyzer; however, two anomalies involving support equipment were reported. The galley bar code reader, which is used by the crew to log their exercise as well as maintain a record on the food and fluid intake, malfunctioned during use but was recovered following troubleshooting. This caused no impact to the associated DSOs. The galley hot water dispensing problem experienced early in the flight may have compromised some data because of the need for accurate volume measurements; however, evaluation is continuing for determining if any data loss occurred. The evaluation results of this DSO will be reported in separate documentation.

DSO 603 - Orthostatic Function During Entry, Landing, and Egress (603B Schedule) - The EDO DSO 603 activities were performed during entry and following wheels stop. The data were given to the sponsor for evaluation, and the results of that evaluation will be reported separately.

DSO 604 - Visual-Vestibular Integration as a Function of Adaptation - All preflight and postflight DSO 604 EDO activities were completed as planned. The data have been given to the sponsor for evaluation, and the results of that evaluation will be reported separately.

DSO 605 - Postural Equilibrium Control During Landing and Egress - The postflight testing was completed. The data were given to the sponsor for evaluation, and the results of that evaluation will be reported separately.

DSO 608 - Effects of Spaceflight on Aerobic and Anaerobic Metabolism During Exercise - All in-flight DSO requirements were met. The results have been given to the sponsor who will report the results separately.

DSO 610 - In-Flight Assessment of Renal Stone Risk - All in-flight sessions were completed as scheduled. The performance of this DSO was affected by the same supporting hardware as used for DSO 492 that was discussed earlier in this section.

DSO 611 - Air Monitoring Instrument Evaluation and Atmosphere Characterization (Microbial Air Sampler) - All data for DSO 611 were collected. The crew reported a clicking noise in the air sampler during the first data take; however, troubleshooting defined the problem, which was corrected prior to the second data take. The data have been given to the sponsor for evaluation, and the results of that evaluation will be reported separately.

DSO 612 - Energy Utilization - All DSO 612 sessions were completed as scheduled. This DSO was also affected by the same supporting hardware as discussed earlier in DSO 492. The data have been given to the sponsor for evaluation, and the results will be reported separately.

DSO 614 - The Effect of Prolonged Space Flight on Head and Gaze Stability During Locomotion - All preflight and postflight protocols were completed and the data have been given to the experimenter. The data are being evaluated, and the results of that evaluation will be reported separately.

DSO 623 - In-Flight Lower Body Negative Pressure (LBNP) Test of Countermeasures and End-of-Mission Countermeasure Trial - All DSO 623 requirements for the flight were successfully accomplished. Minor anomalies that did not impact the scientific results were noted. They were:

a. Early LBNP device runs apparently had a waist seal leak that caused slow transition between pressure steps -- later runs had no difficulty;

b. An unrecoverable data recorder malfunction caused continued operations to be performed using only real-time data;

c. The LBNP controller fuse was blown at vacuum cleaner startup during flight day 14 activities -- the fuse was replaced and normal LBNP operations were resumed.

DSO 626 - Cardiovascular and Cerebrovascular Response to Standing Before and After Space Flight - All preflight and postflight protocols were completed as planned. The data have been given to the sponsor for evaluation, and the results of that evaluation will be reported separately.

DSO 802 - Educational Activities (Objective 2) - Multiple live TV downlink sessions were performed on various subjects by the crew. The video data have been given to the sponsor for evaluation, and the results will be published separately.

DSO 901 - Documentary Television - Video tapes of documentary television activities were recorded for this DSO. The tapes have been given to the sponsor for evaluation.

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

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

## PHOTOGRAPHY AND TELEVISION ANALYSES

### LAUNCH PHOTOGRAPHY AND VIDEO DATA ANALYSIS

The launch photography consisted of 55 films and 24 videos of the launch activities. All films and videos were screened, and no anomalous conditions were noted. In addition, two rolls of film from the one of the 16 mm umbilical well cameras and the 35 mm camera were screened and no anomalies were noted. The 16 mm camera with the 10 mm lens did not function. The film of the ET, taken for DTO 312, was also reviewed and no anomalous conditions were noted.

