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STS-55 SPACE SHUTTLE MISSION REPORT

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Houston, Texas

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STS-55

SPACE SHUTTLE

MISSION REPORT

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INTRODUCTION

The STS-55 Space Shuttle Program Mission Report provides a summary of the Payloads, as well as the Orbiter, External Tank (ET), Solid Rocket Booster (SRB) and Redesigned Solid Rocket Motor (RSRM), and the Space Shuttle main engine (SSME) subsystems performance during the fifty-fifth flight of the Space Shuttle Program and fourteenth flight of the Orbiter vehicle Columbia (OV-102). In addition to the Orbiter, the flight vehicle consisted of an ET (ET-56); three SSME's, which were designated as serial number 2031, 2109, and 2029 in positions 1, 2, and 3, respectively; and two SRB's which were designated BI-057. The lightweight RSRM's that were installed in each SRB were designated as 360L030A for the left SRB and 360W030B for the right SRB.

The STS-55 Space Shuttle Program Mission Report fulfills the Space Shuttle Program requirement, as documented in NSTS 07700, Volume VIII, Appendix E. That document states that each major organizational element supporting the Program will report the results of their hardware evaluation and mission performance plus identify all related in-flight anomalies.

The primary objective of this flight was to successfully launch, operate, and return the German Spacelab D2 payload. The German D2 payload is composed of the Spacelab Module, the unique support structure (USS), and the reaction kinetic in glass melts (RKGM) get-away special (GAS). The secondary objective of this flight was to perform the operations of the Shuttle Amateur Radio Experiment (SAREX-II) payload.

The sequence of events for the STS-55 mission is shown in Table I, the official Orbiter and GFE Projects Problem Tracking List is shown in Table II, and the official MSFC In-Flight Anomaly List is shown in Table III. The Mission Control Center and Payload anomalies are also referenced where applicable. Appendix A lists the sources of data, both formal and informal, that were used in the preparation of this document. Appendix B provides the definition of acronyms and abbreviations used in this document. All times given in this report are in Greenwich mean time (G.m.t.) as well as mission elapsed time (MET).

The STS-55 mission was planned as a 9-day mission with an additional day being highly desirable. The capability for this additional day was determined in real-time based on consumables with mission planning accommodating the longer duration wherever appropriate. Some 90 experiments were planned for completion during the mission by the seven-member crew that was divided into two teams, red and blue, so that scientific operations were performed around the clock.

In addition to presenting a summary of subsystem performance, this report also discusses the payload operations and results, as well as each in-flight anomaly that was assigned to each major element (Orbiter, SSME, ET, SRB, and RSRM). Listed in the discussion of each anomaly in the applicable subsection of the report is the officially assigned tracking number as published by each respective Project Office in their respective Problem Tracking List.

The crew for this fifty-fifth flight of the Space Shuttle was Steven R. Nagel, Col., USAF, Commander; Terence T. Henricks, Col., USAF, Pilot; Jerry L. Ross, Col., USAF, Mission Specialist 1; Charles J. Precourt, Major, USAF, Mission Specialist 2; Bernard A. Harris, Jr., M.D., Civilian, Mission Specialist 3;

Ulrich Walter, Payload Specialist 1; and Hans William Schlegel, Payload Specialist 2. STS-55 was the fourth space flight for the Commander and Mission Specialist 1, the second space flight for the Pilot, and the first space flight for Mission Specialist 2, Mission Specialist 3, Payload Specialist 1, and Payload Specialist 2.

MISSION SUMMARY

After an excellent launch countdown that was leading to an on-time launch from launch complex 39A at 8:51:00 a.m. c.s.t. on March 22, 1993, the initial launch attempt for the STS-55 mission experienced an on-pad abort about 3 seconds prior to the planned lift-off. The Space Shuttle main engine (SSME) oxidizer preburner (OPB) purge pressure exceeded the maximum redline value because one of the five check valves in the purge system leaked and the monitor detected combustion product pressure which exceeded the 50-psia redline. Also, the liquid hydrogen (LH_2) 4-inch External Tank/Orbiter (ET/Orbiter) disconnect valve closed slowly following the on-pad abort on March 22, 1993 (Flight Problem STS-55-V-01A). After replacement of all three SSME's and verification of the performance of the necessary prelaunch subsystems and payloads systems, the launch of STS-55 was rescheduled for April 24, 1993.

