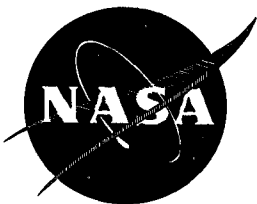


STS-63 SPACE SHUTTLE MISSION REPORT

June 1995



**National Aeronautics and
Space Administration**

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

NOTE

The STS-63 Space Shuttle Mission Report was prepared from inputs received from the Orbiter Project Office as well as other organizations. The following personnel may be contacted should questions arise concerning the technical content of this document.

William H. Arceneaux, JSC
713-483-3335

Orbiter and subsystems

C. A. Snoddy, MSFC
205-544-0391

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

Dianne J. Murphy, JSC
713-483-1055

Payloads/Experiments

G. P. Buoni, JSC
713-483-0639

DTOs and DSOs

F. T. Burns, Jr., JSC
713-483-1262

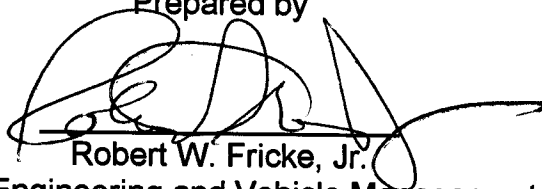
FCE and GFE

STS-63

SPACE SHUTTLE

MISSION REPORT

Prepared by



Robert W. Fricke, Jr.

LESC/Flight Engineering and Vehicle Management Office

Approved by



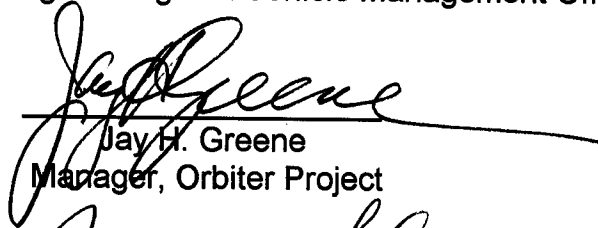
William H. Arceneaux

STS-63 Lead Mission Evaluation Room Manager



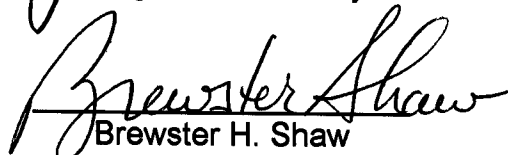
David W. Camp

Manager, Flight Engineering and Vehicle Management Office



Jay H. Greene

Manager, Orbiter Project



Brewster H. Shaw

Director, Space Shuttle Operations

Prepared by

Lockheed Engineering and Sciences Company
for

Flight Engineering and Vehicle Management Office

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

May 1995

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INTRODUCTION

The STS-63 Space Shuttle Program Mission Report summarizes the Payload activities and provides detailed data on the Orbiter, External Tank (ET), Solid Rocket Booster (SRB), Reusable Solid Rocket Motor (RSRM), and the Space Shuttle main engine (SSME) systems performance during this sixty-seventh flight of the Space Shuttle Program, the forty-second since the return to flight, and twentieth flight of the Orbiter vehicle Discovery (OV-103). In addition to the OV-103 Orbiter vehicle, the flight vehicle consisted of an ET that was designated ET-68; three SSMEs that were designated 2035, 2109, and 2029 in positions 1, 2, and 3, respectively; and two SRBs that were designated BI-070. The RSRMs that were an integral part of the SRBs were designated 360Q042A for the left SRB and 360L042B for the right SRB.

The STS-63 mission was planned as an 8-day duration mission with two contingency days available for weather avoidance or Orbiter contingency operations. The primary objectives of the STS-63 mission were to perform the Mir rendezvous operations, accomplish the Spacehab-3 experiments, and deploy and retrieve the Shuttle Pointed Autonomous Research Tool for Astronomy-204 (SPARTAN-204) payload. The secondary objectives were to perform the Cryogenic Systems Experiment (CSE)/Shuttle Glo-2 Experiment (GLO-2) Payload (CGP)/Orbital Debris Radar Calibration Spheres (ODERACS-2) (CGP/ODERACS-2) payload objectives, the Solid Surface Combustion Experiment (SSCE), and the Air Force Maui Optical Site Calibration Test (AMOS). The objectives of the Mir rendezvous/flyby were to verify flight techniques, communication and navigation-aid sensor interfaces, and engineering analyses associated with Shuttle/Mir proximity operations in preparation for the STS-71 docking mission.

The STS-63 Space Shuttle Mission Report fulfills the Space Shuttle Program requirement as documented in NSTS 07700, Volume VIII, Appendix E. The requirement states that each major organizational element supporting the Program will report the results of their hardware (and software) evaluation and mission performance, plus identify all related in-flight anomalies.

The STS-63 sequence of events is shown in Table I, the Orbiter Problem Tracking List is shown in Table II, the Government Furnished Equipment (GFE) Problem Tracking List is shown in Table III and the MSFC Problem Tracking List is shown in Table IV. In addition, the Shuttle integration and Payload in-flight anomalies are referenced in applicable sections of the report. Appendix A lists the sources of data, both formal and informal, that were used in the preparation of this report. Appendix B provides the definition of acronyms and abbreviations used in the document. All times, except for the launch delay times, are given in Greenwich mean time (G.m.t.) and mission elapsed time (MET).

The six-person crew for STS-63 consisted of James D. Wetherbee, CDR., U. S. Navy, Commander; Eileen M. Collins, Lt. Col., U. S. Air Force, Pilot; Bernard A. Harris, Jr.,

M. D., Payload Commander and Mission Specialist 1; C. Michael Foale, Ph. D., Mission Specialist 2; Janice Voss, Ph. D., Mission Specialist 3; and Vladimir Georgievich Titov, Col. Russian Air Force, Mission Specialist 4. STS-63 was the third space flight for the Commander and Mission Specialist 2, the second space flight for the Payload Commander (Mission Specialist 1) and Mission Specialist 3, the first space flight for the Pilot and the first Space Shuttle flight for Mission Specialist 4. Lt. Col. E. M. Collins was the first female Space Shuttle Pilot, and Col. V. G. Titov (a veteran of three Russian space flights) was the second Russian cosmonaut to fly on the Space Shuttle.

MISSION SUMMARY

The STS-63 launch was delayed from 12:47:44 a.m. e.s.t. on February 2, 1995, until 12:22:04 a.m. e.s.t. on February 3, 1995, because inertial measurement unit (IMU) 2 failed during the launch countdown. The high accuracy inertial navigation system (HAINS) IMU was replaced, and the unit was retested satisfactorily.

The STS-63 Shuttle vehicle was launched from Launch Complex 39, pad B at 034:05:22:03.994 G.m.t. (12:22:04 a.m. e.s.t.) on February 3, 1995. The ascent phase was nominal in all respects, and no orbital maneuvering subsystem (OMS) -1 maneuver was required. A determination of vehicle performance was made using vehicle acceleration and preflight propulsion prediction data. The average flight-derived engine specific impulse (Isp) for the time period between SRB separation and the start of 3-g throttling was 452.6 seconds, compared to an MPS tag value of 452.80 seconds.

During the Orbiter separation maneuver from the ET, primary reaction control subsystem (RCS) thruster R1U failed off at 034:05:30:53 G.m.t. (00:00:08:49 MET), and failed leak at 034:05:32:08 G.m.t. (00:00:10:04 MET). Also, primary RCS thruster L2D failed off at 034:05:30:56 G.m.t. (00:00:08:52 MET).

The OMS-2 maneuver was performed at 034:06:04:14 G.m.t. (00:00:42:10 MET). The maneuver was 155.7 seconds in duration and the differential velocity (ΔV) was 252.1 ft/sec. The orbit after completion of the maneuver was 168.8 by 183.9 nmi

Four unsuccessful attempts were made to stop the oxidizer leakage from the RCS R1U thruster by closing the manifold isolation valves, allowing oxidizer manifold pressure to decrease, followed by opening the isolation valves to allow rapid repressurization of the oxidizer manifold. No significant change in the leak signature was observed as a result of these operations. The manifold isolation valves were then closed to isolate the leak. RCS right manifold 1 isolation valves were reopened again at approximately 037:07:29:14 G.m.t. (03:02:07:10 MET) to manage fuel manifold pressure changes that were being caused by solar heating. The oxidizer leak was still present at a lower rate, and the right RCS manifold 1 isolation valves were closed for the Mir rendezvous.

At 034:21:50 G.m.t. (00:16:28 MET), the cabin pressure transducer shifted low by 0.24 psi from 14.64 psi to 14.40 psi. All other available instruments indicated a nominal cabin pressure.

An input/output (I/O) error message against cathode ray tube (CRT) 4 was annunciated and two I/O errors were logged by general purpose computer (GPC) 4 about 35 minutes after powering on CRT 4. The crew found the CRT screen blank, and the display electronics unit (DEU) built-in-test-equipment (BITE) flag tripped. CRT 4 was recovered by performing a power cycle. The DEU/CRT 4 experienced three

recurrences of the failure and the DEU/CRT was recovered each time with a power cycle. The crew used the DEU at their discretion, and there was no mission impact.

The SPARTAN-204 payload was grappled at 035:06:33 G.m.t. (01:01:11 MET), unberthed and used to perform Shuttle Glow (GLO) observations while attached to the remote manipulator system (RMS).

The primary RCS thrusters L1L, L1U, R4U, F3L, and F3U fired simultaneous 80-ms-duration pulses in response to an unexpected +Y/+Z translation hand controller (THC) command following the power-up of the aft THC at 035:11:41:06 G.m.t. (01:06:19 MET). The THC had not been deflected. Data review indicated that the THC command probably resulted from a transient response of the THC contacts upon application of flight controller power.

A hot-fire test of the RCS low-Z thrusters was performed in preparation for the Mir rendezvous. After a nominal firing of F1F, the thruster's oxidizer injector temperature dropped to 16.5 °F, causing leak detection software to deselect the thruster. The temperature drop is characteristic of an oxidizer valve leak. The fuel injector temperature eventually dropped below 40 °F, prompting isolation of the forward RCS manifold 1 at 035:20:27:40 G.m.t. (01:15:05:36 MET), after which the injector temperatures recovered. Manifold 1 was re-opened at 036:04:21 G.m.t. (01:22:59 MET) to allow the force of repressurizing the manifold to clear potential contaminants from the oxidizer valve seat. No further leakage was noted. The thruster was subsequently fired nominally three times and was returned to normal operation.

The rendezvous with the Mir Space Station was performed in an outstanding manner. The Orbiter approached to within 12 meters of the Mir. The approach, stationkeeping, back-away and fly-around were performed flawlessly. The videos were spectacular, originating simultaneously from the Mir and the Orbiter. The Mir cosmonauts reported no vibrations or solar array movement as a result of the approach to the Mir.

At 037:20:06 G.m.t. (03:14:43 MET), the latch A indication in the port radiator latch gang 1-6 actuator began toggling off and on. After toggling frequently for approximately one hour, the indication returned to normal operation except for occasional toggles. The redundant indication (latch B) showed nominal position and no erratic behavior.

The RMS was used to successfully deploy the SPARTAN-204 payload at 038:12:12:28 G.m.t. (04:06:50:24 MET).

The flight control system (FCS) checkout was performed using auxiliary power unit (APU) 3. APU 3 ran for 7 minutes 22 seconds with APU start at 039:10:05:28 G.m.t. (05:04:43:24 MET). Water spray boiler (WSB) cooling was required because of the extended run time of the APU with spray cooling lasting approximately 5 seconds.

The rendezvous with the SPARTAN-204 payload was completed satisfactorily. The Ku-Band radar acquired SPARTAN-204 at 135,000 ft and tracked to a distance of 85 ft. Radar performance was satisfactory throughout the rendezvous operations. The RMS successfully grappled the SPARTAN at 040:11:33:20 G.m.t. (06:06:11:16 MET) and the satellite was berthed at 040:12:10:26 G.m.t. (06:06:48:22 MET).

All preparations for the planned extravehicular activity (EVA) were completed and the two crew members began the EVA at 040:11:56:30 G.m.t. (06:06:34:26 MET). The Development Test Objective (DTO) 833 extravehicular mobility unit (EMU) Thermal Evaluation and EVA worksite evaluation rest period were conducted satisfactorily. The RMS was used to maneuver the extravehicular crewmembers during the EVA.