### ON-ORBIT PHOTOGRAPHY AND VIDEO DATA ANALYSIS

No analysis of on-orbit photography was required in support of this mission.

### ENTRY PHOTOGRAPHY AND VIDEO DATA ANALYSIS

Fourteen videos of the approach and landing phase on KSC runway 33 were reviewed. Also four infrared camera films were obtained for review. In addition, 16 landing films were reviewed. The only anomalous condition noted is discussed in the following paragraph.

Screening of the infrared films revealed four pieces of debris, which fell from the vehicle during the landing gear deployment phase. Two of the items appeared to originate from the main landing gear, and the other two pieces appeared to originate from the nose landing gear area. The debris from the nose landing gear doors was identified as thermal barrier material and a piece of TPS tile that was found missing during the postlanding walkaround inspection of the vehicle. The material from the main landing gear area has been tentatively identified as gap filler material.

TABLE I.- STS-62 SEQUENCE OF EVENTS

Event	Description	Actual time, G.m.t.
APU Activation	APU-1 GG chamber pressure	063:13:48:10.91
	APU-2 GG chamber pressure	063:13:48:12.16
	APU-3 GG chamber pressure	063:13:48:13.31
SRB HPU Activation <sup>a</sup>	LH HPU system A start command	063:13:52:32.099
	LH HPU system B start command	063:13:52:32.259
	RH HPU system A start command	063:13:52:32.419
	RH HPU system B start command	063:13:52:32.579
Main Propulsion System Start <sup>a</sup>	Engine 3 start command accepted	063:13:52:53.437
	Engine 2 start command accepted	063:13:52:53.590
	Engine 1 start command accepted	063:13:52:53.704
SRB Ignition Command (lift-off)	SRB ignition command to SRB	063:13:53:00.009
Throttle Up to 104 Percent Thrust <sup>a</sup>	Engine 1 command accepted	063:13:53:04:314
	Engine 3 command accepted	063:13:53:04.318
	Engine 2 command accepted	063:13:53:04.350
Throttle Down to 67 Percent Thrust <sup>a</sup>	Engine 1 command accepted	063:13:53:31.035
	Engine 3 command accepted	063:13:53:31.038
	Engine 2 command accepted	063:13:53:31.071
Maximum Dynamic Pressure (q)	Derived ascent dynamic pressure	063:13:53:52
Throttle Up to 104 Percent Thrust <sup>a</sup>	Engine 1 command accepted	063:13:53:57.436
	Engine 3 command accepted	063:13:53:57.439
	Engine 2 command accepted	063:13:53:57.471
Both SRM's Chamber Pressure at 50 psi <sup>a</sup>	RH SRM chamber pressure mid-range select	063:13:54:59.329
	LH SRM chamber pressure mid-range select	063:13:55:00.769
End SRM Action <sup>a</sup>	RH SRM chamber pressure mid-range select	063:13:55:02.619
	LH SRM chamber pressure mid-range select	063:13:55:03.529
SRB Physical Separation <sup>a</sup>	LH rate APU A turbine speed LOS	063:13:55:06.249
	RH rate APU A turbine speed LOS	063:13:55:06.249
SRB Separation Command	SRB separation command flag	063:13:55:07
Throttle Down for 3g Acceleration <sup>a</sup>	Engine 1 command accepted	063:14:00:31.045
	Engine 3 command accepted	063:14:00:31.047
	Engine 2 command accepted	063:14:00:31.078
3g Acceleration	Total load factor	063:14:00:32.8
Throttle Down to 67 Percent Thrust <sup>a</sup>	Engine 1 command accepted	063:14:01:24.166
	Engine 3 command accepted	063:14:01:24.168
	Engine 2 command accepted	063:14:01:24.198
Engine Shutdown <sup>a</sup>	Engine 1 command accept	063:14:01:30.446
	Engine 3 command accept	063:14:01:30.448
	Engine 2 command accept	063:14:01:30.479
MECO	Command flag	063:14:01:31
MECO	Confirm flag	063:14:01:32

