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NOTE

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STS-65

SPACE SHUTTLE

MISSION REPORT

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INTRODUCTION

The STS-65 Space Shuttle Program Mission Report summarizes the Payload activities as well as the Orbiter, External Tank (ET), Solid Rocket Booster (SRB), Redesigned Solid Rocket Motor (RSRM), and the Space Shuttle main engine (SSME) systems performance during the sixty-third flight of the Space Shuttle Program and the seventeenth flight of the Orbiter vehicle Columbia (OV-102). In addition to the Orbiter, the flight vehicle consisted of an ET that was designated ET-64; three SSMEs that were designated as serial numbers 2019, 2030, and 2017 in positions 1, 2, and 3, respectively; and two SRBs that were designated BI-066. The RSRM's that were installed in each SRB were designated as 360P039A for the left SRB, and 360W039B for the right SRB.

This STS-65 Space Shuttle Program Mission Report fulfills the Space Shuttle Program requirement as documented in NSTS 07700, Volume VIII, Appendix E. The requirement that is stated in that document is that each major organizational element supporting the Program will report the results of their hardware (and software) evaluation and mission performance,, plus identify all related in-flight anomalies.

The primary objective of this flight was to complete the operation of the second International Microgravity Laboratory (IML-2). The secondary objectives of this flight were to complete the operations of the Commercial Protein Crystal Growth (CPCG), the Orbital Acceleration Research Experiment (OARE), and the Shuttle Amateur Radio Experiment (SAREX) II payloads. Additional secondary objectives were to meet the requirements of the Air Force Maui Optical Site (AMOS) and the Military Application of Ship Tracks (MAST) payloads, which were manifested as payloads of opportunity.

The STS-65 mission was planned with a 14-day duration plus 2 contingency days, which were available for weather avoidance or Orbiter contingency operations. The sequence of events for the STS-65 mission is shown in Table I, and the Orbiter Project Office Problem Tracking List is shown in Table II. The official Government Furnished Equipment (GFE) Problem Tracking List is shown in Table III, and the Marshall Space Flight Center (MSFC) Problem Tracking List is shown in Table IV. In addition, the 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 this document. All times are given in Greenwich mean time (G. m. t.) as well as mission elapsed time (MET).

The seven-person crew for STS-65 consisted of Robert D. Cabana, Col., U. S. Marine Corps, Commander; James D. Halsell, Jr., Lt. Col., U. S. Air Force, Pilot; Richard J. Hieb, Mission Specialist 1; Carl E. Walz, Lt. Col, U. S. Air Force, Mission Specialist 2; Leroy Chiao, Ph.D., Mission Specialist 3; Donald A. Thomas, Ph. D., Mission Specialist 4; and Chiaki Mukai, Ph. D., M. D., Payload Specialist 1. STS-65 was the third space flight for the Commander and Mission Specialist 1; the second space flight for Mission Specialist 2; and the first space flight for the Pilot, Mission Specialist 3, Mission Specialist 4, and Payload Specialist 1. Each crewmember was assigned to one of two teams to provide around-the-clock operations during the mission. The red team consisted of the Commander, Pilot, Mission Specialist 1, and Payload Specialist 1; and the blue team consisted of Mission Specialist 2, Mission Specialist 3, and Mission Specialist 4.

MISSION SUMMARY

The STS-65 mission was successfully launched as planned at 189:16:43:00.013 G.m.t. (12:43 p.m. e.d.t. on July 8, 1994). The countdown proceeded in a smooth manner with no unplanned holds. The ascent phase was nominal and all Space Shuttle Elements performed satisfactorily. No orbital maneuvering subsystem (OMS) -1 maneuver was required as a result of the direct insertion trajectory flown.

First stage ascent performance was as expected. SRB separation, entry, deceleration, and water impact occurred as anticipated. Both SRBs were successfully recovered. Performance of the SSMEs, ET, and main propulsion system (MPS) was normal. A determination of overall vehicle performance was made using vehicle acceleration and preflight propulsion prediction data. From these data, the average flight-derived engine specific impulse (Isp) determined for the period between SRB separation and start of 3-g acceleration was 452.1 seconds, which is slightly lower than expected but satisfactory when compared with the predicted value of 452.57 seconds. SSME cutoff (MECO) occurred at 189:16:51:30.31 G.m.t. (510.63 seconds MET) when the vehicle reached the planned MECO target.

The OMS -2 maneuver was performed at 189:17:22:55.2 G.m.t. (00:39:55.2 MET). The two-engine firing was 141.3 seconds in duration and provided a differential velocity (ΔV) of 221.8 ft/sec. The resultant orbit was 162.9 by 160.3 nmi.

At approximately 189:17:23 G.m.t. (00:40:00 MET), following main propulsion system (MPS) vacuum inerting, the liquid hydrogen (LH_2) manifold pressure increased to 17 psia. This increase coincided with the OMS-2 maneuver. On previous missions when vacuum inerting was performed manually, the pressure increased to approximately 6 psia. This was the first flight of the OI-23 software that automated the MPS vacuum inerting procedures. The OI-23 software was verified to have performed as required, and all LH_2 system responses to the software commands were nominal.

A supply water dump was initiated at 192:07:27:20 G.m.t. (02:14:44:20 MET). At 192:07:59:02 G.m.t. (02:15:16:02 MET) (32 minutes later), the dump was prematurely terminated because of excessively low dump-nozzle temperatures. Data analysis concluded that the supply water dump nozzle had accumulated an unknown amount of ice that may also have obstructed the waste water dump nozzle. The supply and waste water dump nozzle heaters were cycled to eliminate the ice from the nozzle area. After the supply and waste water dump nozzle temperatures indicated ice was no longer present, a successful waste water dump was initiated at 193:16:49 G.m.t. (04:00:06 MET). The dump was completed 56 minutes later with good nozzle temperatures and no signs of ice. Supply water dumps were performed using the flash evaporator system (FES) for the remainder of the flight.

At 199:12:36:12.7 (09:19:53:12.7 MET), a transient inertial measurement unit (IMU) 1 (S/N 204) redundant-rate built in test equipment (BITE) message was generated when the azimuth gyro's redundant input axis measured a platform drift rate in excess of 0.7 deg/hr. Additional transient IMU 1 redundant-rate BITE messages were generated after the initial occurrence, and the messages were inhibited by the crew to prevent further alarms. Initially, the transient condition did not significantly degrade the IMU 1 performance. However, the condition gradually worsened and IMU 2 was commanded from standby to operate mode at 201:14:29 G.m.t. (11:21:46 MET) to add redundancy. On flight day 13, the IMU platform experienced a 0.08 degree shift during an event which lasted 10 minutes, and the IMU was declared failed for entry planning purposes. At 204:03:34 G.m.t. (14:10:51 MET), IMU 1 was moded to standby for 13 minutes and back to operate in an attempt to recover nominal operation by resetting the IMU internal processor. The IMU continued operating with the BITE indication occurring randomly, but no BITIE indications resulting in a significant performance degradation were observed after the reset. The IMU was periodically realigned to assure than any platform misalignments caused by drift transients did not exceed the redundancy management (RM) threshold. IMU 1 performance was deemed acceptable for entry, and the IMU was allowed to remain under RM control during entry. IMU 1 performed nominally throughout entry, and no abnormal operation was noted until 3 minutes prior to the normal IMU-1 shut down during the postlanding operations.

The first on-orbit Shuttle test of the Second Tracking and Data Relay Satellite (TDRS) Ground Terminal (STGT) was performed on orbit 183. The S-band successfully provided audio communications, command uplink, and telemetry downlink. The Ku-band provided downlink video from multiple cameras and 2 megabit real-time data on channel 2. The second successful STGT test was performed on orbit 211. Some problems were encountered in locking on the Ku-band channel 2 signal, but the lock-on was completed.

The flight control system (FCS) checkout was performed at 202:07:36:15 G.m.t. (12:14:53:15 MET) using auxiliary power unit (APU) 1, and all data were nominal. The hydraulic/water spray boiler performance during FCS checkout was nominal, and no water spraying was required because of the short APU run-time.

The reaction control subsystem (RCS) hot-fire test was performed at 203:05:02 G.m.t. (13:12:19 MET) and all thrusters were fired twice with good results.

The payload bay doors were closed for the first-day landing opportunities at the Shuttle Landing Facility (SLF) at Kennedy Space Center (KSC), but the landing was waived because of rain within 30 miles of the SLF. Consequently, the mission was extended 24 hours because of the desire to land at KSC.

Two OMS maneuvers were performed after the wave-off of the first landing opportunity. OMS-3 was performed at 203:12:47:44.1 G.m.t. (13:20:04:44.1 MET) and was 32.1 seconds in duration with a ΔV of 51.0 ft/sec. OMS-4 was performed at

203:13:32:42.2 G.m.t. (13:20:04:44.1 MET) and was 30.4 seconds in duration with a ΔV of 49.1 ft/sec. The two OMS maneuvers were performed to obtain an additional end-of-mission (EOM) + 2 day landing opportunity at Edwards Air Force Base. This opportunity was lost when the planned launch time was moved up 20 minutes to extend the launch window.

All deorbit preparations for the landing opportunities on the second day were completed, and the payload bay doors were closed at 204:07:10:05 G.m.t. (14:14:27:05 MET). The deorbit maneuver was initiated at 204:09:40:38.3 G.m.t. (14:16:57:38.3 MET), and was 152.8 seconds in duration with a ΔV of 255.3 ft/sec. Main landing gear touchdown occurred at the SLF on concrete runway 33 at 204:10:38:00 G.m.t. (14:17:55:00 MET) on July 23, 1994. The Orbiter drag chute was deployed satisfactorily at 204:10:38:10 G.m.t., and nose landing gear touchdown occurred 8 seconds after drag chute deployment was initiated. The drag chute was jettisoned at 204:10:38:42.6 G.m.t. with wheels stop occurring at 204:10:39:08 G.m.t. The rollout was normal in all respects. The flight duration was 14 days 17 hours 55 minutes 00 seconds, which is the record-length flight for the Space Shuttle Program.

PAYLOADS

The second International Microgravity Laboratory Spacelab mission brought together over 200 international scientists from 13 countries and six space agencies who developed over 80 investigations for the IML-2 mission. The agencies represented were the European Space Agency (ESA), the French Space Agency (CNES), the German Space Agency (DARA), the Canadian Space Agency (CSA), the National Space Development Agency of Japan (NASDA), and the National Aeronautics and Space Administration (NASA). The areas of science in which investigations were performed were Material Science, Fluid Science, Microgravity Environment and Countermeasure, Bioprocessing, Space Biology, Human Physiology, and Radiation Biology.

The Spacelab, containing 19 separate experiment facilities, was activated at 189:21:04 G.m.t. (00:04:21 MET). Facilities flown for the first time included the Real-Time Radiation Monitoring Device (RRMD); the Performance Assessment Workstation (PAWS); the Vibration Isolation Box Experiment Station (VIBES); the Electromagnetic Containerless Processing Facility (TEMPUS); the Bubble, Drop, and Particle Unit (BDPU); the Quasi Steady Acceleration Measurement; and the Linear Compressor Enhanced Orbiter Refrigerator/Freezer (LCEOR/F).

Carbon dioxide concentration-level requirements were supported remarkably well by augmenting the regenerative carbon dioxide removal system (RCRS) with lithium hydroxide (LiOH) canisters with restricters. LiOH canister changes were made at 15-hour intervals, and this maintained the average partial pressure of carbon dioxide at 2.3 mmHg with peaks to 3.0 mmHg.

Initial problems with high-rate multiplexer (HRM) data throughput and activation of the free flow electrophoresis unit (FFEU) were overcome by successful in-flight maintenance (IFM) procedures. In spite of the problems that delayed the FFEU activation and prematurely deactivated the Applied Research on Separation Methods Using Space Electrophoresis (RAMSES) experiment, almost all experiment objectives were successfully completed.

The Spacelab was deactivated at 203:04:28 G.m.t. (13:11:45 MET) after a very successful mission. During the initial postflight inspection, a loose fire extinguisher was found on the floor in the Spacelab. Additional inspection revealed that the extinguisher was not secured during Spacelab closeout.

LIFE SCIENCES

Aquatic Animal Experiment Unit

The AAEU, which was developed by the National Space Development Agency of Japan, provided an environment for studies of live fish and small amphibians under microgravity conditions. For the STS-65 mission, four experiments were conducted using the AAEU. These were:

a. Mechanism of Vestibular Adaptation of Fish under Microgravity;
b. Otoconia: Early Development of a Gravity-Receptor Organ in Microgravity;
c. Fertilization and Embryonic Development of Japanese Newts in Space; and
d. Mating Behavior of Fish (Medaka) and Development of Their Eggs in Space.

Extensive data were collected on the animal gravity sensor response to microgravity, spawning behavior of Medaka (guppies), and embryo development of both ground- and space-fertilized eggs.

The crew reported that at least 25 Medaka fry and 32 newt eggs had hatched. Two newts died during the flight; however, successful IFM procedures were performed to remove them to prevent contamination of the baby newts and eggs and preserve them for postflight analysis. It is speculated that stress was a leading factor for the cause of death; however, postflight analysis will be conducted to determine the actual cause.