The EVA mass handling procedures were performed during a night pass. Ten minutes into the night pass, extravehicular crewmember 1 (EV1) reported uncomfortably cold hands, and EV2 reported cold hands and feet. Crew thermal comfort was restored during the following day pass. Mass handling activities were shortened and payload bay clean-up was initiated.

The EVA was concluded at 040:16:34:43 G.m.t. (06:11:12:39 MET) with an official EVA time of 4 hours and 39 minutes. The EMU performance was nominal during the EVA. During airlock repressurization, the EV2 crewmember reported a burning sensation in his eyes. Brown flecks of material were found on the inner surface of the visor when the helmet was doffed.

During the EVA, a small pressure drop was detected in the Spacehab module. The pressure decreased from 14.80 psi to 14.16 psi over a 5-hour 18-minute period.

The Spacehab hatch was closed at 041:15:45 G.m.t. (07:10:23 MET). All entry stowage and deorbit preparations were completed. The payload bay doors were successfully closed and latched at 042:08:06:28 G.m.t. (08:02:44:24 MET). The deorbit maneuver for a Kennedy Space Center (KSC) landing was performed at 042:10:44:04 G.m.t. (08:05:22:00 MET), and the maneuver was 254.3 seconds in duration with a ΔV of 450.4 ft/sec.

Entry was completed satisfactorily, and main landing gear touchdown occurred at concrete runway 15 at 042:11:50:19 G.m.t. (08:06:28:15 MET) on February 11, 1995. The Orbiter drag chute was deployed satisfactorily at 042:11:50:27 G.m.t., and nose landing gear touchdown occurred 6 seconds later. The drag chute was jettisoned at 042:11:51:05 G.m.t., with wheels stop occurring at 042:11:51:40 G.m.t. The rollout was normal in all respects. The flight duration was 8 days 6 hours 28 minutes and 15 seconds with landing occurring on orbit 129. The APUs were shut down 21 minutes 39 seconds after landing.

MIR RENDEZVOUS AND FLY-AROUND

The primary objective of the STS-63 mission was accomplished with the successful completion of the Mir rendezvous and fly-around. The rendezvous and fly-around were jeopardized by the oxidizer leaks from RCS thrusters R1U and F1F. Flight rules for STS-63 stated that if low-Z redundancy were lost, the Shuttle would not approach the Mir within 1000 ft, and no venting would be allowed within 40 nmi. of the Mir.

Final negotiations with the Russians for a rendezvous with the Mir were intensified when the Orbiter RCS thrusters R1U and F1F started leaking. After recovery of thruster F1F, and an analysis of the leaking R1U thruster indicated that the small oxidizer leak would not contaminate the Mir, the Russians agreed to the conduct of the flight day 4 rendezvous as planned. To stop thruster R1U from leaking required the closure of the R1 manifold, and this in turn eliminated low-Z redundancy by isolating thruster R1A. It was finally agreed that the R1 manifold would be closed and the Shuttle could approach the Mir. If thruster R3A had failed, the R1 manifold would be reopened to re-enable R1A, and the Mir would tolerate the small leak from R1U while the Orbiter backed away. No additional thruster failures occurred during the rendezvous and fly-around operations.

In final preparation for the Mir rendezvous, a single OMS right-engine straight-feed height-adjust (HA) maneuver was initiated at 034:14:20:15 G.m.t. (00:08:58:11 MET). The maneuver was approximately 39.7 seconds in duration and imparted a 32.1 ft/sec ΔV to the vehicle. The Orbiter was in a 188 x 182 nmi. orbit as a result of the maneuver. The post-maneuver data review indicated nominal OMS performance.

At 035:14:26:48 G.m.t. (01:09:04:24 MET), a left OMS engine straight-feed nominal correction (NC) rendezvous maneuver was initiated. The maneuver was approximately 24.5 seconds in duration and imparted a 20.1 ft/sec ΔV to the vehicle. The maneuver placed the Orbiter in a 199 by 182 nmi. orbit.

At 036:18:37:39 G.m.t. (02:13:15:35 MET), the OMS-5 maneuver, a left-engine straight-feed firing, was initiated. The firing was approximately 49.6 seconds in duration, and imparted a 40.7 ft/sec ΔV to the vehicle. A 208 X 197 nmi. orbit was established as a result of the maneuver. The OMS performance during the maneuver was again nominal.

The OMS was used to perform two orbit-adjust maneuvers critical to the Mir rendezvous. Both maneuvers were performed in the straight-feed configuration using only the left engine. The OMS-6 nominal height (NH) maneuver was initiated at 037:14:24:03 G.m.t. (03:09:01:59 MET). This maneuver was 10.4 seconds in duration and resulted in a ΔV of 8.5 ft/sec. The OMS-7 terminal initiation (TI) maneuver was initiated at 037:16:36:43 G.m.t. (03:11:14:39 MET) and was 18.6 seconds in duration.

The firing imparted a ΔV of 15.4 ft/sec. The orbit following OMS-7 was 213.7 x 205 nmi. and the Orbiter vehicle was in-plane with the Mir.

The Shuttle vehicle approached the Mir on the V-bar to within 40 feet (approximately 12 meters), performed stationkeeping with the Mir for 15 minutes, then backed away and performed a fly-around at 400 ft. The approach, stationkeeping, back-away and fly-around were performed flawlessly. The crews exchanged greetings via the very high frequency (VHF) communication system and provided spectacular live video, which originated simultaneously from the Mir and the Shuttle. The Mir cosmonauts reported no vibrations or solar array movement as a result of the approach.

After the Shuttle backed away, the Mir was maneuvered back to its inertial attitude. The Russians reported that the Mir attitude control system (ACS) performance was as expected. Errors remained small, and no saturation firings were commanded. Control was maintained via the gyrodins using five from the KVANT module and four from KVANT-2. Visual assessments of the docking targets in the video indicated that both vehicles were remaining quite stable.

PAYLOADS

The primary payload for the STS-63 mission was the Spacehab-3 module and its experiments. The Spacehab-3 module is a pressurized, commercially developed space research laboratory that was located in the forward end of the payload bay. STS-63 was the third flight of the Spacehab module -- the first two highly successful missions were STS-57 in June 1993 and STS-60 in February 1994. The Spacehab module contained over 20 experiments, which represented a diverse cross-section of technological, biological, and scientific disciplines.

In addition to the Spacehab, the SPARTAN-204 payload obtained data in the far ultraviolet region of the spectrum from diffuse light sources. The SPARTAN-204 payload had two operational periods during the mission. The payload was initially grappled and unberthed to measure Orbiter surface glow. The surface glow measurements were made while the SPARTAN-204 was still attached to the RMS on flight day 2. Far ultraviolet spectrographic data were also obtained while pointing at a primary RCS thruster while it was firing. The payload was then berthed. On flight day 5, the SPARTAN-204 was unberthed and released for a 48-hour observation period, separated from the Orbiter.

Three payloads were carried as a part of the Hitchhiker Program and were known as the CGP/ODERACS-II.

SPACEHAB-3

This second flight of Spacehab flight unit -1 (FU-1) was completely successful except for the problems experienced with video system enhancements added to the Spacehab module for this mission. Modifications to the module air circulation system made after STS-60 were successful. Neither fan-inlet-debris screen blockage nor flexible duct deformation were noted and the fan differential pressure (ΔP) remained nominal throughout the mission.

Problems with Hitchhiker data dropout on Ku-band channel 2 were noted when down-linking Spacehab video through the video switching unit (VSU) on Ku-band channel 3. A related problem was distortion of the Public Affairs Office (PAO) video and shared camcorder video routed through the VSU when the Orbiter S-band frequency modulation (FM) system was in operation. Various cable-configuration changes were made to the VSU during the flight to troubleshoot the problem, and it is now suspected that the VSU design is the source of both problems.

The VSU is a new piece of hardware developed to enhance the Spacehab data system. It allows the connection of up to eight video sources in Spacehab to a single output to the Orbiter video system. Video sources to the VSU can be switched by ground command or on-board using the payload and general support computer (PGSC).

When camcorders were connected to the Spacehab video output, which was connected to the Orbiter video system using Orbiter video interface units (VIUs) in the configuration used on previous flights, the performance was completely nominal in all Ku-band and FM system modes. This is another strong indication that the problems were isolated to the VSU. The VSU will be modified and retested before a reflight occurs.

Experiment operations occurred on or close to the preplanned timeline throughout the mission and the communications and cooperation between the Spacehab Payload Operations Control Center (POCC), the Mission Control Center (MCC), and the Orbiter flight crew were excellent. Additional effort was expended to make the first flight of the Charlotte robotic experiment a success, and these efforts were successful, as Charlotte attained or exceeded all of its preflight objectives.

Overall, the Spacehab complement of experiments was very successful when evaluated from an operational standpoint. Scientific success will be measured after the return of the experiments and data to the Principal Investigators (PI's) and data are evaluated.

The status of the Spacehab experiments at the end of the flight was as follows:

- a. Astroculture IV - The Astroculture (ASC) IV experiment operations were nominal. All planned on-orbit operations were successfully completed.
- b. Bioserve Pilot Laboratory - The Bioserve Pilot Laboratory (BPL) experiment operations were nominal. All planned on-orbit operations were successfully accomplished.
- c. Protein Crystallization Facility - The light scattering and temperature-controlled facility performed nominally. All planned on-orbit operations were successfully completed.
- d. Three-Dimensional Microgravity Accelerometer - The Three Dimensional Microgravity Accelerometer (3-DMA) unit is believed to have collected data during ascent. The unit was turned off early in the on-orbit phase because the unit's hard drives were not cycling properly, causing the unit to over-heat. The unit was switched to descent mode and repowered for entry. Despite some concerns regarding on-orbit data recording, the PI believes that the 3-DMA functioned as expected in the ascent and entry modes.
- e. Biological Research in Canisters - The Biological Research in Canisters (BRIC) experiment hardware performed nominally. All planned on-orbit operations were successfully completed.

f. Commercial Generic Bioprocessing Apparatus - The Commercial Generic Bioprocessing Apparatus (CGBA) experiment hardware performed nominally. All planned on-orbit operations were successfully completed.

g. Charlotte - The Charlotte robotic hardware performed nominally with all on-orbit operations successfully completed. The robot attained or exceeded all of its preflight objectives. The PI was very pleased with the operation of the robot on orbit.

h. Chromosome and Plant Cell Division in Space - The Chromosome and Plant Cell Division in Space (CHROMEX) experiment hardware operated nominally. All planned on-orbit operations were successfully completed.

i. Commercial Protein Crystal Growth-Vapor Diffusion Apparatus - The Commercial Protein Crystal Growth-Vapor Diffusion Apparatus (CPCG-VDA) experiment hardware operated nominally. All planned on-orbit operations were successfully completed.

j. Charged Particle Directional Spectrometer - The Charged Particle Directional Spectrometer (CPDS) experiment hardware operated nominally. All planned on-orbit operations were successfully completed.

k. Cosmic Radiation Effects and Activation Monitoring - The Cosmic Radiation Effects and Activation Monitoring (CREAM) experiment hardware operated nominally. All planned on-orbit operations were successfully completed.

l. Equipment for Controlled Liquid Phase Sintering Experiment - The Equipment for Controlled Liquid Phase Sintering Experiment (ECLIPSE) experiment hardware performed nominally. All planned on-orbit operations were successfully completed.

m. Gas Permeable Polymer Membrane - The Gas Permeable Polymer Membrane (GPPM) hardware performed nominally. All planned on-orbit operations were successfully completed.

n. Fluids Generic Bioprocessing Apparatus - The Fluids Generic Bioprocessing Apparatus (F-GBA) hardware performed nominally. All planned on-orbit operations were successfully completed.

o. Protein Crystal Growth-Small Thermal Enclosure System - Hand-Held Diffusion Test Cells/Protein Crystallization Apparatus for Microgravity - The Protein Crystal Growth-Small Thermal Enclosure System (PCG-STES) - Hand-Held Diffusion Test Cells (HH-DTC)/Protein Crystallization Apparatus for Microgravity (PCAM) experiment performed nominally. All planned on-orbit operations were successfully completed.

p. Immunology Experiment - The Immunology (IMMUNE) experiment hardware performed nominally. All planned on-orbit operations were successfully completed.

q. National Institute of Health-Cells - The National Institute of Health-Cells (NIH-C) hardware performed nominally. All planned on-orbit operations were successfully completed.

r. Radiation Monitoring Experiment-III - The Radiation Monitoring Experiment-III (RME-III) performed nominally. All planned on-orbit operations were successfully completed.

s. Space Acceleration Measurement System - The Space Acceleration Measurement System (SAMS) hardware was deactivated on flight day 6 as the optical disk drives appeared to not be recording, and the SAMS was not repowered for the rest of the mission. Prior to that time, the SAMS was operating properly.

t. Window Experiment - The Window Experiment (WINDEX) hardware performed nominally. All planned on-orbit operations were successfully completed.