<sup>a</sup>MSFC supplied data

TABLE I.- STS-62 SEQUENCE OF EVENTS (Continued)

Event	Description	Actual time, G.m.t.
ET Separation	ET separation command flag	063:14:01:50
APU Deactivation	APU-3 GG chamber pressure	063:14:09:08.72
	APU-1 GG chamber pressure	063:14:09:23.82
	APU-2 GG chamber pressure	063:14:09:39.44
OMS-2 Ignition	Left engine bi-prop valve position	063:14:35:20.0
	Right engine bi-prop valve position	063:14:35:20.0
OMS-2 Cutoff	Left engine bi-prop valve position	063:14:37:32.0
	Right engine bi-prop valve position	063:14:37:32.2
Payload Bay Doors Open	PLBD right open 1	063:15:27:24
	PLBD left open 1	063:15:28:45
OMS-3 Ignition	Left engine bi-prop valve position	N/A
	Right engine bi-prop valve position	073:07:02:38.9
OMS-3 Cutoff	Left engine bi-prop valve position	N/A
	Right engine bi-prop valve position	073:07:03:20.9
OMS-4 Ignition	Left engine bi-prop valve position	073:07:43:29.0
	Right engine bi-prop valve position	N/A
OMS-4 Cutoff	Left engine bi-prop valve position	073:07:44:15.9
	Right engine bi-prop valve position	N/A
Flight Control System Checkout		
APU Start	APU-3 GG chamber pressure	075:06:50:56.49
APU Stop	APU-3 GG chamber pressure	075:06:58:37.34
OMS-5 Ignition	Right engine bi-prop valve position	075:08:08:33.1
	Left engine bi-prop valve position	075:08:08:33.1



TABLE I.- STS-62 SEQUENCE OF EVENTS (Concluded)

Event	Description	Actual time, G.m.t.
OMS-5 Cutoff	Right engine bi-prop valve position	075:08:09:10.7
	Left engine bi-prop valve position	075:08:09:10.9
Payload Bay Doors Close	PLBD left close 1	077:09:32:14
	PLBD right close 1	077:09:34:00
APU Activation For Entry	APU-2 GG chamber pressure	077:12:11:58.90
	APU-1 GG chamber pressure	077:12:25:17.03
	APU-3 GG chamber pressure	077:13:03:14.50
Deorbit Maneuver Ignition	Left engine bi-prop valve position	077:12:16:50.2
	Right engine bi-prop valve position	077:12:16:50.2
Deorbit Maneuver Cutoff	Left engine bi-prop valve position	077:12:18:57.7
	Right engine bi-prop valve position	077:12:18:57.7
Entry Interface (400K)	Current orbital altitude above reference ellipsoid	077:12:38:06
Blackout Ends	Data locked at high sample rate	No blackout
Terminal Area Energy Management	Major mode change (305)	077:13:03:25
Main Landing Gear Contact	LH MLG tire pressure	077:13:09:41
	RH MLG tire pressure	077:13:09:41
Main Landing Gear Weight On Wheels	LH MLG weight on wheels	077:13:09:41
	RH MLG weight on wheels	077:13:09:41
Drag Chute Deploy	Drag chute deploy 1 CP Volts	077:13:09:54.7
Nose Landing Gear Contact	NLG tire pressure	077:13:10:00
	NLG WT on Wheels -1	077:13:10:00
Drag Chute Jettison Wheels Stop	Drag chute jettison 1 CP Volts	077:13:10:21.6
	Velocity with respect to runway	077:13:10:35
APU Deactivation	APU-3 GG chamber pressure	077:13:12:15.31
	APU-1 GG chamber pressure	077:13:30:04.67
	APU-2 GG chamber pressure	077:13:30:06.49