The aquarium and fish packages operated nominally for the majority of the mission. The crew manually called down housekeeping data until the HRM channel 7 data throughput problem was corrected by an IFM procedure. A subsequent IFM procedure to overcome a low water pressure anomaly was successfully executed by injecting water into the aquarium package.

Biorack

The Biorack, developed by the European Space Agency, enabled the study of the effects of microgravity and cosmic radiation on isolated cells, tissues, bacteria, and small animals and plants. A total of 19 experiments from seven European countries was placed into the 200 separate containers in this facility for the STS-65 mission.

The experiments were:

a. Antigen Presentation and T-Cell Proliferation in Microgravity (Antigen);
b. Lymphocyte Activation, Differentiation, and Adhesion Dependence on Activation (Adhesion);
c. Lymphocyte Movements and Interactions (Motion);
d. Effect of Microgravity on Cellular Activation: The Role of Cytokines (Phorbol);

e. Cell Microenvironment and Membrane Signal Transduction in Microgravity (Signal);
f. Effect of Stirring and Mixing in a Bioreactor Experiment in Microgravity (Bioreactor);
g. Molecular Biological Investigations of Animal Multi-Cell Aggregates Reconstituted under Microgravity (Aggregate);
h. Regulation of Cell Growth and Differentiation by Microgravity: Retinoic Acid-Induced Cell Differentiation (Mouse)
i. Sea Urchin Larva, a Potential Model for Studying Biomineralization and Demineralization Processes in Space (Urchin);
j. Investigation of the Mechanisms Involved in the Effects of Space Microgravity on Drosophila Development, Behavior and Aging (Drosophila);
k. The Role of Gravity in the Establishment of Embryonic Axes in Amphibian Embryo (Eggs);
l. Effect of Microgravity on Lentil Morphogenesis (Lentil);
m. Root Orientation, Growth Regulation, Adaptation, and Agravitropic Behavior of Genetically Transformed Roots (Transform);
n. Plant Growth and Random Walk (Random);
o. Efficiency of Radiation Repair on Prokaryotes (Repair); and
p. Radiation Repair Kinetics in Eukaryotes (Kinetics).

All experiment investigations were successful including the Drosophila investigation that studied the behavior and aging process of fruit flies. The failure of M1 centrifuge used for incubator C was overcome by installing a makeshift drive belt over the drums of this centrifuge and the functional M2 centrifuge. Other facility hardware including a glovebox and a cooler performed nominally. However, during the Biorack power-up, the Biorack power blower LED did not light, but the blower ran as long as the door was closed. Power to the glovebox was cycled and normal operations were restored.

Biostack

The Biostack (BSK) experiment consisted of three sealed aluminum BSK containers, which were mounted in a Spacelab rack, and was a part of a multinational program to determine the impact of high-atomic-number, high-energy cosmic radiation particles on life in space. The BSK experiment uses radiation detectors located between a variety of biological specimens to monitor particles entering the Spacelab module.

Operations of the passive, sealed detectors used to study the effects of cosmic radiation on biological samples were nominal.

Extended Duration Orbiter Medical Project

The Extended Duration Orbiter Medical Project (EDOMP) consisted of two investigations which were designed to protect the health and safety of the crewmembers during a 13- to 16-day mission in space.

The Lower Body Negative Pressure (LBNP) experiment evaluated the effectiveness of a treatment designed to counteract orthostatic intolerance, the lightheadedness some members of a crew may experience when returning from a 13- to 16-day mission. The LBNP operations, which were nominal, continued to test the hypothesis that the effects of fluid loss due to the headward shift of body fluids in spaceflight can be countered by ingestion of a large quantity of saline solution in conjunction with the application of negative pressure to the lower body.

The Microbial Air Sampler (MAS) is a hand-held, battery operated air sampler, which collects samples of air in predetermined places at predetermined times. Particles entering the MAS are trapped on plastic strips containing agar. These strips were replaced after two minutes of sampling and stored for postflight analysis. The MAS failed during the first sampling operation, and the first data-take was lost. An IFM procedure was performed in which the sample strip was replaced and normal operation was restored. However, only four of the five planned data-takes were completed satisfactorily because of this problem.

The American Echocardiograph Research Imaging System (AERIS) failed to record data during one session. An IFM procedure was performed and nominal operation was restored for the remainder of the mission.

Linear Compressor Enhanced Orbiter Refrigerator/Freezer

The LCEOR/F encountered problems early in the mission; however, the starting and stopping temperatures for the compressor were each lowered 8 °C and the LCEOR/F operated nominally with a duty cycle of 55 to 60 percent for the remainder of the mission. Experiment operations, including a defrost procedure and loading of phase-change materials (PCMs) and crew beverages, were completed successfully. Although the unit was unpowered during ascent, it was powered continuously during on-orbit operations and entry during, which an automatic temperature recorder (ATR) was used to collect temperature data.

Slow Rotating Centrifuge Microscope

The Slow Rotating Centrifuge Microscope (NIZEMI) facility provided scientists with the capability to observe both living and non-living matter exposed to levels of gravity ranging from 10^{-3} g to 1.5 g. The science investigations that were a part of the NIZEMI experiment were as follows:

a. Gravisensitivity and Geo(Gravi)taxis of the Slime Mold;
b. Graviorientation in *Euglena gracilis* (Euglena);
c. Influence of Accelerations on the Spatial Orientation of the *Protozoan Loxodes Striatus* (Loxodes);
d. Effects of Microgravity on Aurelia Ephyra Behavior and Development (Jellyfish);

e. Gravireaction in Chara Rhizoids in Microgravity (Chara) (Lost because of over-temperature anomaly);
f. Gravisensitivity of Cress Roots (Cress);
g, Lymphocyte Movements and Interactions (Motion); and
h. Convection Stability of a Planar Solidification Front (Moni).

All experiment samples except the Chara sample were completed as planned. An over-temperature anomaly in which the experiment module internal temperature rose from 21 °C to 58 °C was noted early in the flight. This problem was seen previously during preflight testing and was caused by a sticking relay, but could not be corrected because of the lack of time before flight.

Microgravity Effects on Standardized Cognitive Performance Measures

The Microgravity Effects on Standardized Cognitive Performance Measures experiment, which consisted of six computerized cognitive performance tests called PAWS, will help determine the astronauts' mental ability to perform operational tasks in space.

The Commander, Pilot and Mission Specialist 2 successfully completed all experiment objectives to measure human workload and performance in zero gravity.

Applied Research on Separation Methods Using Space Electrophoresis

The RAMSES experiment uses a continuous-flow electrophoresis unit to purify biological samples. An adjustable electric field was applied across the flow, causing the differently charged components to diverge into a wide beam consisting of separate streams of molecules, which pass through 40 outlets into collection tubes. These collection tubes were refrigerated and returned to Earth for postflight analysis. A number of samples were processed during the flight in support of investigations that were as follows:

a. Optimization of Protein Separation; and
b. Electrohydrodynamic Sample Distortion.

An initial problem with a non-operational Electrode Buffer Pump (EBP) was resolved by cycling the power. Recurrence of the anomaly resulted in the hypothesis that gases generated by electrolysis were not being evacuated as fast as the gases were being produced following an experiment run. A waiting period following each experiment run was included in the procedures and this allowed continuous operation.

Premature shutdown of the RAMSES experiment occurred when the data showed a large power spike across the Orbiter fuel cells. Troubleshooting confirmed that the problem was due to a blown rectifier diode that caused the power spike and blew a fuse in the facility power control and interface system (PCIS). In spite of this condition, the science team was still able to complete five of seven flight objectives (FOs), and the majority of the sixth FO. Approximately 80 to 90 percent of the total science objectives were completed.

Real-Time Radiation Monitoring Device

The RRMD measured the high-energy cosmic radiation in the Spacelab while on-orbit, and in turn, transmitted these data to the Payload Operations Control Center at Marshall Space Flight Center (MSFC). In addition, the device contained bacteria with high radiation sensitivity. These cells were analyzed during postflight operations to determine radiation damage as well as their capability to recover and repair themselves after a cosmic ray impact.

Radiation measurement activities were nominal. However, some data-take opportunities were lost because of the HRM channel data throughput problem experienced early in the mission. This anomaly caused a total loss of data from the RRMD for these opportunities. The crew performed an IFM procedure on flight day 3 that resulted in a solid lock-on of the data. Also, the experiment was inadvertently powered off. The crew found that the power circuit breaker on panel L4W was open and subsequently closed it.

Spinal Changes in Microgravity

The Spinal Changes in Microgravity (SCM) experiment was developed because two out of every three persons who go into space experience back pain. As a result, the lengthening of the spinal column was studied to determine if that condition is the cause of the back pain.

Stereophotographs of the spine and ultrasound imaging of vertabral spacing were successfully recorded, and these data will be used to study the effects of microgravity on the spine and neurosensory system. Extensive replanning was completed to fill the timeline voids caused by the late activation of the FFEU and the initial failure of the AERIS that also used the SCM.

Thermoelectric Incubator and Cell Culture Kits

The Thermoelectric Incubator (TEI) was a general purpose incubator used in Spacelab to maintain biological specimens at a constant temperature, humidity, and carbon-dioxide concentration. The Cell Culture Kits (CCK) were used to culture slime mold and plant and animal cells in microgravity. Both of these pieces of equipment were used in conjunction with the FFEU experiments.

Early in the mission at 191:00:15 G.m.t. (01:07:32 MET), a tripped circuit breaker was reset, and nominal TEI science data gathering continued without interruption for the remainder of the mission.

MATERIALS SCIENCE

Advanced Protein Crystallization Facility

The Advanced Protein Crystallization Facility (APCF) provided an environment for growing a variety of protein crystals using three different methods. These were:

a. vapor diffusion;
b. liquid-liquid diffusion; and
c. dialysis.

The associated crystal growth facilities operated nominally during the mission.

Bubble, Drop and Particle Unit

The BDPU was a facility developed to study fluid behaviors and interactions such as bubble growth, evaporation, condensation, and thermocapillary flows. The crew interchanged experiment test containers with dedicated fluid cells. The experiments that used the BDPU are as follows:

a. Bubble Migration, Coalescence and Interaction with Melting and Solidification Fronts;
b. Thermocapillary Migration and Interactions of Bubbles and Drops;
c. Bubble Behavior Under Low Gravity';
d. Thermocapillary Instability in a Three-Layer System;
e. Nucleation, Bubble Growth, Interfacial Micro-Layer, Evaporation and Condensation Kinetics; and
f. Static and Dynamic Behavior of Liquid in Corners, Edges and Containers.

This new facility was responsible for many firsts in the study of fluids and the behavior of droplets under thermal gradients. Fluid shift and non-hazardous containment leaks (controlled by a second level of containment) resulted in at least the partial loss of the KOSTER and MONTI investigations.

Critical Point Facility

The Critical Point Facility (CPF) provided a facility for several experiments to measure and visually record special fluid properties at their "critical point". The facility measured fluid density fluctuations near the critical point using laser light scattering and interferometry. The experiments that used this facility were:

a. The Piston Effect;
b. Thermal Equilibrium in a One-Component Field;

c. Density Equilibration Time Scale; and
d. Heat Transport and Density Fluctuations in a Critical Field.

The reflight of this facility reconfirmed previous findings from the IML-1 mission. An improved thermostat was installed since the IML-1 mission, and this enabled the facility to perform without interruption and gather significant science data.

Free Flow Electrophoresis Unit

The FFEU was used to study whether space-based electrophoresis will improve the purity of certain biological materials which are normally difficult to separate on Earth. A number of different types of samples were flown for testing and is as follows:

a. Gravitational Role in Electrophoretic Separations of Pituitary Cells and Granules;
b. Separation of Chromosome DNA of a Nematode, C. *elegans*, by Electrophoresis; and
c. Experiments Separating the Culture Solution of Animal Cells in High Concentration under Microgravity.

After overcoming activation problems, all FFEU science investigations were attempted. Although degradation of one sample occurred that prevented a pituitary separation for one flight objective, the majority of science was successfully completed. The success is due to the excellent replanning of the experiment timeline by the flight control team.

Large Isothermal Furnace

The Large Isothermal Furnace (LIF) was used to heat large materials samples in a vacuum, and then cool the samples very rapidly to determine the relationships between structure, processing, and properties of materials. The two experiments, comprising five samples, that were conducted with this facility were:

a. Gravitational Role in Liquid Phase Sintering; and
b. Effect of Weightlessness on Microstructure and Strength of Ordered TiAl Intermetallic Alloys.

Furnace operations to melt and uniformly mix compounds, and then cool them to produce a solid sample, operated nominally and all science investigations were successfully completed.

Quasi-Steady Acceleration Measurement

The Quasi-Steady Acceleration Measurement (QSAM) experiment was primarily designed to detect steady, very low frequency, residual accelerations between 0 and

0.02 Hertz. Data were recorded throughout the mission on optical disks, which were returned for postflight evaluation.

The hardware, which consisted of four rotating sensors, three static sensors and an optical recorder, successfully recorded low-frequency accelerations in the Spacelab. Several instances of problems with the optical recorder were corrected by either changing the optical disk or performing a self-test.

Space Acceleration Measurement System

The Space Acceleration Measurement System (SAMS) instrument monitored and recorded higher-frequency onboard accelerations and vibrations that were experienced in the Spacelab module during flight. Data were recorded throughout the mission on optical disks, which were returned for postflight evaluation.