SHUTTLE POINTED AUTONOMOUS RESEARCH TOOL FOR ASTRONOMY-204

The SPARTAN-204 portion of the mission was performed in two phases. The first phase consisted of the crew grappling the payload with the RMS and unberthing it from the support structure. The SPARTAN-204 payload was then pointed toward the Orbiter tail to observe and measure the surface glow, and these observations included measurements taken during a primary RCS thruster firing. After completion of the first phase, the payload was reberthed in its support structure where it remained until the Mir rendezvous was completed. Following the rendezvous and stationkeeping activities as well as separation maneuvers from the Mir, the RMS was again used to grapple, unberth, and deploy the SPARTAN-204 for almost 48 hours of free-flight observations.

Initial indications from the data are that all SPARTAN-204 systems operated as expected throughout the mission. On flight day 2, the SPARTAN-204 attached operations were successfully completed with two surface glow observations and day and night thruster-firing observations. These tasks were followed by a Trajectory Control Sensor (TCS) performance test, after which the SPARTAN-204 spacecraft was reberthed in the payload bay. Two days later, SPARTAN-204 was released at the beginning of its window at 038:12:27 G.m.t. (04:07:05 MET) to begin making observations of celestial targets in the far-ultraviolet wavelength. SPARTAN-204 was grappled at 040:11:33 G.m.t. (06:06:11 MET). Final berthing of SPARTAN-204 was completed in record time using biased references in the berthing camera view that were determined during the SPARTAN-204 release. Postflight analysis will determine the success of data collection during the SPARTAN-204 free-flight period.

HITCHHIKER PAYLOADS

The Hitchhiker Program enables customers to fly quick-reaction and low-cost experiments on Shuttle. Three experiments were flown as part of this payload, and the acronym that was used to describe the payload was CGP/ODERACS-II. The titles and descriptions of the payloads that make up the acronym are as follows:

1. Cryogenic System Experiment (CSE) validated and characterized the on-orbit performance of two thermal management technologies that comprise a hybrid cryogenic system.
2. Shuttle Glow (GLO-2) experiment investigated the mysterious shroud of luminosity, called the "glow phenomenon", that was observed by crewmembers of previous missions.
3. Orbital Debris Radar Calibration System-II (ODERACS-II) experiment placed small calibration targets in low Earth orbit that were used to calibrate ground-based radar and optical systems.

In addition, the IMAX camera was also flown on this structure.

Cryogenic System Experiment GLO-2 Payload

The Cryogenic System Experiment (CSE) GLO-2 Payload (CGP) was activated at 034:10:10 G.m.t. (00:04:48 MET) after which a successful functional checkout was performed. All systems continued to operate nominally throughout the mission, and this resulted in over 100 percent of the mission objectives being accomplished using the Oxygen Heatpipe and the Improved Spacecraft Standard Cryocooler (ISSC).

The GLO-2 payload was able to complete 100 percent of its mission objective by collecting Jupiter spectra, aurora, airglow, dayglow, moon, earth limb, payload bay scan and stellar observations. GLO-2 operated nominally, but in a reduced science data-take mode because the data recording unit (DRU) was not responding throughout the mission. Data were collected on the 16-megabyte random access memory and dumped to the ground when possible, or provided directly to the ground when Ku-band coverage was available. The high-voltage power supply (HVPS) failed intermittently through flight day 2 but operated nominally during the data takes. An in-flight maintenance (IFM) procedure that reversed the cable polarity was successful in restoring the video signal capability.

Orbital Debris Radar Calibration Spheres-2

The ODERACS successfully deployed three spheres (2, 4, and 6 inches in diameter) and three dipoles (1.6 inches in diameter by 5.2, 1.7, and 5.2 inches in length, respectively) over a span of 15.2 seconds into a 182 by 190 nmi. orbit at 035:04:57 G.m.t. (00:23:35 MET). The deployment was moved to flight day 2 to provide a better elevation to the ground site. From video analyses, the exit velocities were determined to be within 8 to 14 percent of what was expected. Targets were visible as they separated from the Orbiter. The dipoles were visually calculated to be tumbling at a rate of once per second. Haystack ground station detected most of the targets on the first over-flight and later reported tracking all targets. After 40 days, the separation distance between the first and last sphere was approximately 3,000 kilometers.

IMAX Cargo Bay Camera

The IMAX cargo bay camera (ICBC) performed flawlessly throughout the mission. Over 8 minutes of film of the V-bar approach to the Mir, stationkeeping with the Mir, and separation from the Mir was exposed. Approximately 51 seconds of film was exposed while EV-1 was on the RMS at 040:15:18 G.m.t. (06:09:56 MET). The remaining film was exposed with an earth view of South America at 041:14:43 G.m.t. (07:09:21 MET).

SOLID SURFACE COMBUSTION EXPERIMENT

The SSCE was flown for the eighth time on this flight in the continuing study of flame propagation in the microgravity environment. The experiment tested the combustion of different materials under different atmospheric conditions. All activities for this experiment were conducted between 036:07:52 G.m.t. (02:02:30 MET) and 036:09:22 G.m.t. (02:04:00 MET). Postflight analysis is required to determine the success of this experiment.

AIR FORCE MAUI OPTICAL SITE

The flight path of STS-63 did not provide opportunities for the AMOS or the site at Arecibo, Puerto Rico, to observe thruster firings.

VEHICLE PERFORMANCE

SOLID ROCKET BOOSTERS

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

For this flight, the low-pressure heated ground purge in the SRB aft skirt was used to maintain the case/nozzle joint temperatures within the required LCC ranges. At T-15 minutes, the purge was changed to high pressure to inert the SRB aft skirt. Liftoff was normal and both SRBs performed satisfactorily during powered flight with no anomalies noted.

Both SRBs were successfully separated from the ET at T+ 125.040 seconds, and both SRBs were located by radar near the retrieval ships. Because of the high seas, the recovery of the SRBs was delayed approximately 24 hours. The postflight assessment of the SRBs revealed major damage to the forward assemblies, the ET attachment (ETA) rings, and the aft assemblies of both boosters (Flight Problem STS-63-B-1). Both forward skirts were buckled and cracked. The thrust vector control (TVC) systems on both boosters sustained heavy damage. Both of the ETA rings were damaged, and the left-hand aft skirt sustained structural damage. Investigation has concluded that the damage occurred after separation. The left-hand forward skirt and the left-hand main parachute index no. 2 were not found. The left-hand forward skirt and the left-hand TVC tilt actuator were lost during the tow back to port because of the high seas.

As a result of the heavy damage, a prediction of the steady-state surface winds in the SRB retrieval area will be provided to the Mission Management Team prior to ET tanking on future missions. Steady-state surface winds in excess of 26 knots increase the risk of SRB damage at water impact. Also, a requirement change notice (RCN) to the OMRSD will be processed to make surface winds in the SRB retrieval area a consideration throughout the launch window.

REUSABLE SOLID ROCKET MOTORS

The Reusable Solid Rocket Motors (RSRMs) performed nominally. No LCC or OMRSD violations were noted during the countdown. All prelaunch RSRM temperatures were maintained within acceptable limits.

Power-up and operation of field-joint heaters was accomplished routinely. The field-joint heaters were powered approximately 29 percent of the time during the LCC time frame to maintain temperatures in the normal operating range. The igniter-joint heater operation was nominal with power being applied approximately 64 percent of the time to maintain temperatures in the normal operating range.

Data indicate that the flight performance of both RSRMs was well within the allowable performance envelopes, and the performance was typical of that observed on previous flights. The RSRM propellant mean bulk temperature was 60 °F at liftoff. The propulsion performance of the RSRMs is shown in the following table.

RSRM PROPULSION PERFORMANCE

Parameter	Left motor, 60 °F		Right motor, 60 °F	
	Predicted	Actual	Predicted	Actual
Impulse gates				
I-20, 10 ⁶ lbf-sec	64.94	65.36	65.27	65.12
I-60, 10 ⁶ lbf-sec	173.41	175.32	174.17	175.58
I-AT, 10 ⁶ lbf-sec	296.73	297.84	296.97	297.01
Vacuum Isp, lbf-sec/lbm	268.4	269.4	268.4	268.5
Burn rate, in/sec @ 60 °F at 625 psia	0.3688	0.3703	0.3697	0.3707
Burn rate, in/sec @ 60 °F at 625 psia	0.3688	0.3703	0.3697	0.3707
Event times, seconds ^a				
Ignition interval	0.232	N/A	0.232	N/A
Web time ^b	110.8	110.1	110.3	109.8
50 psia cue time	120.6	120.0	120.1	119.8
Action time ^b	122.7	122.4	122.2	122.0
Separation command	125.5	124.9	125.5	124.9
PMBT, °F	60	60	60	60
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	3.1	2.8	2.9
Tailoff Imbalance Impulse differential, Klbf-sec	Predicted		Actual	
	N/A		159.9	

Impulse Imbalance = left motor minus right motor

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

^b Referenced to liftoff time (ignition interval).

EXTERNAL TANK

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

Typical ice/frost formations were observed on the ET during the countdown. Frost was observed on the liquid hydrogen (LH₂) tank acreage during the T-3 hour hold, but the frost subsided as the relative humidity increased. Normal quantities of ice or frost were present on the liquid oxygen (LO₂) and LH₂ feedlines and on the pressurization line brackets, and some frost or ice was present along the LH₂ protuberance air load (PAL) ramps. These observations were acceptable per NSTS-08303. The ice/frost personnel reported that no anomalous thermal protection system (TPS) conditions were noted.

The ET pressurization system functioned properly throughout engine start and flight. The minimum LO₂ ullage pressure experienced during the ullage pressure slump was 14.0 psid.

ET separation was confirmed. The postflight prediction of the ET impact point was approximately 63 nmi. uprange of the preflight prediction.

SPACE SHUTTLE MAIN ENGINE

All Space Shuttle main engine (SSME) parameters were normal throughout the countdown and were typical of prelaunch parameters observed on previous flights. Engine ready was achieved at the proper time; all LCC were met; and engine start and thrust buildup were normal. All Interface Control Document (ICD) start and shutdown transient requirements were met. Engine performance during start, mainstage, throttling and shutdown was nominal and as predicted, with cutoff times for SSME 1, 2, and 3 being 517.49, 517.60, and 517.70 seconds, respectively (referenced to engine start command). Controller and software performance was excellent.

Flight data indicate that the SSME performance during propellant dumping operations was normal. High pressure oxidizer turbopump (HPOTP) and high pressure fuel turbopump (HPFTP) temperatures appeared to be well within specification throughout engine operation. Main engine cutoff (MECO) occurred at T+511.1 seconds.

There were no SSME in-flight anomalies; however, spikes were noted in several pressure measurements that were attributed to ground radar. As a result, an integration anomaly (Flight Problem STS-63-I-01) was assigned to evaluate this condition. In conjunction with this anomaly, the SSME 1 main combustion chamber (MCC) coolant discharge pressure spiked at engine start (ES) + 77.5 seconds, HPOTP secondary seal cavity pressure channel A spiked at ES + 82.2 seconds, channel B spiked at ES + 84 seconds, and the fuel system purge pressure spiked at ES + 92.2 seconds.

SHUTTLE RANGE SAFETY SYSTEM

The 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.

An 18-inch length of SRSS ground checkout coaxial cable flew attached to the connector at the ET umbilical; normally this cable separates at the connector. Since this cable installation is outside the NSTS 08303 stated debris zone, no flight debris concern existed. Furthermore, this cable location is in a benign aerodynamic heating region, and no thermal concerns existed.