TABLE II.- STS-62 ORBITER PROBLEM TRACKING LIST

Number	Title	Reference	Comments
STS-62-V-01	Engine 3 GH <sub>2</sub> Flow Control Valve Sluggish	063:13:53 G.m.t. 000:00:00:35 MET IM 62RF01 IPR 65V0003	Engine 3 GH <sub>2</sub> flow control valve cycled 17 times during the first 35 seconds of ascent (prior to the throttle bucket). A sluggish open-response of 0.2 to 0.5 second (should be < 0.3) was noted with possible hesitation on 3 cycles. KSC: Troubleshooting
STS-62-V-02	APU 3 Pump Inlet Pressure (V46P0310A)	063:16:23 G.m.t. 000:02:30 MET IM 62RF03 IPR 65V0006	About 2 1/2 hours after liftoff, APU-3 pump inlet pressure began cycling from approximately 250 psi to above off-scale-high (612 psi). At 000:05:10 MET, the crew opened the fuel tank isolation valves in an attempt to relieve the pressure back to the tank. However, the pump inlet pressure showed no decrease, nor was there an increase seen in the fuel tank pressure. After switching to the B heaters, a second isolation valve opening was attempted. The inlet pressure sluggishly stabilized to tank pressure. A third isolation valve opening was attempted with instantaneous results. APU-3 was used for FCS checkout and entry with nominal performance. Suspect water intrusion into the insulation caused freezing of the hydrazine.  KSC: Postlanding sniff checks indicated no hydrazine leak. No apparent anomalies found within the insulation or heaters. Both were removed and sent to RI-Downey for evaluation and test.
STS-62-V-03	Anomalous APU Temperature Measurements <u>LEVEL III CLOSURE</u>	064:01:18 G.m.t. 000:11:25 MET IPR 65V0002 IM 62RF13	o V46T0170A - APU 1 Fuel Pump Drain Temperature 2 off-scale low. o V46T1273A - APU 2 Isolation Valve B Temperature 1 - off-scale low. o V46T1372A - APU 3 GGM Heat Sink Temperature These measurements share DSC OM 01 card 21 and MDM of 04 card 9.  KSC: Troubleshooting isolated the problem to DSC OM1.
STS-62-V-04	PRSD H <sub>2</sub> Tank 6 A Heater Failed <sup>2</sup>	065:22:02 G.m.t. 002:08:09 MET IM 62RF04 IPR 65V0005	EDO Pallet H <sub>2</sub> tank 7 heater A failed off in both auto and manual control modes. Switched H <sub>2</sub> Tank 6 and 7 to B heaters.  KSC: Verified that heater A failed off. Tank 6 cryogenic control box found open. The fuse was replaced and unit appears to be functioning nominally. NDE failure analysis on the fuse shows the fuse opened probably due to slightly high current over an extended period of time. Destructive failure analysis to follow.
STS-62-V-05	Water Coolant Loop 1 Accumulator Quantity Transducer Drift <u>LEVEL III CLOSURE</u>	064:10:14 G.m.t. 000:20:21 MET IM 62RF05 IPR 65V0004	The water coolant loop (WCL) 1 accumulator quantity dropped from 44.9 to 19.5 percent in 56 seconds. The quantity recovered in approximately 10 seconds with the final value toggling between 44.4 and 44.9 percent. High rate data showed no transients by the WCL 1 pump ΔP transducer, pump outlet pressure transducer, or the WCL 1 interchanger flowrate transducer, thus indicating an instrumentation problem.  KSC: Troubleshooting the problem. Suspect contamination on transducer coil as probable cause.