Approximately 9 hours before the planned launch on April 24 (second attempt) while changing the mode of inertial measurement unit (IMU) 2 (model KT-70) from standby to operate, an IMU 2 platform-fail built-in test equipment (BITE) indication was received (Flight Problem STS-55-V-02). Several mode cycles between standby and operate were made and the failure was not repeated. As a result of the initial failure indication and the uncertainty of the possible recurrence of the failure, a decision was made to replace the IMU and reschedule the launch for April 26, 1993.

The STS-55 Space Shuttle Vehicle was launched at 116:14:50:00.017 G.m.t. (9:50 a.m. c.d.t.) from Kennedy Space Center (KSC) on April 26, 1993. The ascent phase was nominal.

After the successful launch, the LH_2 4-inch disconnect valve did not close when commanded several seconds prior to ET separation; however, it did close at ET/Orbiter umbilical retraction which is part of the ET separation sequence (Flight Problem STS-55-V-01B).

A determination of vehicle performance was made using vehicle acceleration and preflight propulsion prediction data. From these data, the average flight-derived specific impulse (I_{sp}) determined for the time period between SRB separation and start of 3-g throttling was 453.2 seconds as compared to the average value of 452.74 seconds.

A review of the postlaunch lightning data at KSC revealed radio frequency (RF) signals that were detected by the Lightning Detection and Ranging (LDAR) system during ascent between 48 and 50 seconds mission elapsed time (MET). Orbiter data showed simultaneous electromagnetic disturbances being registered on UHF receiver 4. The LDAR was tuned to 63 MHz and registered 11 pulses, and the UHF receiver operated at 243 MHz. These data indicate that the interference was broadband in nature and would imply lightning since it is characterized by broadband pulses in this frequency range. However, a review of the launch films revealed no visible discharge.

The waste water liquid pressure increased by 13 psig to 22 psig during the first 5 hours of the mission. A concern was expressed with respect to the tank bellows being stuck; however, an increase in waste tank quantity had accompanied several of the waste liquid pressure increases due to urine/fan separator use. Furthermore, past data indicated that the bellows in the OV-102 vehicle waste tank exerted more force when compared with other vehicles, thus requiring a higher liquid pressure to fill the tank.

At 117:02:24 G.m.t. (00:11:34 MET), about three hours into a flash evaporator system (FES) water dump, the gaseous nitrogen regulator pressure in the common manifold for the supply and waste water tanks dropped to 6 psig. The FES water dump was terminated 11 minutes later to prevent any anomalous FES operation. Troubleshooting and malfunction-procedure workarounds pinpointed a probable leak in the nitrogen system that pressurizes the water tanks. The water alternate pressure valve was opened and all water tanks were pressurized with cabin air. A FES supply water dump was subsequently completed successfully.

At approximately 118:02:12 G.m.t. (01:11:22 MET), the crew reported that a puncture was found in the wall of the waste water tank (Flight Problem STS-55-V-04). Subsequent video was downlinked showing the puncture and deformation of the waste water tank wall. The crew reported no signs of liquid leakage, therefore indicating that the tank bellows was still intact. The postflight investigation showed that an existing dent in the tank wall jammed one side of the bellows, eventually forcing a rulon tab, which is connected to the bellows, to puncture the tank wall. As a result of the gaseous nitrogen leak, the contingency water container (CWC) was placed in use for holding the waste water. Waste water dumps from the CWC were successfully performed throughout the flight. An in-flight maintenance (IFM) procedure to isolate the GN_2 leak from the water tank pressurization system was completed successfully at 118:23:34 G.m.t. (02:08:44 MET), and all supply water tanks were repressurized to 16 psig.

At 117:18:38 G.m.t. (01:03:48 MET), the heater for reaction control subsystem (RCS) thruster L4D failed on (Flight Problem STS-55-V-06). The heater was controlled manually for the remainder of the flight. The injector upper temperature was limited to 160°F (operational) and 185°F (non-operational). The injector lower temperature was limited to 60°F. The switch controlling the thruster L4D heater also controls the heaters on five other thrusters. This failure did not impact operations on this flight.