Accelerometer heads in three Spacelab locations nominally recorded accelerations caused by Orbiter maneuvers and crew motion. A problem with disk drive 2 was corrected by reseating the disk in the drive.

Electromagnetic Containerless Processing Facility

The TEMPUS, a levitation melting facility, provided containerless processing of metallic samples in an ultraclean microgravity environment. The facility used an electric current flowing through coils of copper tubing to produce magnetic fields, which created an area of minimum field strength in which the sample would levitate. Twenty-two metallic samples were accommodated during the mission. A number of experiments shared this facility and these were:

a. Effects of Nucleation by Containerless Processing in Low Gravity;
b. Non-equilibrium Solidification of Largely Undercooled Melts;
c. Structure and Solidification of Largely Undercooled Melts of Quasicrystal-Forming Alloys;
d. Thermodynamics and Glass Formation in Undercooled Liquid Alloys;
e. Metallic Glass Research in Space: Thermophysical Properties of Metallic Glasses and Undercooled Alloys;
f. Viscosity and Surface Tension of Undercooled Melts; and
g. Measurement of the Viscosity and Surface Tension of Undercooled Melts under Microgravity Conditions and Supporting Magnetohydrodynamic Calculations.

The initial flight of the TEMPUS facility provided unprecedented science results. A problem with samples adhering to their containment cage was mitigated by many completely successful experiment runs, and the fact that, in most cases, excellent data were gathered prior to the sample sticking to its cage.

Vibration Isolation Box Experiment Station

The VIBES investigated the effects of so-called "g-jitter" disturbances caused by crew movement and experiment equipment operations in space laboratories such as Spacelab.

Operations were nominal for this experiment composed of special materials designed to mitigate the effects of accelerations.

COMMERCIAL PROTEIN CRYSTAL GROWTH

STS-65 was the fifth flight of the CPCG experiment. This secondary payload used the commercial refrigerator/incubator module (CRIM) in the Orbiter middeck. A total of 60 samples focusing on six different proteins in various formulations were flown for this payload.

The CPCG CRIM experienced a thermal electric device (TED) signal dropout at 194:08:43 G.m.t. (04:16:00 MET) that resulted in lost thermal performance. The temperature of the unit rose to approximately 13 °C over a 9.5-hour period. Diagnostic data were checked by the crew who verified that the TED was dropping in and out. To achieve a stable environment, the CRIM command temperature was changed to 13 °C, and the temperature of the unit remained at 13 °C ± 1.8 °C for the remainder of the mission. Impact of the temperature instability to the protein samples can only be assessed during postflight laboratory work at the Principal Investigators' laboratory. The postflight assessment indicated that crystals were grown in five of the six protein samples. However, only three of the five protein crystals yielded x-ray diffraction-grade crystals, and only two of the six protein materials yielded good crystals.

ORBITAL ACCELERATION RESEARCH EXPERIMENT

The OARE was used to make highly accurate measurements of very low frequency (steady state to 1 Hz) Orbiter accelerations experienced during on-orbit operations and the initial portion of the entry phase of the mission. The OARE can measure and record accelerations on the order of one-billionth of the acceleration of Earth's gravity (10 nano-g's).

The OARE acquired near steady-state microgravity acceleration data in support of IML-2 experiments throughout the on-orbit phase of the mission from 10 minutes after launch until approximately 10 minutes after entry interface. All operations were performed as planned, including acquisition of data during vehicle rotations performed to calibrate the SAMS. The OARE data obtained during these rotations will be used for scale factor calibrations of the OARE sensor system. In addition to obtaining acceleration data in support of the IML-2 requirements, the data acquired during the pitch/drag OARE maneuver and during entry will be used to assess the vehicle aerodynamic characteristics at orbital altitudes. The initial assessment of the data dumped at MSFC indicated nominal instrument performance throughout the flight.

SHUTTLE AMATEUR RADIO EXPERIMENT

The SAREX project, which has flown on 13 previous Shuttle missions, was designed to encourage public participation in the Space Program and support the conduct of educational initiatives. This objective is being accomplished by demonstrating effective communications between the Shuttle and low-cost ground stations using amateur radio voice and digital techniques.

All 13 scheduled schools were successfully contacted by the Space Shuttle Columbia astronauts. These schools included two foreign schools: Tatebayashi Children's Science Exploratorium in Japan; and a German school, Franhofer Realschule in Ingolstadt, Germany.

In addition to the scheduled contacts, one unscheduled contact was also arranged with General Thomas Stafford at the Aerospace America Annual Airshow in Oklahoma City, OK. Commander Cabana communicated through bridge stations in Hawaii and California and was heard by approximately 150,000 people.

The packet operation aboard the Columbia that included a portion of the commemorative Apollo 11 period performed nominally with approximately 3,000 connections to the Shuttle packet radio.

MILITARY APPLICATIONS OF SHIP TRACKS

The MAST experiment was sponsored by the Office of Naval Research, and the objective of the MAST experiment was to determine how pollutants generated by ships modify the reflective properties of clouds. Use of high-resolution photographs obtained in support of this experiment will provide insight into the processes of ship track production on a global scale.

Over 300 high-resolution photographs were taken of 17 targets. These results far exceeded the requirements for photographs of four targets.

AIR FORCE MAUI OPTICAL SYSTEM

The AMOS is an electrical-optical facility on the Hawaiian island of Maui. The facility tracks the Orbiter as it flies over the area and records signatures from thruster firings, water dumps, or the phenomena of "Shuttle Glow". No specific crew or vehicle (thruster firings) activity in support of this experiment was performed during this mission.

VEHICLE PERFORMANCE

SOLID ROCKET BOOSTERS

All SRB subsystems performed as expected. The SRB prelaunch activities were all normal, and no Launch Commit Criteria (LCC) or Operational Maintenance Requirements and Specification Document (OMRSD) violations were identified. For this flight, the low-pressure heated ground purge in the SRB aft skirt was not required to maintain the case/nozzle joint temperatures within the required LCC ranges. The purge was activated at T-26 minutes for the high-flow rate inerting of the SRB aft skirt. The calculated flexible bearing mean bulk temperature was 78 °F.

Analysis of the SRB data indicates nominal performance of all subsystems. Two new maximums for experience bases were set for the thrust vector control (TVC) system. One was established on the left-hand tilt fuel supply module (FSM) pressure difference between APU start and cutoff. The second new experience base was the right-hand tilt actuator maximum rate during separation null. Data concerning both of these new experience bases have been evaluated, and no anomalous operation was found.

Both SRB's were successfully separated from the ET at T+123.48 seconds, and reports from the recovery area, which were based on visual sightings, indicate that the SRB deceleration subsystems performed as designed. Both SRBs were sighted during descent and were recovered and brought to Cape Canaveral for return to KSC where disassembly and refurbishment activities were initiated.

During the disassembly process, two anomalous conditions were identified and they were:

a. Two of four mounting fasteners for the right-hand SRB range safety system (RSS) safe and arm (S&A) were not properly seated (Flight Problem STS-65-B-01); and

b. One broken fastener was found on the left-hand SRB aft integrated electronics assembly (IEA) end cover on the systems tunnel side (Flight Problem STS-65-B-02).

REDESIGNED SOLID ROCKET MOTORS

The RSRMs operated satisfactorily throughout the ascent phase. Prelaunch activities were satisfactory and no LCC or OMRSD violations were identified. Power-up and operation of all igniter and field joint heaters was completed in a routine manner, and all RSRM temperatures were maintained within acceptable limits throughout the countdown.

The field joint heaters operated for 11 hours 36 minutes during the prelaunch time frame with the heaters on 17 percent of the time during the LCC time frame. The igniter joint heaters operated for 23 hours 11 minutes with the heaters powered up 5 hours earlier than expected. Power was applied to the igniter heating elements 29 percent of the time.

Data indicate that the flight performance of both RSRMs was well within the allowable performance envelopes and was typical of the performance observed on previous flights. The RSRM propellant mean bulk temperature (PMBT) was 81 °F at liftoff. The following table shows the performance data of the RSRMs.

RSRM PROPULSION PERFORMANCE

Parameter	Left motor, 81 °F		Right motor, 81 °F	
	Predicted	Actual	Predicted	Actual
Impulse gates				
I-20, 10^6 lbf-sec	66.16	66.34	66.17	66.43
I-60, 10^6 lbf-sec	176.13	176.04	176.16	176.42
I-AT, 10^6 lbf-sec	296.75	296.06	297.02	296.30
Vacuum Isp, lbf-sec/lbm	268.6	268.0	268.6	268.0
Burn rate, in/sec @ 60 °F at 625 psia	0.3679	0.3687	0.3676	0.3694
Burn rate, in/sec @ 81 °F at 625 psia	0.3735	0.3743	0.3732	0.3750
Event times, seconds[a]	0.232	N/A	0.232	N/A
Ignition interval	108.8	109.1	108.9	108.5
Web time[b]	118.5	118.6	118.3	117.6
Separation cue, 50 psia	120.6	120.7	120.5	119.8
Action time[b]	123.5	123.5	123.5	122.5
Separation command				
PMBT, °F	81	81	81	81
Maximum ignition rise rate, psia/10 ms	90.4	N/A	90.4	N/A
Decay time, seconds (59.4 psia to 85 K)	2.8	3.0	2.8	3.1
Tailoff Imbalance Impulse differential, Klbf-sec	Predicted		Actual	
	N/A		600.6	

Impulse Imbalance = left motor minus right motor
[1] All times are referenced to ignition command time except where noted by a [2].
[2] Referenced to liftoff time (ignition interval).

The postflight inspection of the RSRMs revealed that the left-hand forward stiffener ring outer diameter had a radially inward axial crack (approximately 0.25 inch deep) located at 90.5 degrees (between the bolt holes) (Flight Problem STS-65-M-01).

EXTERNAL TANK

The ET loading and flight performance were excellent, and all flight objectives were satisfied. No ET in-flight anomalies were identified from the telemetry or photographic data. All ET electrical and instrumentation equipment performed satisfactorily. No LCC or OMRSD violations were identified.

No evidence of unacceptable acreage ice formation was noted during the propellant loading for STS-65. All observed icing conditions were within the historical conditions as referenced in the Ice/Debris Inspection Criteria Document (NSTS-08303). These acceptable conditions included a recurring thermal protection system (TPS) defect of a single crack in the TPS where the foam bridges between the vertical strut cable tray and fitting fairing, and this condition is caused by joint rotation at that point.

A review of the Development Test Objective (DTO) 312 post-separation 35 mm photographs taken with a 300 mm lens with a 2X extender, and the photographs from the umbilical-well-mounted 35 mm and two 16 mm cameras showed the following:

a. Two divots, approximately 6 inches in diameter with exposed substrate, were located in the LH_2 to intertank splice just outboard of the cable tray protuberance air load (PAL) ramp.

b. A shallow divot, approximately 6 inches in diameter, was located in the LH_2 CPR foam just aft of the intertank splice between the +Y bipod attachment and the LO_2 feedline support bracket.

c. Several small, 1- to 2-inch diameter, "popcorn divots" were located on the intertank stringers just forward of the bipods.

d. A small divot, 2 inches in diameter, was located on the ice/frost ramps at station 1152 and at station 1787.

All of these observations were similar to the observations from previous flights.

The ET pressurization system functioned properly throughout engine start and flight. The minimum LO_2 ullage pressure experienced during the ullage pressure slump was 14.1 psid.

The ET tumble valve was disabled as it had been for 33 of the last 34 flights. The postflight predicted impact point was approximately 36 nautical miles uprange of the preflight predicted landing point.

SPACE SHUTTLE MAIN ENGINES

All SSMEs performed satisfactorily throughout the countdown. Data 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. Engine performance during mainstage and shutdown was nominal and as predicted with cutoff times of 516.95, 517.07, and 517.20 seconds (referenced to the engine start command) for SSMEs 1, 2, and 3, respectively. The engine Isp was rated at 452.1 seconds based on trajectory data. Block II controller and software performance was satisfactory. MECO occurred 510.63 seconds after liftoff. No in-flight anomalies were identified in the data review, nor were any significant problems noted; however, the following observations were made during the review.

a. The SSME 2 high pressure oxidizer turbopump (HPOTP) intermediate seal pressure shifted upward at engine start plus 270 seconds. This shift was within the experience base and was similar to the green-run performance of this pump.

b. The SSME 1 high pressure fuel turbine (HPFT) channel B discharge temperature oscillated during the thrust bucket. This condition was previously seen on SSME no. 2019 during STS-26 and is attributed to turbine coolant flow redistribution.

c. The SSME 2 POGO pressure purge and ancillary monitor lower limit (0 psia) was violated after engine shutdown, and a failure identification (FID) was posted. The lower limit requirement has been in effect since the first flight of Block II software (STS-49). This condition was not seen before STS-65 since the propellant vacuum inert was always performed after the engine controllers were powered down. With the new vehicle software, OI-23, propellant vacuum inert is automated and may occur when the controllers are powered. Since this limit is not required, it will be eliminated for STS-66 and subsequent flights.

d. The SSME 2 digital control unit (DCU) -B reported a DCU-A power loss after engine shutdown and a FID was posted. This is a normal occurrence although the FID may not be seen in real time in the vehicle data table due to the data sample rate. The condition is seen regularly in the controller FID buffer after the post-landing memory dump.