TABLE II.- STS-62 ORBITER PROBLEM TRACKING LIST

Number	Title	Reference	Comments
STS-62-V-06	<p>PRSD 02 Tank 7 Quantity Failed Off-scale High LEVEL III CLOSURE</p>	<p>075:08:09 G.m.t. 11:18:16 MET IM 62RF08 IPR 65V0009</p>	<p>PRSD 02 tank 7 quantity indication (V45Q3205A) failed off-scale high at 075:08:09:46 G.m.t. This measurement is routed through MDM OF4 card 14 channel 00. There are several other tank quantity measurements as well as other Orbiter measurements on this same MDM card which have been nominal throughout the mission.</p> <p>This measurement is routed through DSC 40V75A83 (EDO DSC), card 3, channel A. On that same DSC card, there are three other tank quantity measurements which have been nominal. Data indicate the anomalous quantity measurement is due to a faulty sensor/wire.</p> <p>KSC: Troubleshooting traced fault to tank probe or junction box. Tank was removed and replaced.</p>
STS-62-V-07	<p>Poor Quality Dump From Operations Recorder 2 LEVEL III CLOSURE</p>	<p>075:00:00 G.m.t. 11:10:07 MET IM 62RF09 PR INS-2-17-1047</p>	<p>The Operations (OPS) Recorder 2 initially had poor dump quality on tracks 6 and 7. The recorder continued to degrade over 24 hours with tracks 5, 6, 7, 8, and 10 having excessive dropouts. Recorder removed and sent to NSLD for troubleshooting and repairs.</p>
STS-62-V-08	<p>WCS Fan Separator 1 Failure</p>	<p>077:06:19 G.m.t. 13:16:26 MET IM 62RF10 PR ECI-2-A0087</p>	<p>Fan Separator 1 stalled for 30 seconds and popped all three ac circuit breakers. Earlier in the flight, this fan separator exhibited an extended startup signature.</p> <p>KSC: WCS removed and sent to JSC for troubleshooting and repair.</p>
STS-62-V-09	<p>Failed-off Left Vent Door 5 Open 2 Indication</p>	<p>077:13:03 G.m.t. 13:23:10 MET IPR 65V0011 IM 62RF11</p>	<p>During the vent door open sequence on entry (at M = 2.4), the left vent door 5 open 2 indication (V59K3465X) failed to indicate OPEN. The ac 2 currents associated with left vent door 5 motor 2 showed that this motor drove the entire time the software open command was set high (~10 sec total drive time). Motor 1 drove nominally during the open sequence.</p> <p>KSC: Troubleshooting duplicated the problem. Door is mechanically rigged properly. Anomaly isolated to PDU.</p>
STS-62-V-10	<p>NLGD Thermal Barrier Debond</p>	<p>077:13:09:22 G.m.t. 13:23:16:22 MET PR FWD-2-17-4590 IM 62RF12</p>	<p>Six thermal barriers, total size approximately 36" x 3" x 1.5", were missing from the nose landing gear doors. Runway infrared cameras recorded these objects falling from the Orbiter when the nose landing gear doors were opened on final approach. Investigation revealed that the vendor did not sand off the Type A coating on the bonding surface. The ceramic cement has poor adhesion characteristics to the Type A coating at the high temperatures which caused the barrier to debond and fall out of the nose landing gear door area.</p>

TABLE II.- STS-62 ORBITER PROBLEM TRACKING LIST

Number	Title	Reference	Comments
STS-62-V-11	RCRS Controller Bed Pressure B Sensor Drifting Low	056:16:38 G.m.t. 06:21:15 MET IM 62RF16	<p>The regenerable CO<sub>2</sub> removal system (RCRS) controller 2 bed B pressure sensor was biased about 1 psia from actual pressure in the cabin. The RCRS was operated with controller 2 for the last half of the flight and there were no shut downs. Postflight evaluation into the sensor's history shows that this sensor was biased 0.55 psia two years ago during ATP. Since then, it seems that the sensor has drifted another 0.45 psia and is now biased 1 psia from actual. The replacement of the sensor was determined necessary because the trip limit for the controller to shut down is based on a biased sensor of 1.8 psia or greater from actual.</p>
STS-62-V-12	Cracked TPS Tiles on the Vertical Tail	Postlanding IM 62RF17	<p>Three cracked TPS tiles on the vertical tail were discovered during the postflight inspections. The cracked tiles are located on the side of the vertical tail where the vertical tile meets the SILTS pod. The damage location follows the horizontal stiffener in that area. No structural damage was found beneath the tiles.</p>