At 118:15:27 G.m.t. (02:00:37 MET), the FES experienced an over-temperature shutdown. The FES was deactivated until normal supply water pressure of 30 psia was restored. At 118:23:47 G.m.t. (02:08:57 MET), with GN_2 pressure restored, a FES water dump was initiated. After 5 minutes of stable operation, the FES again experienced an over-temperature shutdown. The crew cycled the FES and it immediately shut down without reaching its control band. All shutdowns occurred on the primary A controller. The shutdowns were attributed to ice formation in the topping core while operating at low supply-water pressure. The ice was successfully removed using a flush procedure about 14 hours after the last FES shutdown. The radiators were bypassed to increase the Freon inlet temperature to the FES and then the secondary controller was cycled several times to flush the ice from the core. A momentary drop in the right topping duct temperatures indicated that some ice passed through the duct. The FES was operated on the primary controller B for about an hour before the FES and the duct heaters were deactivated to conserve power for the remainder of the mission. The radiators were deployed at 119:14:50 G.m.t. (03:00:00 MET) to provide additional heat rejection since the FES was no longer being operated. The radiators were stowed at 125:00:10 G.m.t. (08:10:00 MET), and the FES primary B controller was used for supplemental cooling. The primary A controller was selected for two water dumps, starting at 125:19:30 G.m.t. (09:04:40 MET) and 125:20:53 G.m.t. (09:06:03 MET), and the controller operation was nominal, therefore, exonerating any controller malfunction as a cause of the earlier shutdowns.

Following a problem earlier in the mission when a thermal impulse printer system (TIPS) message sent via Ku-band was not received onboard, a procedure was developed to correct the problem. The encryption bypass isolation assembly (EBIA) must be powered on for TIPS to operate through the Ku-band. This procedure kept the EBIA powered while the Text and Graphics System (TAGS) was powered off. The TIPS configuration operated well until late in the mission when it was turned off to save paper for future graphics requirements.

RCS interconnect operations to the right orbital maneuvering subsystem (OMS) was established at 119:23:16 G.m.t. (03:18:26 MET).

The hydraulic system 3 main pump case drain temperature measurement (V58T0385A) exhibited an unusual signature (Flight Problem STS-55-V-07). Because the main pump does not operate on-orbit, the temperature in the line should be relatively constant. However, this temperature measurement responded rapidly to each hydraulic system 3 circulation pump run. Hydraulic systems 1 and 2 main pump case drain temperature measurements did not respond to circulation pump runs. Postflight troubleshooting showed the sensor had been bonded to the hydraulic system 3 filter module high pressure outlet line. The sensor will be moved to the correct line.

Consumables savings continued to increase to the level desired so that the extension day could be added to the flight. The Mission Management Team (MMT) decided that the mission would be extended by one day. The landing was planned for Thursday morning (May 6, 1993) at approximately 8:00 a.m. c.d.t.

OMS propellant usage by the RCS during interconnect operations was discontinued at 122:17:58:50 G.m.t. (06:03:08:50 MET) with 7.65 percent of OMS propellant used from the left OMS and 7.43 percent of the OMS propellants used from the right OMS.

At 123:23:35:39 G.m.t. (07:08:45:39 MET), the crew entered an Item 18 Execute to initiate the mass memory unit (MMU) 1 checkpoint. Thirteen seconds later, Off/Busy MMU 1 and Checkpoint Fail fault messages were annunciated by general purpose computer (GPC) 4, and GPC 4 logged a single input/output (I/O) error plus other indications (Flight Problem STS-55-V-10). The crew cycled the MMU power in accordance with normal malfunction procedures and the checkpoint was satisfactorily completed on a subsequent attempt. The failure history of MMU 1 as well as the software interfaces were investigated in an effort to determine the cause of this occurrence. MMU 1 was used throughout the rest of the mission without a recurrence of this anomaly.

A fuel cell purge was performed at 120:15:12 G.m.t (04:00:22 MET), 70.5 hours after the previous purge. This effectively met the goal of 72 hours between purges. Another fuel cell purge was completed at 123:14:58 G.m.t. (07:00:08 MET), 72 hours after the previous purge.

At 124:12:59 G.m.t. (07:22:09 MET), GPC 4 annunciated an input/output error on CRT 4 (Flight Problem STS-55-V-11). The crew reported that the CRT 4 display electronics unit (DEU) BITE flag was tripped and that CRT 4 was blank. The crew performed the malfunction procedure, but the CRT was not recovered. CRT 4 was powered down and remained powered down for the rest of the mission. Due to the signature, it is believed that the problem resides in the DEU.

The flight control system (FCS) checkout was completed at approximately 125:10:50 G.m.t. (08:20:00 MET), and the data review indicated that the checkout was nominal. APU 1 consumed 15 lb of fuel during the 5 minutes 9 seconds of satisfactory operation. All hydraulics functions were nominal during the checkout, and no water spray cooling was required.

The RCS hot-fire test was performed at 125:11:06 G.m.t. (08:20:16 MET). Data review indicated that all thrusters performed as expected.