SHUTTLE RANGE SAFETY SYSTEM

The Shuttle Range Safety System (SRSS) closed-loop testing was completed as scheduled during the countdown. All SRSS S&A devices were armed, and all system inhibits were turned off at the appropriate times. All SRSS measurements indicated that the system operated as expected throughout the launch phase. As planned, the SRB S&A devices were safed and SRB system power was turned off prior to SRB separation. The ET system remained active until ET separation from the Orbiter.

ORBITER SUBSYSTEMS

Main Propulsion System

The overall performance of the MPS was nominal with no hardware in-flight anomalies identified. STS-65 was the first flight of the MPS dump and vacuum inerting procedures developed for the OI-23 software, and performance during the dump and entry repressurization was different than expected.

Liquid hydrogen loading operations were normal through all phases of the activity. The analysis of loading system data show that the LH_2 load at the end of replenish was 231,791 lbm. Compared to the predicted load of 231,853 lbm, the loading accuracy was -0.03 percent, which is well within the required loading accuracy of ± 0.37 percent.

Liquid oxygen loading continued satisfactorily until about nine minutes after fast fill start when an overspeed indication was received from pump A127 and a LO_2 revert occurred. During the revert, pump A126 was brought on line and loading continued. The analysis of loading system data show the LO_2 load was 1,387,731 lbm. Compared to the predicted load of 1,387,828 lbm, the loading accuracy was -0.01 percent, which is well within the required loading accuracy of ± 0.43 percent.

Real-time analysis of hydrogen leak detector and hazardous gas detection system data showed no violations of the hazardous gas concentration limits. The maximum hydrogen concentration level in the Orbiter aft compartment was 95 ppm (corrected), which compares very favorably with previous data for this vehicle. Leak detector 56 and 57 indicated low sampling rates, possibly due to a line blockage. However, leak detector 57 was used as the primary detector because of the higher sampling rate. The Hydrogen Umbilical Mass Spectrometer (HUMS) served as the secondary detector.

MPS performance during ascent was nominal. The LH_2 and LO_2 pressurization and feed systems performed satisfactorily and satisfied all tank ullage pressure and SSME inlet net positive suction pressure (NPSP) requirements. Likewise, performance analyses of the propulsion systems during all phases of flight indicate nominal performance and all requirements were satisfied.

Analysis of the gaseous hydrogen (GH_2) flow control valve (FCV) performance show SSME 1 and 2 FCVs performed as expected. However, the SSME 3 FCV violated the File IX inlet pressure change requirement of 300 to 420 psid (actual inlet pressure change = 280 psid) during 11 actuation cycles. A review of data from the past two flights showed that 300 ± 20 psid is nominal performance for a FCV in the SSME 3 position. Analysis of system drawings indicate that pressure losses due to vehicle/SSME 3 plumbing layout restrict pressure differentials to lower values than SSME 1 and SSME 2. Analysis of all previous flight data support this assessment. Previous readings of 280 psid were not declared anomalous because of variations in data evaluation. Consequently, SSME 3 FCV performance was nominal, and a File IX change is being made to change the allowable differential pressure band for SSME 3.

The LH_2 manifold pressure unexpectedly increased to a maximum pressure of 17 psia following the vacuum inerting procedure (Flight Problem STS-65-V-08). An initial pressure rise rate was evident as the solid hydrogen changed to a liquid. The pressure rise rate increased as liquid hydrogen started to boil-off to a gaseous state. A third change in the rise rate corresponded to the OMS-2 firing which caused solid and liquid hydrogen to come in contact with the "warm" feedline walls and rapidly flash off to gas. Postflight analysis of the MPS dump/vacuum inert performance indicated that this first use of the new OI-23 software automated dump sequence resulted in a lower amount of residual hydrogen after the dump (estimate of 2 lb, which is lowest in flight history). However, preflight predictions from the MPS Propellant Dump model has indicated that residuals after the dump should have been less than 1 lbm (about 0.3 lbm). Since the residuals were greater than the predicted value, the 5-minute coast time between dump and vacuum inert was insufficient to allow all of the solid hydrogen to sublimate to gas. This resulted in the hydrogen residual after the vacuum inerting that caused the observed manifold pressure increase.

The evaluation of the dump performance also indicated that all the helium that was budgeted to be introduced into the LH_2 system via the return-to-launch-site (RTLS) repressurization valves did not enter the manifold as approximately 50 percent was blown out of the manifold relief valve. An evaluation is being made to determine the corrective actions that would eliminate the residuals.

Once the manifold pressure reached its peak value of 17 psia, it quickly began decaying and reached ambient pressure in approximately 90 minutes. This observed leak rate corresponded to a system leakage on the order of 7,000 scim. This leak rate was higher than expected (also higher than allowable for a decay rate at ambient temperatures), but it did not exceed the system leak rate at cryogenic temperatures. Troubleshooting at KSC identified a seal leak in SSME 2 that may have been a significant contributor to the on-orbit leak. No out-of-specification leaks were noted in the MPS hardware.

During the 650-second entry purge, the helium usage was 59.37 lbm, and the requirement for OV-102 is 55.7 ± 1.1 lb (Flight Problem STS-65-V-09). STS-65 was the first flight of the operational increment (OI) -23 software and therefore, the first use of the automated MPS helium system entry configuration that is a part of OI-23. On all flights since STS-26, only the SSME 1, 2, and 3 helium supply A-leg isolation valve have been opened during entry. In this configuration, helium for the blowdown purge and manifold repressurization was provided only through the SSME 2 helium supply A-leg regulator (through the SSME 2 crossover valve). In OI-23, the SSME 1, 2, and 3 helium supply A- and B-leg isolation valves, as well as the pneumatic system isolation valves, are opened for entry. This configuration allows three regulators (SSME 2A and 2B and the pneumatic system regulators) to supply helium for the blowdown purge and manifold repressurization. As a result, the helium pressure being provided for the blowdown remained approximately 100 psi higher than the average single-regulator pressure, thus providing a greater mass flow during the purge. Analysis indicates that approximately 3 to 4 lbm more helium consumption should be expected when using the OI-23 software. Adding 4 lbm to the nominal OV-102 flow of 55.7 lbm results in a consumption very close to the 59.37 lbm that was used during STS-65.

As a result of the STS-65 mission findings, the File IX requirement will be modified to specify the expected consumption for each vehicle with the OI-23 entry configuration including the 3-sigma values that are calculated with all the data available since STS-26.

Reaction Control Subsystem

The performance of the RCS was satisfactory. RCS propellant consumption for the mission totaled 5,036.5 lbm. The RCS was not interconnected to the OMS during this mission.

At 196:11:58 G.m.t. (06:19:15 MET), the crew reported that while reconfiguring the RCS from the A to the B helium regulators, the left RCS B event indicator (talkback) as well as the A event indicator showed barberpole when the B switch was taken from CLOSE to GPC. The procedure was repeated later in the flight and no anomalous indications were noted visually or in the data. During postflight crew debriefings, the talkback was reported to be present only momentarily and only after moving the B switch from GPC to OPEN. This condition is consistent with previous occurrences of valve bounce caused by a pneumatic hammer effect.

At 199:09:14:20 G.m.t. (09:16:31:20 MET), vernier thruster R5D was failed off by the RM because of low chamber pressure (Flight Problem STS-65-V-05). On the failed pulse, the chamber pressure initially went to 25.7 psia. A nominal pulse from this thruster, which showed no signs of degraded chamber pressure due to combustion residue or iron nitrate contamination, occurred 9 seconds earlier. The thruster was hot-fired per flight rule 6-31, and the performance was nominal with no evidence of degraded chamber pressure. The RM was cleared and the vernier thrusters were reselected. The thruster was successfully fired several hundred times during the remainder of the mission. The engineering community determined the failure was most likely in the reaction jet driver (RJD), the multiplexer/demultiplexer (MDM), or the wiring between the two boxes. A bite status read (BSR) was performed to verify the MDM, and it was all zeros, indicating the MDM probably performed as designed during this period. Extensive ground testing, which included trickle currents, wire wiggles, demating and inspecting connectors as well as hi-pot testing failed to reproduce the anomaly.

Orbital Maneuvering Subsystem

The OMS performed very satisfactorily during the four firings, and 13,694.9 lbm of propellants were consumed during the 355.78 seconds of firing on each engine. Data showed that all oxidizer probes for the quantity gauging system operated satisfactorily, but only the left aft fuel probe was operating properly. The following table provides data concerning the OMS firings.

OMS FIRINGS

OMS firing	Engine	Time, G.m.t./MET	Firing duration, seconds	ΔV, ft/sec
OMS-2	Both	189:17:22:55:2 G.m.t. 000:00:39:55.2 MET	141.3	221.8
OMS-3	Both	203:12:47:44.1 G.m.t. 013:20:04:44.1 MET	32.1	51.0
OMS-4	Both	203:13:32:42.2 G.m.t. 013:20:49:42.2 MET	30.4	49.1
Deorbit	Both	204:09:40:38.3 G.m.t. 014:16:57:38.3 MET	152.8	255.3

A bias was noted in the right OMS aft fuel quantity gage during the deorbit maneuver. The quantity gage was reading approximately 15 percent higher than expected. This condition did not impact the mission.

Power Reactant Storage and Distribution Subsystem

The STS-65 mission was the fourth flight of the Extended Duration Orbiter (EDO) pallet. The power reactant storage and distribution (PRSD) subsystem performed in a nominal manner throughout the mission with no anomalies or problems noted. A total of 4911 lbm of oxygen and 593 lbm of hydrogen were consumed during the mission. A total of 204 lbm of the oxygen usage was for crew breathing. Consumable oxygen and hydrogen remaining at landing would have provided a mission extension of 47 hours at an average power level of 18.8 kW.

Fuel Cell Powerplant Subsystem

The fuel cell powerplant (FCP) subsystem performance was nominal with no anomalies or problems identified. The fuel cells consumed 4706 lbm of oxygen and 593 lbm of hydrogen in producing 6660 kWh of power at an average power level of 18.8 kW and load of 631 amperes. The fuel cells produced 5299 lbm of water during the mission. Eight purges were performed, occurring at approximately 19, 81, 127, 175, 222, 268, 322, and 347 hours MET. On the previous mission that used these fuel cells, purge intervals of 72 hours were achieved; however, on this mission the purge intervals were approximately 48 hours. The loads on the fuel cells for this mission were higher than on the previous mission, and this contributed to the more rapid performance decay.

During the postlanding inert purging of the fuel cells, the oxygen manifold pressure decayed at an unacceptable rate. Excessive leakage was measured from the oxygen purge port. The leak was isolated to fuel cell 3, and a steady 100-sccm leak rate was measured with an increase to 400 to 500 sccm leakage rate every 8 to 11 seconds. As a result, the fuel cell (S/N 122) will be replaced prior to the next flight.

Also during postlanding operations at KSC, the fuel cell 2 coolant pressure increased for an unknown reason from 65.3 psia to 73.2 psia. The fuel cell was depressurized and then repressurized, and again the same signature was observed. The fuel cell is designed to vent when the coolant pressure reaches 70 psia. This is the first time this behavior has been observed during the Space Shuttle Program and the behavior is unexplained. As a result, fuel cell 2 (S/N 121) will also be replaced.

Auxiliary Power Unit Subsystem

The APU subsystem performed nominally with no anomalies noted. The APUs were shut down after landing in the APU 2, APU 1, and APU 3 order to fulfill the requirements of DTO 414. APU fuel consumption and run time are shown in the following table.

Flight phase	APU 1	(S/N 409)	APU 2	(S/N 308)	APU 3	(S/N 408)
	Time, min:sec	Fuel consumption, lb	Time, min:sec	Fuel consumption, lb	Time, min:sec	Fuel consumption, lb
Ascent	20:58	48	20:45	53	21:05	50
FCS checkout	7:14	18				
Entry[a]	64:57	120	82:13	176	64:59	124
Total	93:09	186	102:58	229	86:04	174

[a] APUs ran for approximately 20 minutes 12 seconds after main gear touchdown.

APU 2 had one gearbox repressurization as the gearbox gaseous nitrogen (GN_2) pressure reached approximately 6.2 psia. Also, the APU 2 drain line pressure decayed from 16 psia to 9.2 psia during the course of the 15-day mission. Neither of these conditions were cause for concern.

Hydraulics/Water Spray Boiler Subsystem

The hydraulics/water spray boiler (WSB) subsystem performed very satisfactorily throughout the mission. No power drive unit (PDU) backdriving was observed in the data as a result of the APU shutdown order (APU 2, APU 1, and APU 3) that was performed in support of DTO 414. No problems or anomalies were noted in the data review. One item of interest from this mission was that the total number of circulation pump runs was the highest of any mission (279) in the Space Shuttle Program.

Electrical Power Distribution and Control Subsystem

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

Environmental Control and Life Support Subsystem

The active thermal control subsystem (ATCS) performed nominally with no problems or anomalies identified. The flow proportioning valves on Freon coolant loops 1 and 2 were switched to the payload position at 189:19:23 G.m.t. (00:02:40 MET) and 190:16:08 G.m.t. (00:23:25 MET), respectively, to support Spacelab cooling requirements. Both loops were returned to the interchanger position at 203:03:46 G.m.t (13:11:03 MET) after Spacelab deactivation.