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

ORBITER SUBSYSTEM PERFORMANCE

Main Propulsion System

The overall performance of the main propulsion system (MPS) was as expected. LO₂ and LH₂ loading were performed as planned with no stop-flows or reverts. No LCC or OMRSD violations were identified.

Throughout the period of preflight operations, no significant hazardous gas concentrations were detected. The maximum hydrogen concentration level in the Orbiter aft compartment (occurred shortly after start of fast-fill) was approximately 100 ppm, which compares favorably with previous data from this vehicle.

A comparison of the calculated propellant loads at the end of replenish versus the inventory results in a loading accuracy of +0.01 percent for LH₂ and +0.03 percent for LO₂.

MPS performance throughout ascent was nominal. All fill and drain valves closed normally, and the gaseous hydrogen (GH₂) flow control valves performed nominally. The ET pressurization system functioned properly throughout the flight. All net positive suction pressure (NPSP) requirements were met throughout the flight.

This was the first flight of the new dump patch to the OI-23 software, and the patch performed as predicted with the maximum pressure after the vacuum inert being 14 psia.

Manifold repressurization for entry was normal with 61.3 lbm of helium used.

Reaction Control Subsystem

The RCS performed adequately in fulfilling all requirements placed on the subsystem during the mission. The RCS consumed 4575.4 lbm of propellant from the RCS tanks,

and 3241.4 lbm of the OMS propellants during interconnect operations. Three anomalies were identified and these are discussed in the following paragraphs.

During the Orbiter separation maneuver from the ET, primary RCS thruster R1U was failed off by the redundancy management (RM) at 034:05:30:53 G.m.t. (00:00:08:49 MET), and was failed leak at 034:05:32:08 G.m.t. (00:00:10:04 MET) (Flight Problem STS-63-V-01). Also, primary RCS thruster L2D was failed off by RM at 034:05:30:56 G.m.t. (00:00:08:52 MET) (Flight Problem STS-63-V-02). Thruster L2D remained deselected for the remainder of the flight.

Four unsuccessful attempts were made to stop the oxidizer leak from the RCS R1U thruster by closing the manifold 1 isolation valves, allowing oxidizer manifold pressure to decrease, and opening the isolation valves allowing rapid repressurization of the oxidizer manifold beginning at 036:12:41 G.m.t. (02:07:19 MET). The manifold 1 oxidizer pressure was allowed to decrease to 100 psi on the first two attempts and to 50 psi on the third attempt. The manifold isolation valves were then closed for more than 4 hours and subsequently reopened. No significant change in the leak signature was observed as a result of these operations. The manifold isolation valves were then closed to isolate the leak. RCS right manifold 1 isolation valves were reopened again at approximately 037:07:29:14 G.m.t. (03:02:07:10 MET) to manage the fuel manifold pressure changes that were being caused by solar heating. Although the leak had decreased, thruster R1U continued to leak at 150 to 200 cc/hr. Therefore, the right RCS manifold 1 isolation valves were closed for the Mir rendezvous. The RCS performance during the rendezvous maneuvers was nominal.

The RCS low-Z hot-fire was performed in two phases. Phase 1 was initiated at 035:19:16:52 G.m.t. (01:13:54:48 MET) and involved one pulse of the F1F, F2F, L3A, and R3A thrusters. Phase 2 was initiated at 035:19:20:04 G.m.t. (01:13:58:00 MET) and involved one pulse of the L1A, R1A, and F3F thrusters. Following phase 1 of the hot-fire, the thruster F1F oxidizer injector temperature dropped to 16.5 °F (Flight Problem STS-63-V-03), and as a result, leak detection software deselected the thruster. The temperature drop is characteristic of an oxidizer valve leak. The fuel injector temperature eventually dropped below 40 °F, prompting isolation of the forward RCS manifold 1 at 035:20:27:40 G.m.t. (01:15:05:36 MET), after which the injector temperatures recovered. Manifold 1 was re-opened at 036:04:21 G.m.t. (01:22:59 MET) to allow the force of repressurizing the manifold to clear potential contaminants from the oxidizer valve. During three subsequent firings of thruster F1F, good thruster performance was observed with normal chamber pressure (Pc) and injector temperature profiles. No further leakage was noted, and thruster F1F was returned to normal operation but was not fired again during the mission.

Orbital Maneuvering Subsystem

The OMS performed satisfactorily during the seven firings (two dual engine and five single engine) performed during the mission. A total of 21,820.6 lbm of propellants was

used during the seven firings and the RCS interconnect operation, which used 8.29 percent from the left pod and 16.74 percent from the right pod. The following table shows the data for the seven OMS firings.

OMS FIRINGS

OMS firing	Engine	Ignition time, G.m.t./MET	Firing duration, seconds	ΔV , ft/sec
OMS-2	Both	034:06:04:14.7 G.m.t. 00:00:42:10.7 MET	155.7	252.1
OMS-3	Right	034:14:20:16.2 G.m.t. 00:08:58:12.2 MET	39.7	32.1
OMS-4	Left	035:14:26:49 G.m.t. 01:09:04:45 MET	24.5	20.1
OMS-5	Left	036:18:37:39.5 G.m.t. 02:13:15:35.5 MET	49.6	40.7
OMS-6	Left	037:14:24:04.3 G.m.t. 03:09:02:00.3 MET	10.4	8.5
OMS-7	Left	037:16:36:43.3 G.m.t. 03:11:14:39.3 MET	18.6	15.4
Deorbit	Both	042:10:44:04.3 G.m.t. 08:05:22:00.3 MET	254.3	450.4

Power Reactant Storage Distribution Subsystem

The power reactant storage and distribution (PRSD) subsystem performance was satisfactory with no anomalies noted. A total of 2237 lbm of oxygen and 272 lbm of hydrogen was consumed during the mission. Of the oxygen total, 76 lbm was provided to the crew cabin for crew breathing. The four manifold isolation valves were cycled during the mission. The mission extension capability was 54 hours at an average power level of 15.8 kW, and 78 hours at an extension-day average power level of 11.1 kW.

Fuel Cell Powerplant Subsystem

The fuel cell powerplant subsystem performed satisfactorily, producing 3142 kWh of electricity at an average power level of 15.8 kW and average load of 517 amperes during the 198.5 hours of operation. The fuel cells consumed 272 lbm of hydrogen and 2161 lbm of oxygen and produced, as a by-product, 2433 lbm of water. Fuel cell 3 ended the mission with 2194 total accumulated hours on the stack, the most total hours for any Space Shuttle fuel cell in use.

Approximately 15 minutes after the start-up of fuel cell 3, the hydrogen flow on two occasions indicated increases from 0.80 to almost 1.10 lb/hr. The flow reading soon returned to the nominal value and read nominally throughout the mission.

Approximately 3 hours prior to landing at 042:09:04:22 G.m.t. (08:03:42:18 MET), the fuel cell 2 hydrogen-pump-motor voltage sensor indication increased instantaneously from 0.62 Vdc to 0.82 Vdc, indicating that the hydrogen pump was drawing more current. The voltage gradually decreased to the 0.62-Vdc level after 45 seconds. No change in fuel cell performance was noted during this transient. Review of the AC bus 2 phase currents during the same time period indicated that the phase A and B currents rose 160 mA, and phase C decreased 160 mA. If the pump was drawing more current due to a higher load, all three phase currents would be expected to change more gradually as well as increase in all three phases. A similar occurrence but of lesser magnitude was observed during prelaunch operations for STS-42 (same vehicle) in the same fuel cell position but not the same fuel cell. Extensive troubleshooting after STS-42 did not isolate the cause of the problem. The conclusion reached was that since this anomaly occurred on the same vehicle and same position, the fuel cell was probably not the cause.

Auxiliary Power Unit Subsystem

The APU subsystem performed nominally throughout the mission with no in-flight anomalies noted. The APUs were shut down after ascent in the APU 2, APU 1, and APU 3 order to fulfill the requirements of DTO 414, sequence B. The results of this DTO are discussed in the Development Test Objective section of this report. The APU fuel consumption and run-time by APU position and serial number are shown in the table on the following page.

The exhaust gas temperature (EGT) 1 measurement on APU 1 operated erratically during entry; however, this condition did not impact APU operation. APU 1 also had two gearbox repressurizations during entry. The first occurred one minute after start, and the second occurred about 30 minutes after start. Neither of these repressurizations affected entry operations.

APU RUN TIMES AND FUEL CONSUMPTION

Flight phase	APU 1 (S/N 407)		APU 2 (S/N 204)		APU 3 (S/N 306)	
	Time, min:sec	Fuel consumption, lb	Time, min:sec	Fuel consumption, lb	Time, min:sec	Fuel consumption, lb
Ascent	19:50	50	19:38	58	19:54	49
FCS checkout					7:22	16
Entry ^a	65:30	129	92:45	207	65:32	145
Total	85:20	179	112:25	265	92:48	210

^a The APUs ran for about 21 minutes 33 seconds after landing.

Hydraulics/Water Spray Boiler Subsystem

The hydraulics/water spray boiler (WSB) subsystem performed nominally throughout the mission. The main hydraulic pump outlet pressure of hydraulic system 1 showed unusual oscillations at APU 1 start prior to entry. The oscillations were about 250-psi peak-to-peak with the maximum value under 975 psi. The specification for this condition states that the oscillation peaks are to be no greater than 1000 psi. These oscillations did not affect WSB performance during entry.

Ascent was performed on WSB system 2 controller B and entry was performed on controller A in an attempt to isolate out-of-specification over-cooling conditions that have been experienced on six of the seven previous missions of this vehicle. Typically, controller A is used for ascent and controller B is used for entry. However, using the A controller resulted in no over-cooling conditions of WSB system 2 during this mission. Initial indications are that the B controller may be contributing to the over-cooling conditions that have been experienced. The next flight of this vehicle will use the same controller configuration for additional verification that the B controller may be at fault.

Electrical Power Distribution and Control Subsystem

The electrical power distribution and control (EPDC) subsystem performed nominally throughout the mission. All data analyzed showed nominal voltage and current signatures, and no specified limits were violated.

One in-flight anomaly, the loss of CRT 4 during the flight was evaluated to determine if the cause of the anomaly could possibly be a remote power controller (RPC) problem.

Environmental Control and Life Support System

The active thermal control system (ATCS) performed satisfactorily. The ATCS successfully supported payload cooling requirements after the flow proportioning valve in Freon cooling loop (FCL) 2 was placed in the payload position at 034:07:25 G.m.t. (00:02:03 MET). The loop was returned to the interchanger position at 041:16:12 G.m.t. (07:10:50 MET).

The radiator cold-soak provided cooling during entry through touchdown plus 10 minutes when ammonia system A, using the primary/GPC controller, was activated. This was the first flight of the system A controller since it was adjusted to compensate for under-temperature operation on this particular heat exchanger. System A controlled to 36 °F, well above freezing temperatures. System A operated for 36 minutes and was deactivated 46 minutes after landing when the ground cooling cart was connected to the vehicle. The flow proportioning module in FCL 2 was returned to the payload position 41 minutes after landing to support Spacehab postlanding cooling requirements.

The supply water and waste management systems performed adequately throughout the mission. By the completion of the mission, all of the waste water and supply water in-flight checkout requirements were performed and satisfied.

Supply water was managed through the overboard dump system and the flash evaporator system (FES). Three supply water dumps were performed simultaneously with the waste water dumps. The supply water dumps were performed at an average dump rate of 1.51 percent/minute (2.50 lb/min). The supply water dump line temperature was maintained between 66 °F and 96 °F throughout the mission with the operation of the line heater.

Waste water was gathered at approximately the predicted rate. Three waste water dumps were performed at an average rate of 1.87 percent/minute (3.1 lb/min). The waste water dump line temperature was maintained between 57 °F and 85 °F throughout the mission, while the vacuum vent line temperature was between 60 °F and 84 °F, and the vacuum vent nozzle was between 146 °F and 174 °F.