TABLE III.- STS-62 GFE PROBLEM TRACKING LIST

Number	Title	Reference	Comments
STS-62-F-01	SORG Dispensing Random Amounts of Hot Water <u>LEVEL III CLOSURE</u>	064:15:27 G.m.t.	The crew reported that, when dispensing hot water, the Galley dispensed twice as much as specified. The crew reported the problem as being sporadic.
STS-62-F-02	WCCS Wall Unit C Channel 1 Static <u>LEVEL III CLOSURE</u>	065:07:55 G.m.t.	Crew began getting static on both the forward and return links on air-to-ground 1. The crew isolated the problem to the C1 Channel. Anytime the crew switched and tried to use this wall unit, they got the static.
STS-62-F-03	CCTV Camera D Iris Problem <u>LEVEL III CLOSURE</u>	066:06:36 G.m.t.	Camera D would not focus and the image looked as if there was a film on the lens. The power was cycled, but this did not correct the problem. While troubleshooting, the iris was commanded to full open, but no difference in the image was noted. The iris was taken to close, and the picture disappeared. This suggests that the iris was not opening up enough.
STS-62-F-04	Multiple Headset Adapter Not Stowed <u>LEVEL III CLOSURE</u>	063:20:15 G.m.t.	Crew reported the third (extra) multiple headset adapter (MHA) was not stowed in locker MF430. The cushion within locker was configured for a MHA, but it was not there.
STS-62-F-05	WCCS Headset Failed <u>LEVEL III CLOSURE</u>	075:04:17 G.m.t.	Crew reported that they had a headset failure on the middeck. The crew swapped the headset with another one. The crew tagged and bagged the faulty headset.
STS-62-F-06	Wrist CCTV Camera Vertical Lines in Image <u>LEVEL III CLOSURE</u>	076:16:03 G.m.t.	Downlinks from the RMS wrist TV camera displayed two vertical lines floating through the image horizontally. The same pattern was seen on downlinks from the DEE right angle and MEE cameras (on the dexterous end effector payload).
STS-62-F-07	Camcorder S/N 1002 Multicolor Spots <u>LEVEL III CLOSURE</u>	076:12:29 G.m.t.	Downlink of camcorder video, during low-light levels, displayed numerous colored spots.
STS-62-F-08	CCTV Camera 'A' Image Instability <u>LEVEL III CLOSURE</u>	075:19:29 G.m.t.	The CCTV camera 'A' image had occasional jerking, flashes of color patches, and image tearing.

TABLE IV.- MSFC ELEMENTS PROBLEM TRACKING LIST

Problem/Title	Element	Description	Comments/Status
<p>STS-62-B-1 Blistering of Hypalon over ETA on Right SRB Frustum</p>	<p>SRB (USB) A15878 PV6-262712</p>	<p>During postflight inspection of the right SRB frustum, blistering of the hypalon was observed over multiple areas of the BTA closeout material.</p>	<p>STS-62 was the first flight with BTA applied forward of the ETA ring (region defined as debris concern zone to the vehicle). Blistering of hypalon over BTA was previously observed on the aft skirts of STS-51 (reference IFA No. STS-51-B-2). Based on a series of extensive thermal tests, the STS-51 occurrence was attributed primarily to radiant heating. The rationale for flight of this configuration on forward assemblies was that radiant heating during ascent was not expected. For this reason, this problem was considered a program IFA.</p> <p>All areas, except one location, exhibited blistering indicative of the entry phase (post ascent). On the trailing edge of the frustum, below the BSM cluster, the BSM soot pattern demonstrated blisters which most likely formed prior to SRB separation. The subject location is known as the hottest body point on the frustum and was removed for further and thermal evaluation. Physical examination of the subject Hypalon-coated BTA concluded that there were no heat effects on the exposed BTA. The development flight instrumentation and design thermal profiles predict that an insufficient heat rate exists to cause blistering until after launch (L) + 90 seconds.</p> <p>The results of aerodynamic heating tests conducted as the MSFC Improved Hot Gas Test Facility demonstrated that blistering over the BTA does not occur until approximately L + 120 seconds. The physical evidence, hot-gas tests, and thermal profiles support a late ascent occurrence. Furthermore, slow motion video analysis of the hot gas test films confirmed that blistered Hypalon burns off instead of becoming detached debris. This finding coupled with the late ascent time frame of occurrence eliminates the possibility of debris of sufficient mass, as well as a transfer mechanism into the Orbiter. Consequently, this localized condition on the frustum poses no debris threat or flight safety concerns. Corrective action was not deemed necessary.</p> <p>The IFA problem report remains open in the Level II MSFC PRACA tracking system. This IFA was closed with Level II closure signatures obtained outside the PRCB (PRCBD No. S62100A) on April 1, 1994.</p>