The radiator cold-soak provided cooling during entry through landing plus 11 minutes when ammonia boiler system B was activated using the secondary B controller. System B operated for 40 minutes and was depleted entirely. Ground cooling was established at 204:11:33 G.m.t., 55 minutes after landing.

Water was managed through the use of the FES for supply water because of a supply-water dump-nozzle-icing anomaly discussed on the following page. Three supply water dumps were performed at an average rate of 1.52 percent/minute (2.5 lb/minute). The supply water dump line temperature was maintained between 74 and 112 °F throughout the mission with the operation of the line heater.

At 192:07:28 G.m.t. (02:14:45 MET), supply water dump 3 was performed. Data indicated a sharp decrease in nozzle temperatures to 50 °F at which time the dump was terminated (Flight Problem STS-65-V-02). At the same time, a corresponding decrease in the waste dump-nozzle temperatures was also observed. The heaters were kept on and the subsequent nozzle bakeout was erratic, indicating the presence of ice in the nozzle area. A purge of the dump line using the free fluid wand was performed to prevent hardware damage. Based on the dump time during the temperature decrease, it was estimated that up to two gallons of water were frozen. A total of 13 nozzle bakeouts were performed to melt the ice. After both the nozzle heat-up and cool-down times were identical and nozzle temperatures approached previous levels, the first waste water dump was initiated at 193:16:49 G.m.t. (04:00:06 MET) and completed successfully at 193:17:38 G.m.t (04:00:55 MET). Supply water was dumped through the FES for the remainder of the mission. Detailed postflight inspections of the nozzle area show that the tile surrounding the OV-102 nozzles was scalloped to achieve the proper nozzle protrusion, and the nozzle and surrounding room temperature vulcanizing (RTV) material show evidence of deterioration.

Waste water was gathered at approximately the predicted rate. The waste water dump line temperature was maintained between 53 and 81 °F throughout the mission. Three waste water dumps were performed. The first dump had an average flow rate of 1.95 percent/minute (3.2 lb/minute). The second waste water dump was initiated at 198:06:33 G.m.t. (08:13:50 MET) and was performed in three segments. During the second segment, which dumped the waste tank from 42 to 26 percent over a 10.5-minute period, the dump rate degraded. The rate was 2.03 percent/minute during the first 3 minutes and degraded to 1.11 percent/minute by the end of this segment of the dump. The waste tank pressure increased slightly during this segment, which is indicative of blockage. There was no evidence of ice on the dump nozzle. During the first and third dump segments, the rate was a nominal 1.8 to 1.9 percent/minute.

At 202:05:39 G.m.t. (12:12:56 MET), the third waste water dump was initiated. The dump was performed in seven segments, each lasting 5 to 7 minutes before the minimum temperature limits were reached, and the dump rates were degraded to the 1.2 to 1.4 lb/hr rate (Flight Problem STS-65-V-06). At the end of the third waste water dump, enough ullage was available to reach end-of-mission plus 39 hours.

The EDO waste collection system (WCS) performed adequately; however, three anomalies were identified and these are discussed in the following paragraphs. The WCS was removed postflight and sent to the vendor for cleaning and refurbishment.

At approximately 190:13:09:45 G.m.t. (00:20:26:45 MET), the EDO WCS commode fault light indicated a problem during the third compaction cycle (Flight Problem STS-65-V-03A). Data indicated that the compactor piston had stopped approximately at the bottom of the transport tube, or midway in the retraction stroke. The crew inspected the transport tube for hardware damage and found none, and they reported that the piston was down approximately 7 to 8 inches inside the transport tube with the previously compacted bag hovering approximately 5/8 of the way down in the compactor canister. The compactor piston was manually rotated downward approximately seven turns, and the piston was then retracted into the compactor housing with no binding noted. Also, an inspection for damage showed none. The crew configured the system for normal operations, and the commode compactor operations were nominal for the remainder of the mission.

Late in the flight day 3 activities, the crew reported that they experienced difficulty in replacing the commode odor/bacteria filter during the scheduled changeout (Flight Problem STS-65-V-03B). During flight day 4, another crewmember examined the filter and reported that the filter was out of tolerance, but it could be forced into position. However, a different spare filter was installed at that time. During flight day 12 activities, the crew installed the out-of-tolerance filter using some surgical lubricant on the grommet along with one crewmember pushing the filter and another crewmember twisting the filter.

On flight day 6, the crew reported smelling odors whenever the commode was running. The crew changed the commode odor/bacteria filter and installed a charcoal filter in the atmospheric revitalization system (ARS) in place of the LiOH filter; the situation was improved to some degree. The next day, the crew changed the EDO plenum filter and reported that the odors were eliminated.

At 202:15:36:43 G.m.t. (12:22:53:43 MET), WCS fan separator 1 exhibited an unusual signature and the crew reported a gurgling noise and odor from fan separator 1 during operation (Flight Problem STS-65-V-3C). Data indicated liquid was still in the bowl when the fan separator shut down. Two fan separator cycles were immediately performed, and the separator rpm did not reach the normal speed during either cycle. On the third cycle, the urinal fan shut down three minutes before the separator turned off. This caused the urinal fault light to illuminate. Following this occurrence, the crew switched to fan separator 2, which was used for the remainder of the mission. During postflight activities on the day following landing, liquid backflow from the waste tank through the check valves occurred when the water tanks were repressurized for supply water sampling. A four-gallon reduction of the waste water quantity was noted, and water overflowed into the middeck area. The middeck area was cleaned and disinfected.

The ARS performed satisfactorily throughout the mission.

Smoke Detection and Fire Suppression Subsystem

The smoke detection system showed no indications of smoke generation during the flight. However, the left flight deck smoke detector concentration indication dropped off-scale low for two seconds, followed 14 seconds later by negative spikes for a period of five seconds (Flight Problem STS-65-V-10). Also, after landing, a master alarm was received from the left flight deck smoke detector with no concentration change observed in the data. Data evaluation has not shown the cause of these momentary drops. Use of the fire suppression system was not required.

Airlock Support System

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

Avionics and Software Support System

The integrated guidance, navigation and control system performed nominally. STS-65 was the first flight of the OI-23 software and its performance was nominal. One issue was noted and it is discussed in the Main Propulsion System section of this report. No in-flight anomalies were noted in the system.

All five programmed test inputs (PTIs) for DTO 251 (Entry Aerodynamic Control Surface Test - Alternate Elevon Schedule) (Part 7) were executed. The subsonic maneuver for DTO 254 (Subsonic Aerodynamics Verification) was also successfully performed.

The flight control subsystem performed nominally. The aft RCS vernier thruster R5D failed off and the cause is believed to be an anomaly in the reaction jet driver, the multiplexer/demultiplexer, or the wiring between these components. This anomaly is discussed in the Reaction Control Subsystem section of this report.

IMUs 2 and 3 operated properly; however, the flight software issued an IMU 1 redundant rate fail at 199:12:36:12.7 G.m.t. (09:19:53:12.7 MET) and one second later, RM declared IMU 1 failed and deselected it (Flight Problem STS-65-V-04). Examination of the filtered redundant gyro monitor data, which is used by the general purpose computer (GPC) to determine the failure, indicated that the data were in excess of the fail limit of 0.7 deg/hr for a period of 22 seconds, which is consistent with the redundant rate fail. Data also showed that the frequency and length of these BITEs continued to increase; however, the platform values returned to normal values after the BITE cleared. Late in the mission, the drift during transients was as great as 30 sigma with the longest BITE lasting 93 minutes. On flight day 13, data from one of the events showed a platform drift of 0.08 degree, and as a result, the Flight Control Team invoked Flight Rule 8-39, and IMU 1 was declared failed for entry planning purposes. Prior to entry at 204:03:34 G.m.t. (14:10:51 MET), IMU 1 was moded to standby for 13 minutes and back to operate in an attempt to recover nominal operation. The IMU continued operating as noted previously and was realigned periodically to assure that platform misalignments caused by drift transients did not exceed RM thresholds. An agreement was reached to leave all three IMUs selected for entry and to allow RM software to control IMU selection during entry. IMU 1 operated satisfactorily with no BITE indications during entry. The IMU was removed from the vehicle and has been sent to a ground-test facility.

The star tracker performance was nominal as was the data processing system (DPS) hardware and flight software.

The displays and controls subsystem performed nominally.

At 203:06:55 G.m.t. (013:14:12 MET), the aft port payload bay floodlight was cycled on, but the light did not illuminate. Data indicate arcing due to loss of backfill in the floodlight. The light will be replaced during turnaround operations.

Communications and Tracking Subsystems

The communications and tracking subsystems performed nominally.

During prelaunch operations, the FM system 1 transmitter exhibited output-power fluctuations between 14 and 16 watts (16 watts nominal). FM system 1 was used for ascent and it performed nominally. On-orbit, the FM system 1 transmitter again exhibited fluctuating transmitter output power with no degradation in the data noted. However, FM system 2 was selected and used for the remainder of the mission.

Operational Instrumentation/Modular Auxiliary Data System

The operational instrumentation (OI)/modular auxiliary data system (MADS) subsystems performed adequately. Two in-flight anomalies were noted and are discussed in the following paragraphs.

At approximately 191:12:30 G.m.t. (01:19:47 MET), the go-to-mark command was sent to the system control module (SCM) for execution. The SCM executed the command which positions the Orbiter Experiments (OEX) recorder to a pre-determined point for recording data. At 191:21:08 G.m.t. (02:04:25 MET), the go-to-mark command was again sent to the SCM for execution. The commands were verified, but the commands were not executed by the SCM. The SCM was power cycled and the go-to-mark command was again commanded without success (Flight Problem STS-65-V-01). With the SCM malfunction, all OEX on-orbit and entry data were lost. Postlanding, the battery board was removed and a power cycle was commanded to the SCM, and successful SCM operations were restored. After the recorded data were dumped, the lockup condition was reproduced with the battery board removed using the same redundant command sequence as used on-orbit. This test proved that the battery board was not at fault. As a result, a Shuttle Operational Data Book (SODB) addition will be made to document the command sequence limitations.

At 201:00:34 G.m.t. (011:07:51 MET), poor quality dump data were received from track 2 of Operations (OPS) recorder 2 while dumping at the 8:1 ratio and was evident in both the forward and reverse directions through Ku-band channel 2 (Flight Problem STS-65-V-07). Good quality data were received when dumping at the 1:1 ratio through a ground site. As a result, OPS recorder 2 (tracks 3 through 14) was used as an acquisition of signal (AOS) recorder for the remainder of the mission. The postlanding dump of track 2 of this recorder through the T-O umbilical at both 8:1 and 1:1 was not successful. Track 2 was re-recorded in both directions and was then dumped. Degraded data quality was again observed in both directions with the reverse direction worse than the forward direction. The recorder was removed and sent to the NASA Shuttle Logistics Depot (NSLD) to verify the failure. With positive verification from NSLD of the problem, the hardware will be sent to the vendor for failure analysis and repair.

Structures and Mechanical Subsystems

The structures and mechanical subsystems performed satisfactorily during the mission. The landing and braking data are shown in the table on the following page.

The drag chute was deployed nominally at 204:10:38:08.0 G.m.t., approximately 8 seconds after touchdown and 10 seconds prior to nose gear touchdown. The drag chute operated properly and was jettisoned 24.6 seconds after deployment at a ground speed of 52.9 knots.

Landing and Braking Parameters

Parameter	From threshold, ft	Speed, keas	Sink rate, ft/sec	Pitch rate, deg/sec
Main gear touchdown	3025	199.2	~ 3	N/A
Nose gear touchdown	8313	131.6	N/A	4.90

Brake initiation speed	110.0 knots (keas)
Brake-on time	44.4 seconds
Rollout distance	10,211 feet
Rollout time	68 seconds
Runway	33 (Concrete) KSC
Orbiter weight at landing	229,308 feet

Brake sensor location	Peak pressure, psia	Brake assembly	Energy, million ft-lb
Left-hand inboard 1	960	Left-hand outboard	18.04
Left-hand inboard 3	1140	Left-hand inboard	15.80
Left-hand outboard 2	1080	Right-hand inboard	17.96
Left-hand outboard 4	1164	Right-hand outboard	20.75
Right-hand inboard 1	876		
Right-hand inboard 3	888		
Right-hand outboard 2	960		
Right-hand outboard 4	960		

Integrated Aerodynamics, Heating and Thermal Interface

The ascent and entry aerodynamics were nominal with no problems, anomalies, or unexpected conditions identified in the data. Approximately 57 seconds after liftoff, a large condensation cloud was observed, and the cloud has been attributed to the vehicle interaction with the moist atmosphere. The expansion of the flow field caused the creation of an ice crystal cloud, which was no safety threat to the mission.

During entry, DTO 251 Part 7 - Entry Aerodynamic Control Surfaces Test - Alternate Elevon Schedule was conducted. All five of the planned PTIs were completed. Also during entry, DTO 254 Part 2 - Subsonic Aerodynamics Verification was conducted during final approach at a velocity of Mach 0.55. The preliminary analysis of this DTO shows the vehicle response compares well with that predicted from the Ames Vertical Motion Simulator (VMS).