The waste water and supply water dump test was performed from 036:06:14 G.m.t. (02:00:52 MET) to 036:07:37 G.m.t. (02:02:15 MET). Live video of the dump was provided; however, the dump streams were not visible because of lighting conditions. There was no visible buildup of ice on the payload bay door (PLBD). The total supply water dumped overboard was 34 lb. The total waste water dumped overboard was 71.8 lb.

A second simultaneous supply/waste water dump was satisfactorily completed at 038:19:42 G.m.t. (04:14:20 MET). Two cycles were required to dump a total of 96.5 lb of waste water. A single cycle was required to dump 35.3 lb of supply water. The RMS

wrist camera and spotlight were used to view the spray patterns from the nozzles during a night pass in an attempt to evaluate possible water spray impingement on the PLBD. Neither the spray pattern nor any possible impingement were visible in the desired wide-angle view of the dump. No ice deposits were found on the PLBD.

The third simultaneous supply and waste water dump was initiated at 041:16:08:34 G.m.t. (07:10:46:31 MET) and was completed at 041:16:58:26 G.m.t. (07:11:36:22 MET). A total of 46.3 lb of supply water and 104.1 lb of waste water was dumped. Spray patterns were visible when the RMS wrist camera was zoomed in and pointed toward the nozzles, but the patterns were not visible when the camera was panned outboard. No ice deposits were noted on the PLBD.

This was the second flight of the supply water dump line purge assembly (SWDLPA) on OV-103. The SWDLPA provides an automatic air purge of the supply water dump line at the completion of each water dump to prevent the dump valve from "burping". On previous missions of this vehicle before the use of the SWDLPA, the burping has been known to repeat up to 10 times. An air purge was used to stop the burping condition on those flights. A modified procedure was used this mission since during the last flight of OV-103 (STS-64), two singular burps did occur. On STS-63, no burps were noted in the data from the three dumps.

The waste collection system (WCS) performed normally throughout the mission.

The atmospheric revitalization system performed nominally.

At 034:21:50 G.m.t. (00:16:28 MET), the cabin pressure transducer shifted low by 0.24 psi from 14.64 psi to 14.40 psi (Flight Problem STS-63-V-06). All other cues indicated nominal cabin pressure. Since no 10.2-psi activity was planned for this mission, this anomaly had no impact on the flight. At the time of the occurrence, the Spacehab pressure was 14.8 psi.

Airlock Support System

All airlock support system parameters indicated normal performance. The airlock/tunnel adapter was used to support a four-hour 39-minute EVA on flight day 7.

During the EVA, a small pressure drop, equivalent to a 17 to 20 lb/day leak, was detected in the Spacehab module (Flight Problem STS-63-V-08). The pressure decreased from 14.80 psi to 14.16 psi over a 5-hour 18-minute period. Three possible sources of the leak were identified:

- a. Tunnel adapter hatch D sealing;
- b. Hatch D equalization valves; or

- c. Payload air isolation valve and cap assembly.

Postflight troubleshooting will be performed to isolate the cause of the leak.

Smoke Detection and Fire Suppression Systems

All smoke detection parameters indicated normal performance throughout the mission. No indication of smoke generation was evident. Use of the fire suppression system was not required.

Avionics and Software Systems

The performance of the guidance, navigation and control (GN&C) during ascent and entry was nominal. The STS-63 launch was delayed approximately 24 hours from 12:47:44 a.m. e.s.t. on February 2, 1995, until 12:22:04 a.m. e.s.t. on February 3, 1995, because inertial measurement unit (IMU) 2 failed. During the moding of IMU 2 from standby to operate on the day of the first launch attempt, the unit annunciated a platform-fail built in test equipment (BITE) and also indicated that the platform had tumbled. A second attempt at moding from standby to operate was also unsuccessful. The HAINS IMU was removed, replaced and the newly installed unit retested satisfactorily.

The downlisted data from STS-63 indicates that outboard elevon load relief was experienced twice; once 54 seconds after liftoff at Mach 1.15 and again at about 60 seconds at Mach 1.35. The load relief was active for approximately 3 seconds in each instance.

An input/output (I/O) error message against cathode ray tube (CRT) 4 was annunciated and two I/O errors were logged by general purpose computer (GPC) 4 about 35 minutes after powering on CRT 4. The crew confirmed that CRT 4 was operating nominally when it was powered up. The crew found the CRT screen blank, and the display electronics unit (DEU) built-in-test-equipment (BITE) flag tripped (Flight Problem STS-63-V-04). CRT 4 was recovered by performing a power cycle. At 035:08:41 G.m.t. (01:03:19 MET), the crew reported that CRT 4 was again blank, although its power switch was still on. Also, the DEU BITE was tripped and an I/O error message for CRT 4 was noted on the other operating CRTs. The signature was the same as on the first failure - the CRT simply dropped off without a current spike or a circuit breaker tripping. The crew performed a dump of the DEU BITE register, then recovered the CRT with a power cycle when performing the malfunction procedure. The DEU/CRT 4 experienced two additional failures prior to the rendezvous on flight day 4. The DEU/CRT was recovered each time with a power cycle. The flight crew utilized the DEU at their discretion and there was no mission impact. A similar failure signature occurred at the CRT 4 position during ground checkout operations on DEU 4, and the unit was replaced and successfully retested prior to flight.

The primary RCS thrusters L1L, L1U, R4U, F3L, and F3U fired 80-ms-duration pulses in response to an unexpected +Y/+Z THC command following the power-up of the aft THC at 035:11:41:06 G.m.t. (01:06:19:02 MET) (Flight Problem STS-63-V-07). No physical deflection of the THC had occurred coincident with the thruster firings. Initial data review appeared to indicate that the THC command resulted from a transient response of the THC contacts upon application of flight control system (FCS) power. The digital autopilot (DAP) response was nominal for a valid +Y/+Z command. The translation mode was in NORM, requiring the DAP to fire thrusters only while the THC was deflected. Since the power transient duration was under 80 ms, only one minimum-duration firing of 80 ms was commanded.

A similar event occurred during STS-66 in which a -Y/-Z command was generated coincident with power-up of the forward station FCS switch. Tests in the Shuttle Avionics Integration Laboratory (SAIL) following the STS-66 event demonstrated that a THC command can be generated from the flight control power-on operation because of the staggered fall of the THC contact discrete outputs.

The crew reported that thrusters did not fire in response to a short-duration +Y THC input at 041:14:43:14 G.m.t. (07:08:21:15 MET). Previous to, as well as after this occurrence, +Y commands from the same THC resulted in nominal thruster firings. The THC was probably not deflected long enough to fire the thrusters.

The landing was soft and resulted in the RM deselecting the right main gear proximity switch because the indication toggled. However, the redundancy in the system resulted in the correct outputs being generated.

Displays and Controls Subsystems

The displays and controls subsystems performed nominally.

Communications and Tracking Subsystems

All communications and tracking systems performed nominally. The communications systems were also used to support two Development Test Objectives (DTOs) and one Detailed Supplementary Objective (DSO). The results of these DTOs and the DSO are reported in the Development Test Objective/Detailed Supplementary Objective section of this report.

Ku-band channel 2 data became degraded when the camcorder video that was routed through the Spacehab video switching unit (SVSU) was downlinked. Also, degradation of the Spacehab downlink video was noted when the Orbiter S-band FM system was operating. An interface incompatibility between the Orbiter VSU and the SVSU is believed to be the most likely cause of the problem.

Operational Instrumentation/Modular Auxiliary Data System

The operational instrumentation (OI)/Modular Auxiliary Data System (MADS) performed very satisfactorily. No problems or anomalies were identified.

Structural and Mechanical Subsystems

The structural and mechanical subsystems performed nominally with one anomaly identified. The landing and braking data are shown in the following table.

Landing and Braking Parameters

Parameter	From threshold, ft	Speed, keas	Sink rate, ft/sec	Pitch rate, deg/sec
Main gear touchdown	1349	212.2	~ 3.0	N/A
Nose gear touchdown	5437	150.1	N/A	~4.2
Brake initiation speed			58.4 knots (keas)	
Brake-on time			32.8 seconds	
Rollout distance			11,002 feet	
Rollout time			80.4 seconds	
Runway			15 (Concrete) EAFB	
Orbiter weight at landing			224,130.2 lb	
Brake sensor location	Peak pressure, psia	Brake assembly	Energy, million ft-lb	
Left-hand inboard 1	634	Left-hand outboard	5.66	
Left-hand inboard 3	687	Left-hand inboard	7.90	
Left-hand outboard 2	581	Right-hand inboard	6.86	
Left-hand outboard 4	647	Right-hand outboard	4.07	
Right-hand inboard 1	581			
Right-hand inboard 3	726			
Right-hand outboard 2	462			
Right-hand outboard 4	568			

At 037:20:06 G.m.t. (03:14:43 MET), the latch A indication in the port radiator latch gang 1-6 actuator began toggling off and on for approximately 1 and 1/2 hours (Flight Problem STS-63-V-05), after which the indication returned to normal operation except for occasional periods of erratic behavior. The redundant indication (latch B) showed no erratic behavior.

Integrated Aerodynamics, Heating and Thermal Interfaces

The ascent and descent aerodynamics were nominal. Active elevon load relief was initiated at two points in the high dynamic pressure portion of the trajectory during ascent. These new occurrences of load relief were at approximately 54 to 56 seconds and 60 to 62 seconds and are the result of using a modified elevon schedule during STS-63.

The ascent aerodynamic and plume heating were nominal with no instances of problems. Likewise, the aerodynamic entry heating of the SSME nozzles was nominal.

The thermal interface temperatures were nominal as was the whole area of thermal interface heating.

Thermal Control Subsystem

The performance of the thermal control subsystem (TCS) was nominal during all phases of the mission, and all Orbiter subsystem temperatures were maintained within acceptable limits. No problems or anomalies were identified in the TCS area.

Aerothermodynamics

The acreage heating was nominal during entry, and there was no unusual local heating. Boundary layer transition was nominal based on the structural temperature rise data. Boundary layer transition from laminar to turbulent flow occurred at 1200 seconds after entry interface (EI) on the forward centerline and aft left-hand side of the vehicle. Transition occurred at 1175 seconds at the aft right-hand side of the vehicle, indicating slightly asymmetric boundary layer transition.

Thermal Protection Subsystem and Windows

The thermal protection subsystem (TPS) performed satisfactorily during the mission. Based on structural temperature response data (temperature rise), the entry heating was slightly above average for this vehicle, but well within the flight experience.

The TPS sustained a total of 125 hits of which 14 had a major dimension of 1 inch or larger. The lower surface had a total of 84 hits of which 7 had a major dimension of 1 inch or greater and that is much lower than the average of 14. The largest tile damage site measured 5.5 inches by 1.5 inches by 0.75 inch deep, and the damage was located outboard of the ET/Orbiter LH₂ umbilical and directly aft of the left main landing gear and showed no signs of entry heating or erosion. Room temperature vulcanizing (RTV) material from the main landing gear may have come off during gear deployment and caused the damage prior to touchdown; however, no RTV material was found on the runway. No other tile damage was attributed to material from the wheels, tires or brakes. The tires were in good condition after the landing on the KSC runway.

No ice adhered to the payload bay door. The waste and supply water dump nozzles appeared to be in normal condition. No unusual tile damage was visible on the leading edges of the OMS pods and vertical stabilizer.

The number of hits aft of the ET/Orbiter LH₂ and LO₂ umbilicals, believed to be impacts from ice, were less than usual. Also, no tile damage from micrometeorites or on-orbit debris was identified.

The ET/Orbiter separation devices functioned properly and the debris plungers were seated. All ET/Orbiter umbilical separation ordnance retention shutters were closed. No significant amounts of foam or red purge seal adhered to the ET/Orbiter LH₂ umbilical near the 4-inch flapper valve. No debris was found on the runway beneath the ET/Orbiter umbilical cavities;

Orbiter window 4 exhibited moderate-to-heavy hazing. Windows 3 and 5 exhibited light-to-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. A tile-damage site, 5 inches long by 0.4 inch wide, was located on the upper canopy forward of window 7. The tile surface coating was damaged, but all the tile surface coating remained adhered to the tile.

Drag Chute Subsystem

The drag chute performance was nominal with deployment at 182.2 knots estimated air speed (keas), and the chute was jettisoned at 60.7 keas. All drag chute hardware was recovered after landing and no damage was noted. Also, no damage was noted to the vertical stabilizer stinger or around the drag chute door from drag chute deployment.