## 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.

AADSF	Advanced Automated Directional Solidification Furnace
ac	alternating current
AFRSI	advance flexible reusable surface insulation
AIU	audio interface unit
AMOS	Air Force Maui Optical Site
AOS	acquisition of signal
APCG	Advanced Protein Crystal Growth
APSA	Advanced Photovoltaic Solar Array
APE-B	Auroral Photography Experiment-B
APU	auxiliary power unit
ARPCS	atmospheric revitalization pressure control system
ARS	atmospheric revitalization system
ATCS	active thermal control subsystem
ATP	acceptance test procedure
BDS	Bioreactor Demonstration System
BETSU	Brilliant Eyes Thermal Storage Unit
BTA	Booster Trowellable Ablative
CCTV	closed circuit television
CDMS	Command and Data System
CFLSE-ZENO	Critical Fluid Light Scattering Experiment-Zeno
CGBA	Commercial Generic Bioprocessing Apparatus
CO <sub>2</sub>	carbon dioxide
CPCG	Commercial Protein Crystal Growth
CRYOTP	Cryogenic Two Phase
DAP	digital autopilot
dc	direct current
DEE	dexterous end effector
DEED	Dexterous End Effector Demonstration
DLS	dynamic load sensor
DMHS	dome-mounted heat shield
$\Delta P$	differential pressure
DPS	data processing system
DSC	dedicated signal conditioner
DSO	Detailed Supplementary Objective
DTO	Development Test Objective
$\Delta V$	differential velocity
DVP	Developmental Version Payload
ECLSS	Environmental Control and Life Support System
ECT	Emulsion Chamber Technology
EDO	Extended Duration Orbiter
EE	end effector
EISG	Experimental Investigation of Spacecraft Glow
EPDC	electrical power distribution and control subsystem
ESAP	Experiment Support and Activities Plate
e.s.t.	eastern standard time
ET	External Tank
ETR	experiment tape recorder
EVA	extravehicular activity



FCE flight crew equipment  
 FCL freon coolant loop  
 FCS flight control system  
 FCV flow control valve  
 FDA fault detection annunciation  
 FES flash evaporator system  
 FOV field of view  
 FTS force/torque sensor  
 ft/sec feet per second  
 GAS Getaway Special  
 GEI ground environment instrumentation  
 GFE Government furnished equipment  
 GGVM gas generator valve module  
 GH<sub>2</sub> gaseous hydrogen  
 G.m.t. Greenwich mean time  
 GPC general purpose computer  
 H<sub>2</sub> hydrogen  
 HAINS High Accuracy Inertial Navigation System  
 HPOTP high pressure oxidizer turbopump  
 HST Hubble Space Telescope  
 ICD Interface Control Document  
 IDGE Isothermal Dendritic Growth Experiment  
 IFM in-flight maintenance  
 IMU inertial measurement unit  
 INSTEP In-Space Technology Program  
 I/O input/output  
 IR Infrared  
 Isp specific impulse  
 ITEPC Inter Mars Tissue Equivalent Proportional Counter  
 JSC Johnson Space Center  
 KCA Ku-band communications assembly  
 keas knots equivalent air speed  
 KSC Kennedy Space Center  
 kW kilowatt  
 kWh kilowatt hours  
 lbm pound mass  
 LBNP Lower Body Negative Pressure  
 LCC Launch Commit Criteria  
 LDCE Limited Duration Space Environment Candidate Material Exposure  
 LESC Lockheed Engineering and Sciences Company  
 LH<sub>2</sub> liquid hydrogen  
 LO<sub>2</sub> liquid oxygen  
 LRSI low temperature reusable surface insulation  
 lube lubrication  
 MAT magnetic attachment tool  
 MDM multiplexer/demultiplexer  
 MEE magnetic end effector  
 MECO main engine cutoff  
 MEPHISTO Material pour L'Etude des Phenomenes Interessant la Solidification  
                   sur Tere et an Orbite  
 MET mission elapsed time  
 MHA multiple headset adapter  
 MLGD main landing gear door  
 MLP mobile launch platform