The aerodynamic and plume heating during the ascent phase of the mission was nominal, based on the evaluation of vehicle telemetry data and the physical appearance of the plumes. The entry aerodynamic heating was nominal, but heating calculations are continuing. No OEX entry data are available for evaluation because of the failure of the MADS recorder.

The performance of the thermal interfaces was nominal with all temperatures within limits.

Thermal Control Subsystem

The thermal control system performance was nominal and all Orbiter subsystem temperatures were maintained within acceptable limits.

Aerothermodynamics

The entry acreage and local heating were within limits. All structural temperatures were nominal, the TPS damage was within experience, and the trajectory and control surface parameters were nominal. The potential for a structural over-temperature condition was indicated from the TPS damage on the leading edge of the left-hand OMS pod. There was no elevon cove overheating. However, the lack of MADS data prevents a detailed analysis of this area.

Thermal Protection Subsystem

The TPS performed satisfactorily. Based on structural temperature response data (temperature rise), the entry heating was slightly below average. Peak temperatures were also below average and at or near a minimum for this vehicle in some locations, indicating relatively low pre-entry temperatures. Boundary layer transition from laminar to turbulent flow could not be determined because of the failure of the OEX recorder system control module.

Based on preliminary data from the runway inspection, overall debris damage was above average. Preliminary data showed 86 impacts on the lower surface of the vehicle (average = 93 hits), and the number of impacts with a major dimension of 1 inch or greater was 18 (average = 15). The most notable damage site on the vehicle was located on the leading edge of the OMS pod, where the damage measured 6 inches by 3 inches by 2 inches. This damage site extended down into the densified layer of the tile.

The nose cap and "chin panel" tile areas were in good condition. The chin panel to nose cap gap filler was in excellent condition. The gap at this location was nominal.

The left-hand main landing gear door (MLGD) thermal barriers (old, bonded design) had extensive breaching on the forward and aft ends. The right-hand MLGD thermal barriers (new, mechanically attached design) were damaged in several areas, and six barrier segments will be replaced. An Ames gap filler was protruding just forward of the right-hand MLGD. The elevon cove area was in good condition with no abnormalities that could be related to the DTO 251 up-elevon schedule. One large impact damage site on the right-hand inboard elevon will result in replacement of the elevon. Two tiles on the lower leading edge structural system (LESS) panel 8 had damaged corners, local tile glazing, and hardened "horse collar" gap fillers. Discoloration was noted to be more than usual on the upper inboard elevons, but the felt reusable surface insulation (FRSI) was still resilient. No obvious TPS damages or configuration problems were noted on the TPS surrounding the left-hand water/urine dump ports.

The ET door thermal barriers were in nominal condition overall. A left-hand ET door hinge-line tile sustained a large area of damage on the lip of the tile.

The engine dome-mounted heatshield blankets were damaged in the following areas:

a. SSME 1 from 5 to 7 o'clock;
b. SSME 2 at 3 o'clock; and
c. SSME 3 at 1 o'clock.

Base heat shield tile peppering was normal. Also, drag chute deployment caused no tile damage. Windows 3 and 4 exhibited moderate-to-heavy hazing, and windows 2 and 5 exhibited light-to-moderate hazing. Only a light haze was present on the other windows.

REMOTE MANIPULATOR SYSTEM

The remote manipulator system (RMS) was not flown on the STS-65 mission.

FLIGHT CREW EQUIPMENT/GOVERNMENT FURNISHED EQUIPMENT

The flight crew equipment performed adequately. Anomalies that occurred in the flight crew equipment are discussed in the following paragraphs.

The crew reported at 191:14:39 G.m.t. (01:21:56 MET) that the Arriflex camera (16 mm) film magazine (S/N 1016) had jammed (Flight Problem STS-65-F-01). The malfunction procedure to clear the jam was performed successfully; however, the jam recurred a short time later. The film magazine was replaced and normal operation was restored. The failed magazine was stowed and returned for postflight analysis.

The crew reported at 192:23:33 G.m.t. (03:06:50 MET) that the 70 mm Hasselblad camera had jammed and the lens could not be removed (Flight Problem STS-65-F-02A). The crew performed two IFM procedures in an unsuccessful attempt to restore normal camera operation. Additional procedures were called up to the crew, and the crew was able to restore normal operations using these procedures. However, the shutter control button came apart on the camera, and a small spring and retaining ring were lost on the flight deck while repairing the camera (Flight Problem STS-65-F-02B). At 193:00:44 G.m.t. (03:17:49 MET), the crew reported that the camera had jammed again and the lens could not be removed. The crew was able to remove the lens from the body using an IFM procedure after which the crew determined that neither the lens nor the body were working properly. As a result, the camera and lens were stowed for the rest of the mission.

Closed circuit television (CCTV) camera D experienced intermittent degradation of the horizontal synchronization (Flight Problem STS-65-F-03). This condition caused the NASA Ground Terminal to lose lock, which in turn resulted in color shifting (tearing) of the picture.

At 195:22:20 G.m.t. (06:05:37 MET), the crew reported that the left-aft fastener (from crewperson perspective) on the ergometer failed (Flight Problem STS-65-F-04). The crew exchanged the positions of the failed left-aft fastener and the right-forward fastener. The failed fastener had several threads remaining that allowed its use in the right-forward position. As a result, the ergometer was usable for the remainder of the mission.

The crew reported that the galley rehydration station (RHS) did not dispense cold water, but hot water was dispensed normally (Flight Problem STS-65-F-05). After galley power was cycled, the galley dispensed 1/2 ounce of cold water when either the 8-ounce or 7.5-ounce dispense quantities were selected. The crew performed an additional malfunction procedure, and normal operation was restored for the remainder of the mission.

CARGO INTEGRATION

Integration hardware performance was nominal throughout the mission with no anomalies recorded.

DEVELOPMENT TEST OBJECTIVES/DETAILED SUPPLEMENTARY OBJECTIVES

A total of 16 development test objectives (DTOs) and 16 detailed supplementary objectives (DSOs) were assigned to the STS-65 mission. Data were collected on 15 of the 16 DTOs, and on all 16 DSOs. The following paragraphs discuss the results, if known, for each DTO and DSO.

DEVELOPMENT TEST OBJECTIVES

DTO 251 - Entry Aerodynamic Control Surfaces Test - Alternate Elevon Schedule (Part 7) - All five of the planned PTIs were performed. The preliminary analysis of these data show the vehicle response compares well with that predicted from the Ames VMS. Data have been given to the sponsor for evaluation, and the results will be reported in separate documentation.

DTO 254 - Subsonic Aerodynamics Verification (Part 2) - The subsonic maneuver was performed during the final approach to landing. The data were given to the sponsor for evaluation. Initial results indicate that the aileron and rudder inputs were as expected. The final results of this DTO will be published in separate documentation.

DTO 301D - Ascent Structural Capability Evaluation - This was a data-only DTO and data were collected for this DTO. The data were given to the sponsor for analysis and evaluation. The results of the evaluation will be published in separate documentation.

DTO 307D - Entry Structural Capability Evaluation - This was a data-only DTO and data were collected for this DTO. The data were given to the sponsor for analysis and evaluation. The results of the evaluation will be published in separate documentation.

DTO 312 - ET TPS Performance (Methods 1 and 3) - A total of 38 frames of photographic data were obtained of the ET after separation. A 35 mm Nikon camera with a 300 mm lens and a 2X extender (Method 3) were used to photograph the ET. The exposure of the ET is good on 26 frames and the rest are in deep shadow. The focus is variable, and timing data are on the film. The pictures were taken between 189:16:57:45 G.m.t. and 189:17:07:40 G.m.t. (00:00:14:45 MET and 00:00:24:40 MET).

The ET appeared to be in very good shape with no divots visible. On frame 9, a bright area to the left of the right SRB forward attach point appears to be caused by sun glint. A red spot is detectable in a charred area below the nose cone on three frames. Discussions with the ET contractor indicate that this area may have been sanded. Additional analysis will be performed by the ET contractor.

In addition to the 35 mm photographic data, 43 seconds of video of the ET (after separation) were downlinked by the crew. No anomalies on the ET surface or TPS were detected; however, the exposure of the ET is dark. Also, motion or jitter of the ET hampered analysis. The aft dome, +X, -Y, and -Z areas of the ET were imaged. Typical charring on the ET aft dome is visible.

DTO 319D - Orbiter/Payload Acceleration and Acoustics Environment Data - This was a data-only DTO, and data were recorded for this DTO. The data have been given to the sponsor for evaluation. The results of the evaluation will be published in separate documentation.

DTO 414 - APU Shutdown Test (Sequence A) - The APUs were shutdown in the proper sequence (APU 2, APU 1, and APU 3). Data evaluation showed no indication of PDU backdriving. This DTO will continue to be performed until two sequence A's (APU 2, APU 1, and APU 3 in that order) and two sequence B's (APU 3, APU 1, and APU 2 in that order) have been completed.

DTO 623 - Cabin Air Monitoring - All scheduled activities were completed by the crew, and the data have been given to the sponsor for evaluation. The results of the evaluation will be published in separate documentation.

DTO 655 - Foot Restraint Evaluation - The crew collected data for this DTO and the data have been given to the sponsor for evaluation. The results of the evaluation will be published in separate documentation.

DTO 663 - Acoustic Noise Dosimeter Data - All scheduled data takes were performed by the crew, and the data have been given to the sponsor for evaluation. The results of the evaluation will be published in separate documentation.

DTO 665 - Acoustic Noise Sound Level Data - All scheduled data takes were performed by the crew, and the data have been given to the sponsor for evaluation. The results of the evaluation will be published in separate documentation.

DTO 667 - Portable In-Flight Landing Operations Trainer - The scheduled sessions with the Portable In-Flight Landing Operations Trainer (PILOT) were completed by the assigned crewmembers.

DTO 674 - Thermo-Electric Liquid Cooling System Evaluation - All scheduled activities in support of this DTO were completed, and the data have been given to the sponsor for evaluation. The results of the evaluation will be published in separate documentation.

DTO 682 - Inertial Vibration Isolation System - The inertial vibration isolation system (IVIS)/cycle ergometer exercise sessions were successfully completed by the crewmembers. The IVIS received favorable comments from the crew throughout the flight. During an exercise session on flight day 6, the crew reported that a fastener on the cycle ergometer hardware had failed. The crew was able to exchange the failed fastener with another fastener that required less threads, thereby making the cycle/ergometer usable for the rest of the mission.

DTO 805 - Crosswind Landing Performance - This DTO of opportunity was not performed because of the low wind conditions at KSC.

DTO 913 - Microgravity Measurement Device - The Microgravity Measurement Device (MMD) was used to record vibrations during a variety of experiment operations including the cycle/ergometer when it was hard mounted for one session and mounted with the IVIS for the remainder of the sessions. The data files were down linked using the portable audio data modem (PADM). The data have been given to the sponsor for the evaluation, and the results of the evaluation will be published in separate documentation.

DETAILED SUPPLEMENTARY OBJECTIVES

DSO 314 - OV-102 Acceleration Data Collection - The objective of DSO 314 was to acquire high resolution accelerometer package (HiRAP) data to further characterize the low-frequency acceleration environment in the Orbiter that results from crew activities and vehicle operations. The planned data-collection periods included the crew push-off load test, a vehicle attitude deadband change from 1.0 degree to 0.5 degree, and six crew exercise sessions on the ergometer, which was used with the newly developed IVIS. The HiRAP operations were controlled by uplink commands routed through the SCM, which also controlled by OEX recorder that recorded the HiRAP data. The SCM experienced an anomaly on flight day 3 that precluded further operation of the HiRAP and recorder. Data from three of the six crew exercise periods were obtained prior to the failure. Attempts to revive the SCM were unsuccessful; consequently, no other data could be obtained.

DSO 326 -Window Impact Observation - All scheduled observations of the windows were made, and the data have been given to the DSO sponsor. No impacts of any significance were found, and no windows will require replacement.

DSO 484 - Assessment of Circadian Shifting in Astronauts by Bright Light - This DSO was performed during the preflight and postflight activities. The results of this DSO have been given to the sponsor for evaluation, and the results of the evaluation will be published in separate documentation.

DSO 485 - Inter Mars Tissue Equivalent Proportional Counter - The Inter Mars Tissue Equivalent Proportional Counter (ITEPC) collected radiation data throughout the flight. These data have been given to the sponsor for evaluation, and the results of the evaluation will be reported in separate documentation.

DSO 487 - Immunological Assessment of Crewmembers - Data were collected for this DSO during the prelaunch and postflight periods. These data have been given to the sponsor for evaluation, and the results of the evaluation will be reported in separate documentation.

DSO 491 - Characterization of Microbial Transfer Among Crewmembers During Spaceflight - Data were collected for this DSO during the prelaunch and postflight periods. These data were given to the sponsor for evaluation, and the results of the evaluation will be reported in separate documentation.

DSO 603 - Orthostatic Function during Entry, Landing and Egress - Data were collected for this DSO, and these data have been given to the sponsor for evaluation. The results of the evaluation will be published in separate documentation.