REMOTE MANIPULATOR SYSTEM

The RMS performed satisfactorily throughout this fortieth flight of the RMS. The main RMS activities were the SPARTAN-204 deployment and retrieval, mass handling exercises by the EVA astronauts, several Orbiter surveys and attached SPARTAN operations for Surface Glow Observations, Tracking Control System (TCS) tests, and support of DTO 671 operations during the EVA.

About 2 hours 40 minutes after launch, the RMS was powered, the shoulder brace was released and the manipulator positioning mechanisms (MPMs) were rolled out. The shoulder brace release time was 6 seconds.

The RMS checkout procedure was initiated about 6 hours after launch. The checkout was completed successfully with the RMS performance nominal. At the end of the RMS checkout, the arm was used to perform a payload survey using the end effector (EE) camera. With no visual payload anomalies observed, the payload survey was completed and the arm was moved to the extended-park position.

On flight day 2, the RMS was used for SPARTAN-204 attached operations. The arm was used to grapple, unberth and then position SPARTAN to the Surface-Glow observation position. When the surface glow observations were complete, the RMS was used to maneuver SPARTAN between near- and far-field positions for day and night observations of primary RCS thruster firings.

TCS tests were conducted upon completion of the primary RCS thruster-firing observations. To support the TCS tests, six laser retro-reflectors that were mounted on the SPARTAN-204 were used. TCS tracking data were recorded as the arm maneuvered the SPARTAN to eight different test points using the operator-commanded auto sequence (OCAS). Once the TCS tests were complete, the SPARTAN was berthed in the cargo bay. The RMS was then briefly positioned in the pre-cradle position in preparation for an OMS firing, after which it was moved to the extended-park configuration.

Using the EE camera, the RMS was used for several Orbiter surveys on flight day 3. The arm was first used to survey hot firings of primary forward RCS thruster F1F to help troubleshoot an oxidizer leak which had been detected earlier. The survey helped verify that this RCS thruster anomaly had been corrected. The arm was then moved to the modified supply/waste water dump survey position for the first of three such surveys. As an icicle had formed on the payload bay doors during this dump procedure on STS-66, there was an effort made on this flight to characterize the dump nozzle spray profiles with this survey. Due to poor lighting conditions, the spray patterns were not visible.

The arm was also used to survey the RCS thruster R1U leak. Once this survey was complete, the arm was moved to the pre-cradle configuration in preparation for an OMS firing. At the end of the OMS firing, the arm was positioned in the extended-park configuration.

On flight day 4 when preparing for the Shuttle/MIR rendezvous, the RMS was cradled, latched and placed in temperature-monitor mode where it remained until rendezvous operations with the Mir Space Station were completed.

Beginning at 038:11:00:13 G.m.t. (04:05:38:09 MET) on flight day 5, the arm was reselected, uncradled and SPARTAN-204 was grappled in preparation for unberthing and deploying the satellite. After reaching the release position, SPARTAN used a rigidize sensing grapple fixture (RSGF) to execute the pre-programmed post-release sequence. This was done using a quick derigidize/rigidize sequence just prior to the actual release. The first thing that SPARTAN was programmed to do was perform a pirouette maneuver, which demonstrated that it was operating properly. This was seen with the RMS wrist camera, and the Orbiter then began a series of separation maneuvers, moving away from SPARTAN.

Near the end of flight day 5, the second modified supply/waste water dump survey was performed and monitored by the RMS-mounted camera. Again, poor lighting prevented the spray patterns from being visible with the camera. After this survey, the arm was moved to the extended-park position.

On flight day 7, after rendezvous with the SPARTAN satellite, the RMS grappled the free-flyer and berthed it in the cargo bay.

The RMS was used by the spacewalking crew members, EV1 and EV2, during a thermal evaluation of the EMUs and for EVA mass handling exercises with SPARTAN. During the EMU thermal evaluations, one crewmember stood in the portable foot restraint (PFR) on the end of the arm and held on to the second EVA crewmember while the arm moved them approximately 20 ft above the flight deck. Upon completion of this evaluation, the arm was used to move EV2 over to SPARTAN to begin mass handling exercises. While standing in the PFR on the end of the arm, EV2 held on to SPARTAN while it was unlatched and then unberthed using the arm. During the mass handling exercises, which began during a night pass, both EVA crewmembers reported cold extremities. Mass handling exercises were shortened and SPARTAN was berthed and latched back in the payload bay.

On flight day 8, the third and final modified supply/waste water dump survey was monitored using the RMS-mounted camera. This time, with the dump scheduled to ensure proper lighting conditions, the spray patterns of the nozzle were visible with the EE camera. Once this last survey was complete, the arm was cradled, latched and the MPMs were stowed in preparation for return to earth.

EXTRAVEHICULAR ACTIVITY

The checkout of the two EMUs was performed on flight day 6. All life support systems were verified to be operating within design limits. Communications functions were also verified as well as the battery-charging capability.

On flight day 7, the two EVA crewmembers donned their EMUs and performed the normal 4-hour prebreathe before depressurizing the airlock and tunnel adapter to vacuum. At vacuum, the crewmembers egressed the tunnel adapter hatch and began EVA operations.

The mass handling procedures using the SPARTAN-204 were performed during a night pass. Ten minutes into the night pass, the EV1 crewmember began reporting uncomfortably cold hands. Overall body thermal comfort was good. The EV2 crewmember also experienced cold hands and feet. Later mass handling activities were shortened and payload-bay clean-up was initiated.

The thermal over-gloves, which provide thermal protection for the hand, were not used during the mass handling activities but were put on by EV2 at the completion of this activity. EV2 stated that his hands felt a little warmer with the over-gloves on, but the cold could still be sensed through the gloves. Crew thermal comfort was restored during the following day pass.

The 4-hour 39-minute EVA was performed nominally and the EMUs performed nominally. During airlock repressurization to 5 psia, the EV2 crewmember experienced a burning sensation in his eyes. The airlock repressurization was completed, and the crewmember removed the EMU and flushed his eyes with cold water. Investigations conducted during the postflight activities revealed no evidence of contaminants present in the EMU.

FLIGHT CREW EQUIPMENT/GOVERNMENT FURNISHED EQUIPMENT

All flight crew equipment/government furnished equipment (FCE/GSE) performed very satisfactorily. Two in-flight anomalies were identified in the area of FCE/GSE.

During the airlock repressurization following the EVA, the EV2 crewmember reported eye discomfort as well as an odor in the suit (Flight Problem STS-63-F-01). The postflight inspection of the suit revealed small brown flecks on the inner surface of the visor. Lithium hydroxide, internal suit contamination, suit contamination from an external source, and oxygen supply contamination were all investigated as possible causes of the condition, but were found to be improbable causes of the eye irritation. Toxicological tests of the brown flecks showed them to be organic. The eye irritation is believed to have been caused by the anti-fog (modified soap) solution that is placed on the internal surface of the helmet visor prior to each EVA. Four EVA crewmembers from previous missions reported varying levels of discomfort after perceived contact with this solution.

Neither of the electronic cuff checklists (ECCs), worn by the EVA crewmembers, operated correctly during the EVA (Flight Problem STS-63-F-02). The EV1 ECC responded in only one (bottom middle) of the six touch areas; however, the unit resumed full functionality prior to repressurization. The EV2 ECC did not respond in the right two areas and remained unresponsive throughout the EVA. Both units lost their display capability later in the EVA, but the displays returned prior to repressurization.

CARGO INTEGRATION

The integration hardware performance was nominal throughout the mission with no in-flight anomalies identified.

DEVELOPMENT TEST OBJECTIVES/DETAILED SUPPLEMENTARY OBJECTIVES

A total of 21 DTOs and 14 DSOs were assigned to the STS-63 mission. The following subsections provide preliminary data as available on many of the objectives.

DEVELOPMENT TEST OBJECTIVES

DTO 312 - ET TPS Performance - This DTO was not accomplished because of the loss of a thruster during the maneuver to the photographic attitude.

DTO 414 - APU Shutdown Test (Sequence B) - The APUs were shut down in the order required by the DTO. The data showed no anomalous pressure hang-ups or power drive unit (PDU) motor back-driving as a result of this shutdown sequence.

DTO 671 - EVA Hardware for Future Scheduled EVA Missions (14.7 Prebreathe Protocol), Test 9 - The mass handling tool performed as expected. Information on the additional tools evaluated during the EVA may be obtained from the DTO sponsor.

DTO 672 - EMU Electronic Cuff Checklist - STS-63 was the second flight test of the electronic cuff checklist. Based on the results of these two flights, a need has been identified for further refinement related to tolerance to cold temperatures.

DTO 700-5 - Payload Bay Mounted Rendezvous Radar - The TCS was powered during all proximity operations. During the Mir approach, the TCS acquired the target at 614 feet and tracked until the backaway at 322 feet, when a failure prevented the laser from focusing accurately. This failure did not recur during the SPARTAN-204 deployment. Upon commanding, the TCS started tracking SPARTAN-204 at 178 feet and continued to track until 463.7 feet when the relative position of SPARTAN-204 was first outside the bearing rate capability and then outside the operational angles of the TCS. During the SPARTAN-204 retrieval, the TCS exhibited instrumentation problems upon activation that resulted in the crew being asked to inhibit the temperature and voltage fault messages that kept occurring. Following this corrective action, the crew activities did not provide time for initiating the tracking mode. The ground data indicated that the TCS would have acquired and tracked SPARTAN-204 at approximately 2000 ft. While data were acquired during the Mir rendezvous and the SPARTAN-204 deployment, the SPARTAN-204 retrieval was to provide the best source of data for TCS evaluation because the targets were in view at longer distances.

DTO 805 - Crosswind Landing Performance - This DTO was not performed because of the lack of adequate wind conditions at landing.

DTO 833 - EMU Thermal Comfort Evaluations (14.7 prebreathe protocol) (Tests 1 and 2) - The EMU thermal comfort was successfully evaluated in the cold environment. Crew feedback and recorded ambient and glove temperatures are being analyzed for

comparison to thermal models and to determine the next generation of thermal comfort improvements.

DTO 835 - Mir Approach Demonstration (Objectives 2, 4, and 5) - All three objectives were successfully accomplished during the Mir approach and backaway. This information will be evaluated for verification and for its impact on future Phase-1 Mir flights.

DTO 836 - Tools for Rendezvous and Docking (Tests 1, 3, and 4) - The Tools for Rendezvous and Docking (TRAD) DTO provided the complement and configuration of tools for this flight. They included DTO 700-2 (Laser Range and Range Rate Device) [Hand-Held Lidar (HHL)], DTO 700-5 TCS and DTO 700-7 Orbiter Data for Real-Time Navigation Evaluation. These tools were tied together through the Rendezvous Proximity Operations Program (RPOP) software in the payload general support computers (PGSCs). The TCS being inactive during the SPARTAN-204 retrieval limited the evaluation of the tools, but the Mir approach and the SPARTAN-204 deployment did provide data for postflight evaluation of all the TRAD systems.

DTO 838 - Near Field Targeting and Reflecting Alignment System - This DTO was performed with the Spacehab experiment Charlotte. The crew reported that the activities were nominal. Postflight evaluation of the data is required, and the sponsor for this DTO may be contacted for the results.

DTO 1118 - Photographic and Video Survey of Mir Space Station - Video of the Mir Space Station was viewed in real-time. Photography of the Mir was reviewed postflight and the results of the DTO may be obtained from the sponsor.

DTO 1210 - EVA Operations Procedures/Training - Mass handling was successfully completed; however, the RMS-based portion of this DTO was not accomplished. The results of this DTO may be obtained from the sponsor.

The following DTOs were accomplished, but details are lacking on the operations and the results:

- a. DTO 301D - Ascent Structural Capability Evaluation;
- b. DTO 305D - Ascent Compartment Venting Evaluation;
- c. DTO 306D - Descent Compartment Venting Evaluation;
- d. DTO 307D - Entry Structural Capability;
- e. DTO 319D - Shuttle Payload Low Frequency Environment;
- f. DTO 524 - Landing Gear Loads and Brake Stability Evaluation;
- g. DTO 623 - Cabin Air Monitoring;
- h. DTO 677 - Portable In-Flight Landing Operations Trainer (PILOT); and
- i. DTO 832 - Target of Opportunity Navigation Sensors (TONS).