Evaluation of the entry heating damage to the elevon cove of the right wing following the STS-56 mission, during which the alternate elevon schedule was used in support of Development Test Objective (DTO) 251, has shown that the heating was outside the thermal design base and previous flight experience. This resulted in a concern being raised about performing DTO 251 with the alternate elevon schedule during the STS-55 entry. The alternate elevon schedule allows up-elevon deflection of 10° or more if aileron trim is required. Analysis during the flight showed that should an early transition occur following entry interface as it did on STS-56 (coupled with the fact that this Orbiter is approximately 20,000 lb heavier than the STS-56 Orbiter), the damage to the elevon cove may be greater than that seen on STS-56. As a result, a decision was made by the MMT to use the automatic elevon schedule which allows a maximum of 7° up-elevon. Postflight inspections revealed no damage to the elevon cove area.

Both payload bay doors were closed and latched nominally by 126:09:24:51 G.m.t. (09:18:34:51 MET). As a result of unacceptable weather at the Shuttle Launch Facility at KSC, the landing was delayed for one orbit and the landing site was changed to Edwards Air Force Base (EAFB). The deorbit maneuver was performed at 126:13:29:20 G.m.t. (09:22:39:20 MET). The maneuver was approximately 176 seconds in duration and the ΔV was 290.2 ft/sec. All programmed test inputs (PTI's) were performed during entry as planned.

During entry at 126:13:46:14 G.m.t. (09:22:56:14 MET) and 126:13:46:35 G.m.t. (09:22:56:35 MET), fault messages were recorded when the lubrication oil outlet pressure dropped below 25 psia. After the APU warmed up, the pressure increased to a satisfactory level of 30 $\pm$ 5 psia for the remainder of entry. APU 1 also experienced one gearbox repressurization which occurred when the gearbox pressure dropped below 5 psia about 4 minutes prior to landing. This APU has leaked gaseous nitrogen past the turbine seal on previous flights; however, its leakage rate was within specification.

Main landing gear touchdown occurred at Edwards Air Force Base on concrete runway 22 at 126:14:29:59 G.m.t. (09:23:39:59 MET) on May 6, 1993. Nose landing gear touchdown occurred 17 seconds after main gear touchdown with the Orbiter drag chute being deployed satisfactorily at 126:14:30:16 G.m.t. The drag chute was jettisoned at 126:14:30:41 G.m.t. with wheels stop occurring at 126:14:31:00 G.m.t. Preliminary indications are that the rollout was normal in all respects. The flight duration was 9 days 23 hours 39 minutes 59 seconds. All three APU's were powered down by 126:14:44:59 G.m.t., and the Orbiter weighed approximately 227,279 lb at landing. The crew completed the required postflight reconfigurations and departed the Orbiter landing area at approximately 126:15:20 G.m.t.

PAYLOADS

SPACELAB D2

The Spacelab D2 mission was the second under German mission management and responsibility. The first German Spacelab mission (D1) was conducted during the STS-61A mission in November 1985. The Spacelab D2 mission was oriented toward the goals of the space utilization program of the Federal Republic of Germany and also the microgravity program of the European Space Agency (ESA). Besides continuing research areas and scientific experiments from Spacelab D1, the Spacelab D2 mission was multi-disciplinary and covered the fields of materials and life sciences. Numerous universities, research institutes, and industrial concerns in Germany and other countries contributed to the scientific experiment program.

The Spacelab was activated at 116:18:59 G.m.t. (00:04:09 MET) and the payload was activated 28 minutes later. Energy conservation measures allowed the mission to be extended by one day to collect additional science data. A total of 88 experiments in 11 disciplines of science and technology were performed. These experiments spanned a wide range of categories including automation and robotics, telescience, biotechnology, physiology, fluid physics, material solidification and crystallization, Earth observations, and astronomy. The payload was deactivated at 126:06:25 G.m.t. and the final Spacelab deactivation occurred 3 hours 10 minutes later. Preliminary analysis has shown that experiments have met or exceeded the mission objectives in almost all cases.

Material Sciences Experiment Double Rack for Experiment Modules and Apparatus

Rack 3 was the material sciences experiment double rack for experiment modules and apparatus (MEDEA), and contained nine experiments which are as follows:

a. Floating Zone Growth of Gallium Arsenide Experiment.

b. Floating Zone Crystal Growth of Gallium-Doped Germanium.

c. Hysteresis of the Specific Heat CV During Heating and Cooling through the Critical Point.

d. Diffusion of Nickel in Liquid Copper-Aluminum and Copper-Gold Alloys.

e. Directional Solidification of Germanium-Gallium Arsenide Eutectic Composites.

f. Cellular-Dendritic Solidification with Quenching of Aluminium-Lithium Alloys.

g. Directional Solidification of a Copper-Manganese Alloy.

h. Thermoconvection at Dendritic-Eutectic Solidification of a Aluminum-Silicon Alloy.

i. Growth of Gallium-Arsenide from Gallium Solutions.