DSO 604 - Visual-Vestibular Integration as a Function of Adaptation - Data were collected for this DSO, and these data have been given to the sponsor for evaluation. The results of the evaluation will be published in separate documentation.

DSO 605 - Postural Equilibrium Control During Landing and Egress - Data were collected for this DSO during the landing and egress activities. These data were given to the sponsor for evaluation, and the results of the evaluation will be published in separate documentation.

DSO 608 - Effects of Space Flight on Aerobic and Anaerobic Metabolism During Exercise - Operational exercise sessions were completed throughout the flight by all crewmembers. Exercise start and stop times were reported to coordinate with the SAMS experiment and the MMD (DTO 913). The Commander, Pilot, and Mission Specialist 2 participated in DSO 608. All sessions were completed. The last DSO 608 session scheduled for the Pilot was performed with the ergometer hard mounted. The data from these operations have been given to the sponsor for analysis. The results of that analysis will be published in separate documentation.

DSO 610 - In-Flight Assessment of Renal Stone Risk - All scheduled activities in support of this DSO were completed, and the data have been given to the sponsor for evaluation. The results of the evaluation will be published in separate documentation.

DSO 614 - The Effect of Prolonged Space Flight on Head and Gaze Stability. Data were collected during the prelaunch and postflight periods in support of this DSO. These data have been given to the sponsor for evaluation, and the results of the evaluation will be published in separate documentation.

DSO 626 - Cardiovascular and Cerebrovascular Responses to Standing Before and After Space Flight - Data were collected during the prelaunch and postflight periods, and these data were given to the sponsor for evaluation, and the results of the evaluation will be reported in separate documentation.

DSO 901 - Documentary Television - All scheduled activities in support of this DSO were completed. The video data have been given to the sponsor for evaluation, and the results of that evaluation will be reported in separate documentation.

DSO 902 - Documentary Motion Picture Photography - All scheduled activities in support of this DSO were completed. The photographic data have been given to the sponsor for evaluation, and the results of that evaluation will be reported in separate documentation.

DSO 903 - Documentary Still Photography - All scheduled activities in support of this DSO were completed. The photographic data have been given to the sponsor for evaluation, and the results of that evaluation will be reported in separate documentation.

PHOTOGRAPHY AND TELEVISION ANALYSIS

LAUNCH PHOTOGRAPHY AND VIDEO DATA ANALYSIS

The STS-65 mission was launched from Complex 39 A on July 8, 1994. On launch day, 24 videos of the launch activities were screened and no anomalies were noted. Following the launch day screening activities, 53 of 54 planned films were also screened. One camera failed and the film was lost. No anomalies were noted in the review of the video and photographic data.

ON-ORBIT PHOTOGRAPHY AND VIDEO DATA ANALYSIS

No significant on-orbit video or photographic recorded events were observed that required analysis. Video and photographic data from DTO 312 were evaluated.

LANDING PHOTOGRAPHY AND VIDEO DATA ANALYSIS

Landing of the STS-65 Orbiter was delayed one day because of weather constraints. The STS-65 mission was concluded on July 23, 1994 with a landing at KSC. Twelve videos plus NASA Select of the Orbiter approach and landing were evaluated. In addition, 15 landing films were also screened. No Orbiter anomalies were noted in any of the photographic or video data.

TABLE I.- STS-65 MISSION 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	189:16:38:12.74 189:16:38:13.61 189:16:38:14.59
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	189:16:42:32.083 189:16:42:33.243 189:16:42:33.403 189:16:42:33.563
Main Propulsion System Start[a]	ME-3 Start command accepted ME-2 Start command accepted ME-1 Start command accepted	189:16:42:53.437 189:16:42:53.585 189:16:42:53.704
SRB Ignition Command (Liftoff)	Calculated SRB ignition command	189:16:43:00.013
Throttle up to 104 Percent Thrust[a]	ME-3 Command accepted ME-1 Command accepted ME-2 Command accepted	189:16:43:03.078 189:16:43:03:104 189:16:43:03.105
Throttle down to 67 Percent Thrust[a]	ME-3 Command accepted ME-1 Command accepted ME-2 Command accepted	189:16:43:26.478 189:16:43:26.505 189:16:43:26.506
Maximum Dynamic Pressure (q)	Derived ascent dynamic pressure	189:16:43:51
Throttle up to 104 Percent[a]	ME-3 Command accepted ME-1 Command accepted ME-2 Command accepted	189:16:44:00.718 189:16:44:00.745 189:16:44:00.746
Both SRM's Chamber Pressure at 50 psi[a]	RH SRM chamber pressure mid-range select LH SRM chamber pressure mid-range select	189:16:44:57.613 189:16:44:58.453
End SRM Action[a]	RH SRM chamber pressure mid-range select LH SRM chamber pressure mid-range select	189:16:45:00. 053 189:16:45:00. 723
SRB Physical Separation[a]	LH rate APU turbine speed - LOS RH rate APU turbine speed - LOS	189:16:45:03.493 189:16:45:03.493
SRB Separation Command	SRB separation command flag	189:16:45:04
Throttle Down for 3g Acceleration[a]	ME-3 command accepted ME-1 command accepted ME-2 command accepted	189:16:50:32.081 189:16:50:32.110 189:16:50:32.113
3g Acceleration	Total load factor	189:16:50:37.7
Throttle Down to 67 Percent Thrust[a]	ME-3 command accepted ME-1 command accepted ME-2 command accepted	189:16:51:24.241 189:16:51:24.271 189:16:51:24.274
SSME Shutdown[a]	ME-1 command accepted ME-2 command accepted ME-3 command accepted	189:16:51:30.671 189:16:51:30.674 189:16:51:30.721
MECO	MECO command flag MECO confirm flag	189:16:51:31 189:16:51:31
ET Separation	ET separation command flag	189:16:51:50

[a] MSFC supplied data

TABLE I.- STS-65 MISSION EVENTS (Continued)

Event	Description	Actual time, G.m.t.
APU Deactivation	APU-2 GG chamber pressure APU 1 GG chamber pressure APU 3 GG chamber pressure	189:16:58:58.97 189:16:59:11.11 189:16:59:20.23
OMS-1 Ignition	Left engine bi-prop valve position Right engine bi-prop valve position	Not performed - direct insertion trajectory flown
OMS-1 Cutoff	Left engine bi-prop valve position Right engine bi-prop valve position	
OMS-2 Ignition	Left engine bi-prop valve position Right engine bi-prop valve position	189:17:22:55.2 189:17:22:55.2
OMS-2 Cutoff	Left engine bi-prop valve position Right engine bi-prop valve position	189:17:25:16.5 189:17:25:16.7
Payload Bay Doors (PLBDs) Open	PLBD right open 1 PLBD left open 1	189:18:10:45 189:18:12:04
Flight Control System Checkout APU Start APU Stop	 APU-1 GG chamber pressure APU-1 GG chamber pressure	 202:07:36:15.04 202:07:43:28.70
Payload Bay Doors Close	PLBD left close 1 PLBD right close 1	203:07:08:29 203:07:10:39
Payload Bay Doors Reopen	PLBD right open 1(BFS) PLBD left open 1 (BFS)	203:11:27:54 203:11:29:13
OMS-3 Ignition	Left engine bi-prop valve position Right engine bi-prop valve position	203:12:47:44.1 203:12:47:44.2
OMS-3 Cutoff	Left engine bi-prop valve position Right engine bi-prop valve position	203:12:48:16.2 203:12:48:16.2
OMS-4 Ignition	Left engine bi-prop valve position Right engine bi-prop valve position	203:13:32:42.2 203:13:32:42.2
OMS-4 Cutoff	Left engine bi-prop valve position Right engine bi-prop valve position	203:13:33:12.6 203:13:33:12.8
Payload Bay Doors Close (Second time)	PLBD right close 1 PLBD left close 1	204:07:06:52.174 204:07:09:02.609
APU Activation for Entry	APU-2 GG chamber pressure APU-1 GG chamber pressure APU-3 GG chamber pressure	204:09:35:59.188 204:09:53:13.526 204:09:53:15.293
Deorbit Burn Ignition	Left engine bi-prop valve position Right engine bi-prop valve position	204:09:40:38.3 204:09:40:38.3
Deorbit Burn Cutoff	Left engine bi-prop valve position Right engine bi-prop valve position	204:09:43:11.1 204:09:43:11.1
Entry Interface (400K feet)	Current orbital altitude above	204:10:06:06
Blackout end	Data locked (high sample rate)	No blackout
Terminal Area Energy	Major mode change (305)	204:10:31:32
Main Landing Gear Contact	LH main landing gear tire pressure 1 RH main landing gear tire pressure 2	204:10:38:00 204:10:38:00
Main Landing Gear Weight on Wheels	LH main landing gear weight on wheels RH main landing gear weight on wheels	204:10:38:00 204:10:38:01

TABLE I.- STS-65 MISSION EVENTS (Continued)

Event	Description	Actual time, G.m.t.
Drag Chute Deployment	Drag chute deploy 1 CP Volts	204:10:38:08.0
Nose Landing Gear Contact	NLG LH tire pressure 1	204:10:38:17
Nose Landing Gear Weight On Wheels	NLG weight on wheels 1	204:10:38:18
Drag Chute Jettison	Drag chute jettison 1 CP Volts	204:10:38:42.6
Wheel Stop	Velocity with respect to runway	204:10:39:09
APU Deactivation	APU-1 GG chamber pressure APU-2 GG chamber pressure APU-3 GG chamber pressure	204:10:58:10.85 204:10:58:12.14 204:10:58:13.79

TABLE II.- ORBITER PROBLEM TRACKING LIST

No.	Title	Reference	Comments
STS-65-V-01	OEX System Control Module Stopped Executing Commands LEVEL III CLOSURE	191:21:18 G.m.t. 002:04:25 MET IM 65RF01 IPR 73V-0003	During OEX recorder commanding, the OEX System Control Module (SCM) stopped executing commands. Power cycles, software resets and recovery commands did not restore SCM operation. No further on-orbit, entry or postlanding data from MADS, AIP, and ACIP/HIRAP (DSO-314) were recorded. Normal postflight data dump attempt not successful. SCM recovered and OEX recorder dumped after battery board removal. Symptoms were reproduced with battery board removed using same command sequence as used on-orbit. SODB addition to document commanding limitations in work.
STS-65-V-02	Supply Water Dump Nozzle Icing	192:08:00 G.m.t. 002:15:17 MET IM 65RF02 IPR 73V-0017	During the third supply water dump, the supply and waste water dump nozzle temperatures dropped indicating icing. The supply water dump was terminated and nozzle heaters were used to evaporate ice until nozzle temperatures returned to normal, then a waste water dump was performed. Supply water dumps were performed using the FES for the remainder of the flight. Detailed nozzle and TPS inspections showed evidence of RTV deterioration as well as differences in TPS configuration between vehicles. Flow rate and spray pattern verifications were performed.
STS-65-V-03	WCS Problems A. Commode Fault During Compaction Cycle	193:06:06 G.m.t. 003:13:23 MET IM 65RF10	Compactor piston stopped at the midway point during piston retraction during the third compaction cycle resulting in a Commode Fault indication. Crew manually retracted piston and found no problems during compactor, piston, and transport tube inspection. Compactor operations were nominal for remainder of the mission. Possible operation error identified by crew during debriefing. Parts of a sheared roll pin found inside the outer edge of piston during OMRSD cleaning. No KSC action.

TABLE II.- ORBITER PROBLEM TRACKING LIST

No.	Title	Reference	Comments
	B. Commode Filter Anomalies and Odor Management	IM 65RF03	The first replacement commode odor bacteria filter (S/N TBD) did not fit and the original (ascent) filter was reinstalled. The filter was successfully installed on flight day 12 after a lubricant was applied to the grommet and the filter remained installed through entry. Other replacement filters did not encounter interference. Plenum filter replacement and installation of an additional ARS charcoal canister were performed to control odors. Used plenum filter was clean and dry but retained odors. No KSC action.
	C. Fan Separator 1 Stall and Liquid Backflow	IM 65RF11 IPR 73V-0008 PR V070-2-18-0326	Crew reported gurgling noise and odor from fan separator 1 during operation on flight day 13. Data indicate normal fan start-up but low separator drum speed. Liquid backflow may have occurred through the dual fan separator 1 outlet check valves after the previous use for 10 seconds resulting in flooding of the fan separator. The fan separator 1 bowl was still pumping liquid at normal shutdown time. The crew attempted to clear fan separator 1 by restarting without success. Fan separator 2 was used for the remainder of the mission. Liquid backflow from the waste tank through the check valves occurred one day after landing when water tanks were repressurized for supply water sampling resulting in a 4-gallon waste-tank quantity reduction and overflow into the middeck area. Accessible plumbing drained prior to WCS removal for shipment to the vendor.
STS-65-V-04	IMU 1 Redundant Rate Bite	199:12:36 G.m.t. 009:19:53 MET IM 65RF04 PR GNC-2-18-0102	Numerous transient redundant rate BITE messages were generated when the IMU-1 (S/N 204) azimuth gyro experienced spikes exceeding 0.7°/hr. during later transients. No KSC troubleshooting. IMU removed and shipped to ISL. Symptoms reproduced at ISL.