DETAILED SUPPLEMENTARY OBJECTIVES

DSO 327 - Shuttle-Mir VHF Voice Link Verification - Excellent communications with the cosmonauts on the Mir were completed. An additional check was made to determine if the Orbiter crew could communicate with Houston using the Shuttle Amateur Radio Experiment -II (SAREX-II), but interference from the Mir VHF frequency was experienced. Future plans will include transmitting on different frequencies.

The following DSOs were reported to have been accomplished nominally at various times throughout the flight. These were:

- a. DSO 201B - Sensor- Motor Investigation;
- b. DSO 483 - Back Pain Pattern in Microgravity;
- c. DSO 486 - Physical Examination in Space;
- d. DSO 492B - In-Flight Evaluation of a Portable Clinical Blood Analyzer; and
- e. DSO 608 - Effects of Space Flight on Aerobic and Anaerobic Metabolism
During Exercise.

In addition, the following DSOs were assumed to be accomplished; however, no report from the crew was received. These were:

- a. DSO 200B - Radiobiological Effects;
- b. DSO 204 - Visual Observation From Space;
- c. DSO 489 - EVA Dosimetry Evaluation;
- d. DSO 901 - Documentary Television;
- e. DSO 902 - Documentary Motion Picture Photography; and
- f. DSO 903 - Documentary Still Photography.

Two DSOs were programmed to be completed only during the preflight and postflight periods, and they were completed. These were:

- a. DSO 487 - Immunological Assessment of Crewmembers; and
- b. DSO 491 - Characterization of Microbial Transfer Among Crewmembers
During Space Flight.

PHOTOGRAPHY AND TELEVISION ANALYSIS

LAUNCH PHOTOGRAPHY AND VIDEO DATA ANALYSIS

On launch day, all 24 of the launch day videos were reviewed for anomalies. In addition during the days following launch, 52 films were reviewed. No anomalous conditions were found in any of the video or photographic data.

ON-ORBIT PHOTOGRAPHY AND VIDEO DATA ANALYSIS

Analysis of the video taken of the Orbital Debris Radar Calibration Spheres (ODERACS) experiment was performed in support of the Principal Investigator. The velocity of the dipoles and spheres ejected from the Get-Away Special (GAS) canister in the payload bay was calculated from the video data. These data were provided to the Principal Investigator within 30 minutes of the deployment.

An analysis of the nitrogen tetroxide particles (snowballs) leaking from the RCS R1U thruster was performed. The data provided to the Mission Evaluation Manager included size, number and velocity of the "snowballs". These data were provided in support of the decision on the point of closest approach of the Orbiter to the Mir during the rendezvous and stationkeeping activities.

LANDING PHOTOGRAPHY AND VIDEO DATA ANALYSIS

Analysis was performed on the 11 landing videos including NASA Select, which is a composite of all available landing views. No anomalous conditions were identified in this analysis. In addition, 10 landing films were reviewed, and no anomalous conditions were found in the films.

TABLE I.- STS-63 SEQUENCE OF EVENTS

Event	Description	Actual time, G.m.t.
APU Activation	APU-1 GG chamber pressure APU-2 GG chamber pressure APU-3 GG chamber pressure	034:05:17:13.47 034:05:17:14.58 034:05:17:15.60
SRB HPU Activation ^a	LH HPU System A start command LH HPU System B start command RH HPU System A start command RH HPU System B start command	034:05:21:36.124 034:05:21:36.284 034:05:21:36.444 034:05:21:36:604
Main Propulsion System Start ^a	ME-3 start command accepted ME-2 start command accepted ME-1 start command accepted	034:05:21:57.446 034:05:21:57.553 034:05:21:57.675
SRB Ignition Command (Liftoff)	Calculated SRB ignition command	034:05:22:03.994
Throttle up to 104 Percent Thrust ^a	ME-2 command accepted ME-1 command accepted ME-3 command accepted	034:05:22:07.993 034:05:22:07.995 034:05:22:08.006
Throttle down to 94 Percent Thrust ^a	ME-2 command accepted ME-1 command accepted ME-3 command accepted	034:05:22:22.074 034:05:22:22.076 034:05:22:22.087
Throttle down to 69 Percent Thrust ^a	ME-2 command accepted ME-1 command accepted ME-3 command accepted	034:05:22:34.874 034:05:22:34.876 034:05:22:34.887
Maximum Dynamic Pressure (g)	Derived ascent dynamic pressure	034:05:22:55
Throttle up to 104 Percent Thrust ^a	ME-2 command accepted ME-1 command accepted ME-3 command accepted	034:05:22:57.274 034:05:22:57.276 034:05:22:57.287
Both SRM's Chamber Pressure at 50 psi ^a	RH SRM chamber pressure mid-range select LH SRM chamber pressure mid-range select	034:05:24:03.674 034:05:24:03.874
End SRM Action ^a	LH SRM chamber pressure mid-range select RH SRM chamber pressure mid-range select	034:05:24:07.414 034:05:24:07.644
SRB Physical Separation ^a	LH rate APU turbine speed - LOS RH rate APU turbine speed - LOS	034:05:24:08.994 034:05:24:08.994
SRB Separation Command ^a	SRB separation command flag	034:05:24:10
Throttle Down for 3g Acceleration ^a	ME-2 command accepted ME-1 command accepted ME-3 command accepted	034:05:29:31.841 034:05:29:31.844 034:05:29:31.855
3g Acceleration	Total load factor (g)	034:05:29:45.2
Throttle Down to 69 Percent Thrust for Cutoff ^a	ME-2 command accepted ME-1 command accepted ME-3 command accepted	034:05:30:29.121 034:05:30:29.125 034:05:30:29.136

^aData supplied by Marshall Space Flight Center

TABLE I.- STS-63 SEQUENCE OF EVENTS

Event	Description	Actual time, G.m.t.
SSME Shutdown ^a	ME-2 shutdown command accepted ME-1 shutdown command accepted ME-3 shutdown command accepted	034:05:30:35.162 034:05:30:35.165 034:05:30:35.176
MECO	MECO command flag MECO confirm flag	034:05:30:36 034:05:30:36
ET Separation	ET separation command flag	034:05:30:55
APU Deactivation	APU-2 GG chamber pressure APU-1 GG chamber pressure APU-3 GG chamber pressure	034:05:36:52.57 034:05:37:03.29 034:05:37:09.95
OMS 2 Ignition	Right engine bi-propellant valve position Left engine bi-propellant valve position	034:06:04:14.7 034:06:04:14.7
OMS 2 Cutoff	Right engine bi-propellant valve position Left engine bi-propellant valve position	034:06:06:50.4 034:06:06:50.4
PLBD Open	PLBD right open 1 PLBD left open 1	034:07:11:48 034:07:13:07
OMS 3 Ignition	Left engine bi-propellant valve position Right engine bi-propellant valve position	N/A 034:14:20:16.2
OMS 3 Cutoff	Left engine bi-propellant valve position Right engine bi-propellant valve position	N/A 034:14:20:55.9
ODERACS Deploy	Video call	035:04:57:06
SPARTAN First Unberth	Payload select 2 latch 1A release	035:06:48:31.3
SPARTAN First Berth	Payload select 2 latch 1A latch	035:13:18:25.3
OMS 4 Ignition	Left engine bi-propellant valve position Right engine bi-propellant valve position	035:14:26:49.0 N/A
OMS 4 Cutoff	Left engine bi-propellant valve position Right engine bi-propellant valve position	035:14:27:13.5 N/A
OMS 5 Ignition	Left engine bi-propellant valve position Right engine bi-propellant valve position	036:18:37:39.5 N/A
OMS 5 Cutoff	Left engine bi-propellant valve position Right engine bi-propellant valve position	036:18:38:29.1 N/A
OMS 6 Ignition	Left engine bi-propellant valve position Right engine bi-propellant valve position	037:14:24:04.3 N/A
OMS 6 Cutoff	Left engine bi-propellant valve position Right engine bi-propellant valve position	037:14:24:14.7 N/A
OMS 7 Ignition	Left engine bi-propellant valve position Right engine bi-propellant valve position	037:16:36:43.3 N/A
OMS 7 Cutoff	Left engine bi-propellant valve position Right engine bi-propellant valve position	037:16:37:01.9 N/A
SPARTAN Second Unberth	Payload select 2 latch 1A release	038:11:56:32.5
SPARTAN Deploy	Payload captured	038:12:27:36.5
FCS Checkout APU Activation APU Deactivation	APU-3 GG chamber pressure APU-3 GG chamber pressure	039:10:05:28.09 039:10:12:50.27

^aData supplied by Marshall Space Flight Center

TABLE I.- STS-63 SEQUENCE OF EVENTS

Event	Description	Actual time, G.m.t.
SPARTAN Grapple	Payload captured	040:11:33:20.1
SPARTAN Second Berth	Payload select 2 latch 1A latch	040:12:10:27.3
Payload Bay Door Close	PLBD left close 1	042:08:03:04
	PLBD right close 1	042:08:05:29
APU Activation for Entry	APU-2 GG chamber pressure	042:10:39:07.62
	APU-1 GG chamber pressure	042:11:06:22.52
	APU-3 GG chamber pressure	042:11:06:23.39
Deorbit Burn Ignition	Right engine bi-propellant valve position	042:10:44:04.3
	Left engine bi-propellant valve position	042:10:44:04.3
Deorbit Burn Cutoff	Right engine bi-propellant valve position	042:10:48:18.6
	Left engine bi-propellant valve position	042:10:44:18.6
Entry Interface	Orbital altitude/reference ellipsoid	042:11:19:10
Blackout End	Data locked at high sample rate	No blackout
Terminal Area Energy Management (TAEM)	Major Mode Code (305)	042:11:43:56
Main Landing Gear Contact	MLG left-hand outboard tire pressure 1	042:11:50:19
	MLG right-hand outboard tire pressure 2	042:11:50:19
Main Landing Gear Weight On Wheels	MLG right-hand no weight on wheels	042:11:50:19
	MLG left-hand no weight on wheels	042:11:50:25
Drag Chute Deployment	Drag chute deploy 1 cap volts	042:11:50:26.6
Nose Landing Gear Contact	Nose landing gear right-hand tire pressure 1	042:11:50:33
Nose Landing Gear Weight On Wheels	Nose landing gear no weight on wheels	042:11:50:34
Drag Chute Jettison	Drag chute jettison 1 cap volts	042:11:51:05.0
Wheels Stop	Velocity with respect to runway	042:11:51:41
APU Deactivation	APU-1 GG chamber pressure	042:12:11:52.80
	APU-2 GG chamber pressure	042:12:11:53.49
	APU-3 GG chamber pressure	042:12:11:54.59