MMU mass memory unit  
MODE Middeck 0-Gravity Dynamics Experiment  
MPM manipulator positioning mechanism  
MPS main propulsion system  
msec millisecond  
N<sub>2</sub> nitrogen  
NASA National Aeronautics and Space Administration  
NLGD nose landing gear door  
nmi. nautical mile  
NOAA National Oceanographic Atmospheric Administration  
NPSP net positive suction pressure  
NSLD NASA Shuttle Logistics Depot  
NSTS National Space Transportation System  
OARE Orbital Acceleration Research Experiment  
OAST-2 Office of Aeronautics and Space Technology-2  
OCAS operator commanded automatic sequence  
OFI operational flight instrumentation  
OM operation mid  
OMDP Orbiter Maintenance Down Period  
OME orbital maneuvering engine  
OML outer mold line  
OMRSD Operations and Maintenance Requirements and Specifications Document  
OMS orbital maneuvering subsystem  
OPS Operations  
PADM portable audio data modem  
PAL protuberance air load  
PCAM Protein Crystallization Apparatus for Microgravity  
PCIS Passive Cycle Isolation System  
PDIP Payload data interface panel  
PDU power drive unit  
PGSC Payload General Support Computer  
PILOT Portable In-Flight Landing Operations Trainer  
PMBT propellant mean bulk temperature  
POHS Position and Orientation Hold Submode  
PPCO<sub>2</sub> partial pressure carbon dioxide  
ppm parts per million  
PRSD power reactant storage and distribution  
PSE Physiological Systems Experiment  
RCC reinforced carbon carbon  
RCRS regenerable carbon dioxide removal system  
RCS reaction control subsystem  
RM redundancy management  
RMS remote manipulator system  
RSB rudder speedbrake  
RSRM Redesigned Solid Rocket Motor  
S&A safe and arm  
SAMPIE Solar Array Module Plasma Interaction Experiment  
SAMS Space Acceleration Measurement System  
SCN Succinonitrile  
SHP Space Heat Pipe  
SILTS Shuttle Infrared Leeside Temperature Sensing  
SKIRT Spacecraft Kinetic Infrared Test  
SLF Shuttle Landing Facility  
SM systems management

S/N,s/n serial number  
 SRB Solid Rocket Booster  
 SRSS Shuttle Range Safety System  
 SSBUV/A Shuttle Solar Backscatter Ultraviolet/A  
 SSME Space Shuttle main engine  
 SSP standard switch panel  
 STA structural test article  
 STI Shuttle Thermal Imager  
 STS Space Transportation System  
 T critical temperature  
 TES Thermal Energy Storage/thermal enclosure system  
 TPS thermal protection subsystem/thermal protection system  
 TRAC Targeting and Reflective Alignment Concept  
 TSH triaxial sensor heads  
 USMP-2 United States Microgravity Payload -2  
 V volt  
 VDA vapor diffusion apparatus  
 VDT vapor diffusion tray  
 WCL water coolant loop  
 WCCS wireless crew communications system  
 WCS Waste Collection System  
 WSB water spray boiler