TABLE II.- ORBITER PROBLEM TRACKING LIST

No.	Title	Reference	Comments
STS-65-V-05	RCS Vernier Thruster R5D Failed Off	199:09:14 G.m.t. 009:16:31 MET IPR 73V-0004	Vernier thruster R5D was failed off by the RM. The thruster was hot-fired successfully, then reselected. Subsequent performance was nominal. Data indicate possible intermittent loss of R5D command B (enable) signal. MDM FA2 BSR was polled and indicated that no faults were recorded. KSC troubleshooting did not reproduce the anomaly.
STS-65-V-06	Low Waste Dump Flow	198:07:06 G.m.t. 008:14:23 MET IM 65RF05 IPR 73V-0016	The second waste water dump was initiated at 198:06:33 G.m.t. (008:13:50 MET) and was performed in three segments. The dump rate degraded during the second segment of the dump and was nominal during the third segment. A third waste water dump was performed at 202:05:39 G.m.t. (12:12:56 MET) in 7 segments, all with a degraded dump flow rate. Nozzle inspection, water flush and sample, urine solids filter removal and citric acid flush were performed.
STS-65-V-07	Poor Dump Quality Operations Recorder 2 Track 2	201:00:34 G.m.t. 011:07:51 MET IM 65RF06 IPR 73V-0005	Poor quality data were received from track 2 of OPS recorder 2 during a dump at an 8:1 ratio in both the reverse and forward directions. Good quality data were received with 1:1 ratio dump through ground site. Tracks 3 through 14 on OPS recorder 2 were used as an AOS recorder. Postflight dump through T-O at 8:1 and 1:1 from track 2 not successful. Track 2 re-recorded in both directions, and dump reverse was worse than forward with degraded quality in both directions. Recorder removed for shipment to NSLD.
STS-65-V-08	LH2 Manifold Pressure Following Vacuum Inert	189:17:23 G.m.t. 000:40:00 MET IPR 73V-0014	The LH2 manifold pressure rose to an unexpected high peak pressure of 17 psia following vacuum inert. After reaching the peak pressure, the LH2 manifold pressure decreased faster than expected. First use of OI-23 software which included MPS dump and vacuum inert sequence automation. The OI-23 software was verified to have performed as designed and LH2 system responses to software commands was nominal.

TABLE II.- ORBITER PROBLEM TRACKING LIST

No.	Title	Reference	Comments
STS-65-V-08 (Continued)			LH2 manifold large volume decay check failed at 0.696 psi/hr (max. = 0.601 psi/hr). Manifold relief valve leak check and large volume decay check planned.
STS-65-V-09	High MPS Helium Usage During Entry	204:10:29 G.m.t. 014:17:46 MET IPR 73V-0015	A total of 59.7 lb of helium was used during the 650-second system blowdown performed during entry. Nominal usage is 55.7 ± 1.1 lb for OV-102. This condition was caused by the OI-23 software change from single to dual regulation supply. File IX OMRSD change planned.
STS-65-V-10	Left Flight Deck Smoke Detector Transients	197:15:52 G.m.t. 007:23:09 MET	The left flight deck smoke detector concentration indication dropped off-scale low for two seconds followed 14 seconds later by negative spikes for a period of five seconds. After landing, a master alarm was received from the left flight deck smoke detector with no concentration change observed in the data. The smoke detector was replaced.

TABLE III.-GFE PROBLEM TRACKING LIST

No.	Title	Reference	Comments
STS-65-F-01	Arriflex Camera Film Magazine Jam	191:14:39 G.m.t. 001:21:56 MET	Crew reported 16 mm Arriflex Camera film magazine S/N 1016 jammed. Malfunction procedure cleared jam but subsequently recurred. Film magazine replaced, normal operation restored. Film magazine S/N 1016 stowed in the 16 mm bag in locker L100.
STS-65-F-02	70mm Hasselblad Camera Malfunctions A. Camera Jammed/Lens Stuck B. Shutter Trigger Failed/Spring Lost	192:23:33 G.m.t. 003:06:50 MET	A. Crew reported Hasselblad camera jammed-unable to remove lens. An IFM to clear jam and remove lens was successful; however, camera and lens again jammed at 193:00:44 G.m.t. Camera and lens stowed for the remainder of flight. B. Crew reported the retaining ring on the Hasselblad camera shutter release plunger was missing. Crew used gray tape for retention. During a subsequent attempt to repair the jammed camera and lens, the shutter release button plunger spring was lost on the aft flight deck.
STS-65-F-03	CCTV Camera D Degraded Horizontal Sync	193:17:30 G.m.t. 004:00:47 MET	CCTV Camera D is experiencing intermittent degradation of the horizontal synchronization which caused the NASA ground terminal (NGT) frame synchronizer to lose lock, resulting in color shifting (tearing).
STS-65-F-04	Ergometer Fastener Failure	195:22:20 G.m.t. 006:05:37 MET	Crew reported left aft fastener (from seated crewperson perspective) broken. Left aft fastener swapped with right forward fastener. Ergometer was usable for remainder of mission.

TABLE III.-GFE PROBLEM TRACKING LIST

No.	Title	Reference	Comments
STS-65-F-05	Galley RHS Failed to Dispense Cold Water	193:07:49 G.m.t. 003:15:06 MET	Crew reported galley rehydration station (RHS) did not dispense cold water but hot water was dispensed normally. After galley power was cycled, galley dispensed ½ ounce of cold water when either 8-ounce or 7.5-ounce dispense quantities were selected. Crew performed malfunction procedure which restored nominal galley RHS performance.

TABLE IV.- MSFC PROBLEM TRACKING LIST

No.	Title	Ref. time	Discussion
STS-65-B-01	RH RSS Safe and Arm Device Loose Mounting Fasteners	Ascent	The right-hand Range Safety System Safe and Arm device had two of four mounting fasteners that were not properly seated. Gaps under the fastener heads measured 0.06 in. and 0.078 in. with the safety wire intact. Stress analysis shows flight load are not sufficient to cause the gap. Fail-safe analysis shows two remaining fasteners sufficient to retain safe and arm device on the panel. The safe and arm device mounting fasteners will be inspected to verify that no loose washers or gaps exist.
STS-65-B-02	Broken fastener on LH AFT IEA End Cover	Ascent	Left-hand integrated electronics assembly (IEA) end cover has one broken fastener on the systems-tunnel side of the cover. No evidence exists of water-impact damage in this area. Loss of this fastener does not cause loss of the cover; however, generic implications to other cover fasteners will be investigated.
STS-65-M-01	Aft Segment Stiffener Stub Crack	Ascent	Cracks are typically seen at the centerline of cavity A crack was found on the left-hand aft segment forward stiffener ring stub extending radically inward from the outer diameter of the stub. The crack was located at 90.5 degrees and was approximately 1/4 inch deep. Damage occurred during splashdown and the damage was located at the cavity collapse centerline. Splashdown damage to this stub and stiffener rings was more extensive than is typically seen.

TABLE IV.- MSFC PROBLEM TRACKING LIST

No.	Title	Ref. time	Discussion
STS-65-M-01 (Continued)	Aft Segment Stiffener Stub Crack		Cracks are typically seen at the centerline of cavity collapse; however, this crack was unusual in that it occurred between holes. The cracked section was excised and the preliminary examination results indicate that the crack was caused by stress corrosion after splashdown, with no indication of any pre-existent flaw. The final geometry appears to be a half-moon shaped crack with a maximum depth of approximately 1/2 inch. The fracture surface had an intergranular structure indicating hydrogen-assisted stress corrosion cracking (SCC). The probable crack initiation location was on the aft outer flange corner and was approximately 0.060-inch long by 0.012-inch deep from which it grew inward approximately 0.25 inch. The crack initiated during water impact damage and grew during towback due to SCC. All necessary conditions for SCC were present, i.e., residual tensile stress because of water impact cavity collapse loads, probable initiation location, damage to protection system (primer, paint, K5NA, Instafoam, etc.), corrosive environment (salt water) during towback, presence of zinc in primer to help accelerate crack growth, and the susceptibility of the D6AC material to SCC.

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.

AAEU	Aquatic Animal Experiment Unit
AERIS	American Echocardiograph Research Imaging System
AMOS	Air Force Maui Optical Site
AOS	acquisition of signal
APCF	Advanced Protein Crystallization Facility
APU	auxiliary power unit
ARS	atmospheric revitalization system
ATCS	active thermal control system
ATR	automatic temperature recorder
BDPU	Bubble, Drop, and Particle Unit
BITE	built-in test equipment
BSK	Biostack
BSR	BITE status read
CCK	cell culture kit
CCTV	closed circuit television
CNES	French Space Agency
CPCG	Commercial Protein Crystal Growth
CPF	Critical Point Facility
CPR	
CRIM	Commerciaal Refrigerator/Incubator Module
CSA	Canadian Space Agency
DARA	German Space Agency
DCU	digital control unit
DPS	data processing system
DSO	Detailed Supplementary Objective
DTO	Developmental Test Objective
ΔV	differential velocity
deg/hr	degree per hour
EBP	electrode buffer pump
EDO	Extended Duration Orbiter
EDOMP	Extended Duration Orbiter Medical Project
EOM	end-of-mission
EPDC	electrical power distribution and control subsystem
ESA	European Space Agency
ET	External Tank
FCE	flight crew equipment
FCP	fuel cell powerplant
FCS	flight control system
FCV	flow control valve

FES	flash evaporator system
FFEU	Free Flow Electrophoresis Unit
FID	failure identification
FM	frequency modulation
FO	flight objective
FRSI	flexible reusable surface insulation
FSM	fuel supply module
ft/sec	feet per second
g	gravity
GFE	Government furnished equipment
GH_2	gaseous hydrogen
G.m.t.	Greenwich mean time
GN_2	gaseous nitrogen
GPC	general purpose computer
HIRAP	high resolution accelerometer package
HPFT	high pressure fuel turbine
HPOTP	high pressure oxidizer turbopump
HRM	
HUMS	hydrogen umbilical mass spectrometer
IEA	integrated electronics assembly
IFM	in-flight maintenance
IML-2	International Microgravity Laboratory
IMU	inertial measurement unit
ISP	specific impulse
ITEPC	Inter Mars Tissue Equivalent Proportional Counter
IVIS	inertial vibration isolation system
KSC	Kennedy Space Center
kW	kilowatt
kWh	kilowatt hour
LBNP	Lower Body Negative Pressure
LCC	Launch Commit Criteria
LCEOR/F	Linear Compressor Enhanced Orbiter Refrigerator/Freezer
LED	light emitting diode
LESC	Lockheed Engineering and Science Company
LESS	leading edge structural system
LH_2	liquid hydrogen
LIF	Large Isothermal Furnace
LiOH	lithium hydroxide
LO_2	liquid oxygen
MADS	modular auxiliary data system
MAS	Microbial Air Sampler
MAST	Military Application of Ship Tracks
MDM	multiplexer/demultiplexer
MECO	main engine cutoff
MET	mission elapsed time

MLGD	main landing gear door
MMD	Microgravity Measurement Device
MPS	main propulsion system
MSFC	Marshall Space Flight Center
NASA	National Aeronautics and Space Administration
NASDA	National Space Development Agency of Japan
NIZEMI	Slow Rotating Centrifuge Microscope
NPSP	net positive suction pressure
NSLD	NASA Shuttle Logistics Depot
NSTS	National Space Transportation System (i.e., Space Shuttle Program)
OARE	Orbital Acceleration Research Equipment
OEX	Orbiter experiments
OI	operational instrumentation
OMRSD	Operations and Maintenance Requirements and Specifications Document
OMS	orbital maneuvering subsystem
OPS	operations
PADM	portable audio data modem
PAL	protuberance air load
PAWS	Performance Assessment Workstation
PCIS	power control and interface system
PCM	phase change material
PDU	power drive unit
PILOT	Portable In-Flight Landing Operations Trainer
PMBT	propellant mean bulk temperature
POGO	longitudinal oscillation
PRSD	power reactant storage and distribution
PTI	programmed test input
QSAM	Quasi-Steady Acceleration Measurement
RAMSES	Applied Research on Separation Methods Using Space Electrophoresis
RCRS	regenerative carbon dioxide removal system
RCS	reaction control subsystem
RHS	rehydration station
RJD	reaction jet driver
RM	redundancy management
RMS	remote manipulator system
RRMD	Real-Time Radiation Monitoring Device
RSRM	Redesigned Solid Rocket Motor
RSS	range safety system
RTLS	return to launch site
RTV	room temperature vulcanizing
S&A	safe and arm
SAMS	Space Acceleration Measurement System
SAREX	Shuttle Amateur Radio Experiment

SCM	Spinal Changes in Microgravity/system control module
SLF	Shuttle Landing Facility
S/N	serial number
SODB	Shuttle Operational Data Book
SRB	Solid Rocket Booster
SRSS	Shuttle range safety system
SSME	Space Shuttle main engine
STGT	Shuttle TDRS Ground Terminal
TDRS	Tracking and Data Relay Satellite
TED	thermal electric device
TEI	thermoelectric incubator
TEMPUS	Electromagnetic Containerless Processing Facility
TPS	thermal protection subsystem
TVC	thrust vector control
VIBES	Vibration Isolation Box Experiment Station
VMS	Vertical Motion Simulator
WCS	Waste collection system
WSB	water spray boiler

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