^aData supplied by Marshall Space Flight Center

TABLE II.- ORBITER PROBLEM TRACKING LIST

No.	Title	Time	Comments
STS-63-V-01	Primary Thruster R1U Fail Off/Fail Leak Level III Closure	034:05:30 G.m.t. 00:00:08 MET CAR 63RF01 PR RP03-0678	RCS Thruster R1U was deselected after a 320 msec firing. Peak chamber pressure (Pc) reached 2.4 psia. The oxidizer valve began to leak. The oxidizer temperature dropped below 30 °F, and the fuel temperature dropped to the 50 to 60 °F range. Manifold 1 was isolated and repressurized several times without successfully stopping the leak. Manifold 1 was repressurized for entry and re-isolated just prior to touchdown. Leak stopped during entry. KSC: Manifold 1 propellant sampled and thruster replaced.
STS-63-V-02	Primary Thruster L2D Fail Off Level III Closure	034:05:30 G.m.t. 00:00:08 MET CAR 63RF02 PR LP01-24-0672	RCS thruster L2D was deselected after a 320 msec firing. Peak Pc reached was 13 psia. Both oxidizer and fuel flow occurred. Low heat soak-back confirmed low performance. KSC: Thruster replaced.
STS-63-V-03	Primary RCS Thruster F1F Failed Leak Level III Closure	035:19:16 G.m.t. 001:13:54 MET CAR 63RF03 PR FRC3-21-0466	RCS thruster F1F failed leak due to an oxidizer leak after a nominal firing of the thruster. Forward manifold 1 was closed after the fuel injector temperature dropped below the 40 °F lower limit. The manifold was repressurized and the leak stopped. Three successful firings were performed, and the thruster was reselected. Ground testing confirmed that the leak had stopped. Thruster will be refown.
STS-63-V-04	Recurring Loss of CRT 4 Display	034:06:40 G.m.t. 000:01:18 MET IPR 70V-0004 CAR 63RF04	A nominal CRT 4 power-up was noted after orbital insertion. At 034:07:04 G.m.t. (00:01:42 MET), the crew reported that CRT 4 was blank and that the DEU BITE flag was tripped. The failure recurred with the same signature three additional times (035:08:04:06 G.m.t., 037:15:52:53 G.m.t., and 037:16:06:08 G.m.t. CRT 4 was recovered each time with a power cycle. A DEU dump was performed after the second occurrence and it showed only nominal power cycles. A similar failure signature was observed prelaunch, and it resulted in the replacement of DEU 4. KSC: Troubleshooting found forward power control assembly (FPCA) 3 remote power controller (RPC) output intermittent. FPCA 3 replaced.
STS-63-V-05	Port Radiator Latch 1-6 Actuator Latch A Indication Toggling. Level III Closure	037:20:06 G.m.t. 003:14:43 MET IPR 70V-0003 CAR 63RF05	At 037:20:06 G.m.t. (03:14:43 MET), the port radiator latch 1-6 A latched indication (V37X3528E) began cycling off then on with the radiator panel stowed and latched. After approximately one hour of constant toggling, the indication settled and only occasionally repeated the erratic behavior. Redundant B indication (V37X3533E) showed the latch properly closed. KSC: Radiator latches re-rigged and PDU replaced.
STS-63-V-06	Cabin Pressure Sensor Shifted Low	034:21:50 G.m.t. 000:16:28 MET IPR 70V-0005 CAR 63RF06	At 034:21:50 G.m.t. (00:16:28 MET), the cabin pressure transducer shifted low by 0.23 psi from 14.64 to 14.41 psi. All other cues indicated nominal cabin pressure. Spacehab pressure was at 14.8 psi. KSC: Transducer replaced.

TABLE II.- ORBITER PROBLEM TRACKING LIST

No.	Title	Time	Comments
STS-63-V-07	Inadvertent Firing of L1L, L1U, R4U, F3L, and F3U	035:11:41 G.m.t. 01:06:19 MET	The L1L, L1U, R4U, F3L, and F3U primary RCS thrusters fired for 80 msec in response to an inadvertent valid +Y+Z command that occurred when the aft flight control power was applied at 035:11:41:06 G.m.t. (01:06:19:02 MET). No physical deflection of the THC occurred coincident with the thruster firings. A similar event occurred on STS-66 when a -Y/-Z command was apparently generated when the forward station flight control power was applied. Procedural work-arounds will be implemented to prevent a recurrence until permanent changes are implemented. KSC: No action required.
STS-63-V-08	Spacehab Pressure Decay During EVA	040:11:34 G.m.t. 06:06:12 MET IPR 70V-0006	The Spacehab pressure decayed from 14.80 psia to 14.16 psia during the 5-hour 18-minute period that the Airlock was depressurized. No change in Spacehab temperature was noted. During postflight testing, the D hatch seal and equalization valve leak checks were nominal. Tunnel adapter duct isolation valve and cap assembly leak check was double the allowable amount, but < 1 percent of on-orbit leak rate. Removal of lint from seat restored isolation valve to specification level. Removal of paint chips and replacement of bent pin in Marman clamp restored cap assembly to the specification level. Excessive lint build-up found in duct. Cause of build-up and potential corrective actions are under investigation.

TABLE III.- GOVERNMENT FURNISHED EQUIPMENT PROBLEM TRACKING LIST

No.	Title	Time	Comments
STS-63-F-01	EV2 Eye Discomfort During Repressurization after EVA	040:17:07 G.m.t. 06:11:45 MET	The EV2 crewmember reported eye discomfort and odor during airlock repressurization following the EVA. Small brown flecks were found on the inner surface of the helmet visor.
STS-63-F-02	Electronic Cuffs Unresponsive	040:17:07 G.m.t. 06:11:45 MET	The electronic cuffs (ECCs) worn by the EV1 crewmember responded in only one of six touch areas (bottom middle). The ECC worn by the EV2 crewmember did not respond on the right two areas. Both lost the display later during the EVA, and then the display reappeared prior to repressurization. The unit worn by the EV1 crewmember resumed normal functioning just prior to repressurization. The unit worn by EV2 remained unresponsive.

TABLE IV.- MSFC PROBLEM TRACKING LIST

No.	Title	Time	Comments
STS-63-B-01	Left-Hand and Right-hand SRB Damage to Both Forward Skirts and Both Aft Assemblies	Postflight inspection	<p>The left-hand and right-hand SRBs sustained significant damage primarily to both forward skirts and both aft assemblies. Both forward skirts were cracked and buckled. The left-hand forward skirt and left-hand tilt actuator were lost during the SRB tow back to port. Ascent film review has not revealed any anomalies. No identified ascent loads could cause this conditions. Similar but less severe damage was sustained to the left-hand SRB on STS-37 and STS-44. That damage was primarily manifested in the forward skirt. The previous conclusion was that damage occurred during descent.</p> <p>This occurrence is not a safety of flight concern as the investigation has eliminated ascent and SRB separation phases as possible times of occurrence. It is concluded that the SRB damage is attributed to splashdown and the the SRBs are at an increased risk of sustaining damage when surface winds in the retrieval area are high.</p>
STS-63-I-01	Main Engine 1 Experienced Single Point Spikes on Three Pressure Measurements	034:06:39:53 G.m.t. 000:01:17:50 MET	<p>Main engine 1 experienced single-point spikes on three pressure measurements. The main combustion chamber (MCC) coolant discharge pressure spiked at engine start + 77.5 seconds, the high-pressure oxidizer turbopump (HPOTP) secondary seal cavity pressure channel A spiked at + 81.9 seconds, and the HPOTP secondary seal cavity pressure channel B spiked at 83.5 seconds. The remainder of the flight showed no additional spikes. The time and amplitude of the spikes match those believed to be caused by ground radar noise. These two sensors have passed screening by the micro-focus X-ray/PIND technique with excellent scores, which would say the the sensors are clean with respect to contamination which could cause spikes.</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.

ACS	attitude control system (Mir Space Station)
AMOS	Air Force Maui Optical Site
APU	auxiliary power unit
ASC	Astroculture-IV Experiment
ATCS	active thermal control system
BITE	built-in test equipment
BPL	Bioserve Pilot Laboratory
BRIC	Biological Research in Canisters
cc/hr	cubic centimeters per hour
CGBA	Commercial Generic Bioprocessing Apparatus
CGP	Cryogenic Systems Experiment/Shuttle Glow-2 Experiment Payload
CHROMEX	Chromosome and Plant Cell Division in Space
CPCG	Commercial Protein Crystal Growth
CPDS	Charged Particle Directional Spectrometer
CREAM	Cosmic Radiation Effects and Activation Monitoring
CRT	cathode ray tube
CSE	Cryogenic Systems Experiment
DEU	display electronics unit
DSO	Detailed Supplementary Objective
DTO	Developmental Test Objective
ΔP	differential pressure
ΔV	differential velocity
ECC	electronic cuff checklist
ECLIPSE	Equipment for Controlled Liquid Phase Sintering Experiment
EE	end effector
EGT	exhaust gas temperature
EI	entry interface
EMU	extravehicular mobility unit
EPDC	electrical power distribution and control subsystem
ET	External Tank
EV1	extravehicular crewmember 1
EV2	extravehicular crewmember 2
EVA	extravehicular activity
FCE	flight crew equipment
FCL	Freon coolant loop
FCS	flight control system
FES	flash evaporator system
F-GBA	Fluids - Generic Bioprocessing Apparatus
FM	frequency modulation
ft/sec	feet per second
FU-1	Flight Unit-1
GAS	Getaway Special
GFE	Government furnished equipment

GH ₂	gaseous hydrogen
GLO-2	Shuttle Glow Experiment Payload
G.m.t.	Greenwich mean time
GN&C	guidance, navigation and control
GPC	general purpose computer
GPPM	Gas Permeable Polymer Membrane
HA	height adjust maneuver
HAINS	high accuracy inertial navigation system
HH-DTC	Hand-held Diffusion Test Cells
HHL	hand-held LIDAR
HPFTP	high pressure fuel turbopump
HPOTP	high pressure oxidizer turbopump
HVPS	high-voltage power supply
Hz	Hertz
ICBC	IMAX cargo bay camera
ICD	Interface Control Document
IFM	in-flight maintenance
IMMUNE	Immunology Experiment
IMU	inertial measurement unit
I/O	input/output
Isp	specific impulse
ISSC	Improved Spacecraft Standard Cryocooler
keas	knots estimated air speed
KSC	Kennedy Space Center
kW	kilowatt
kWh	kilowatt hour
lb	pound
lbm	pound-mass
LCC	Launch Commit Criteria
LESC	Lockheed Engineering and Science Company
LH ₂	liquid hydrogen
LIDAR	light distance and ranging
LO ₂	liquid oxygen
mA	milliampere
Mach	measurement of speed of sound
MADS	modular auxiliary data system
MC1	midcourse correction 1 (maneuver)
MCC	Mission Control Center
MDM	multiplexer/demultiplexer
MECO	main engine cutoff
MET	mission elapsed time
Mir	Russian Space Station
MMT	Mission Management Team
MPM	manipulator positioning mechanism
MPS	main propulsion system
MSFC	Marshall Space Flight Center
MVAC	Module Vertical Access Kit
NASA	National Aeronautics and Space Administration
Nc	nominal correction (maneuver)

NCC	nominal corrective combination (maneuver)
Nh	nominal height (maneuver)
NIH-C	National Institute of Health-Cells
nmi.	nautical miles
NPSP	net positive suction pressure
NSTS	National Space Transportation System (i.e., Space Shuttle Program)
ODERACS	Orbital Debris Radar Calibration Spheres-2
OMRSD	Operations and Maintenance Requirements and Specifications Document
OMS	orbital maneuvering subsystem
PAL	protuberance air load
P _c	chamber pressure
PCAM	Protein Crystallization Apparatus for Microgravity
PCG-STES	Protein Crystal Growth - Small Thermal Enclosure System
PDU	power drive unit
PFR	portable foot restraint
PGSC	payload and ground support computer
PI	Principal Investigator
PILOT	Portable In-Flight Landing Operations Trainer
PLBD	payload bay door
PMBT	propellant mean bulk temperature
POCC	Payload Operations Control Center
PRSD	power reactant storage and distribution
psi	pound per square inch
psid	pound per square inch differential
RCN	Requirements Change Notice
RCS	reaction control subsystem
RM	redundancy management
RME-III	Radiation Monitoring Equipment-III
RMS	remote manipulator system
RSGF	rigidize sensing grapple fixture
RSRM	Redesigned Solid Rocket Motor
RTV	room temperature vulcanizing (material)
S&A	safe and arm
SAIL	Shuttle Avionics Integration Laboratory
SAMS	Space Acceleration Measurement System
SAREX	Shuttle Amateur Radio Experiment
SPARTAN-204	Shuttle Pointed Autonomous Research Tool for Astronomy-204
SRB	Solid Rocket Booster
SRSS	Shuttle range safety system
SSCE	Solid Surface Combustion Experiment
SSME	Space Shuttle main engine
SVSU	Spacehab video switching unit
SWDLPA	supply water dump line purge assembly
TCS	Trajectory Control Sensor/thermal control system
3-DMA	Three-Dimensional Microgravity Accelerometer
THC	translational hand controller
TI	terminal initiation
TONS	Target of Opportunity Navigation Sensors

TPS	thermal protection subsystem
TRAD	Tools for Rendezvous and Docking
TVC	thrust vector control
VDA	Vapor Diffusion Apparatus
Vdc	Volts direct current
VHF	very high frequency
VIU	video interface unit
VSU	video switching unit
WCS	Waste collection system
WINDEX	Window Experiment
WSB	water spray boiler