Both the ellipsoid heating facility (ELLI) and the gradient furnace with quenching (GFQ) experiments were able to achieve more runs than planned prior to the mission. The high precision thermostat (HPT) was able to make measurements to substantiate the singularity of thermo-physical properties, specifically the critical temperature zone. This substantiation was unclear from the Spacelab D1 data.

Werkstofflabor Material Sciences Laboratory

The Werkstofflabor (WL) Material Sciences Laboratory was located in rack 8 of the Spacelab module. The facility consisted of five furnaces, a fluid physics module, and a crystal growth module. The laboratory contained the following experiments.

a. OSIRIS: Oxide Dispersion Strengthened Single Crystalline Alloys Improved by Resolidification in Space.

b. Impurity Transport and Diffusion in INSB Melt under Microgravity Environment.

c. Cellular-Dendritic Solidification at Low Rate of Aluminium-Lithium Alloys.

d. Directional Solidification of the Lithium Fluoride - Lithium Barium Fluorine - Eutectic.

e. Separation Behavior of Monotectic Alloys.

f. Liquid Columns' Resonances.

g. Stability of Long Liquid Columns.

h. Higher Modes and their Instabilities of Oscillating Marangoni Convection in a Large Cylindrical Liquid Column.

i. Marangoni-Benard Instability.

j. Onset of Oscillatory Marangoni Flows.

k. Marangoni Convection in a Rectangular Cavity.

l. Stationary Interdiffusion in a Non-Isothermal Molten Salt Mixture.

m. Transport Kinetics and Structure of Metallic Melts.

n. Nucleation and Phase Selection During Solidification of Under-cooled Alloys.

o. Heating and Remelting of an Allotropic Iron-Carbon-Silicon Alloy in a Ceramic Skin and the Effect of the Volume Change on the Mold's Stability.

p. Immiscible Liquid Metal Systems.

q. Convective Effects on the Growth of GainsB Crystals.

r. Vapor Growth of INP-Crystal with Halogen Transport in a Closed Ampoule.

s. Solution Growth of Gallium Arsenide Crystals Under Microgravity.

t. Crystallization of Nucleic Acids and Nucleic Acid-Protein Complexes.

u. Crystallization of Ribosomal Particles.

The experimenters were very pleased with the results obtained from this very complex experiment facility. Experimentation in this facility included diffusion coefficient measurements, which describe the internal mobility of liquids and are important basic data in the chemical and metallurgical processes. In the Spacelab D-2 mission, approximately 40 experiments were made with metallic melts, salt, and glass melts.

Holographic Optics Laboratory

The Holographic Optics Laboratory (HOLOP) was located in rack 11 of the Spacelab module and contained the following experiments.

a. Marangoni Convection in a Rectangular Cavity.

b. Interferometric Determination of the Differential Interdiffusion Coefficient of Binary Molten Salts.

c. Idile: Measurements of Diffusion Coefficients in Aqueous Solution.

d. Nugro: Phase Separation in Liquid Mixtures with Miscability Gap.

A preliminary review of the data showed that all objectives were successfully accomplished.

Baroreflex

The Baroreflex experiment was located in rack 12, and the experiment was used to investigate the theory that lightheadedness and a reduction in blood pressure in astronauts upon standing after landing may arise because the normal reflex system regulating blood pressures behaves differently after having adapted to a microgravity environment. Successful measurements were made on all crew members, and the investigating team is pleased with the results.

Robotics Experiment

The Robotics Experiment (ROTEX) was a six-joint robotic arm that operated within an enclosed workcell in rack 6 of the Spacelab module. The arm used teleprogramming and artificial intelligence to evaluate the designs, verification and operation of advanced autonomous systems for future application.

The complete automation system of the ROTEX experiment performed extremely well. Several modes were successfully demonstrated including telescience operations from the ground and by the crew. The arm performed extremely well in capturing a free-floating object.

Anthrorack

The Anthrorack (AR) was developed by ESA, and is designed to investigate human physiology under microgravity conditions. The AR provided a set of common user stimulation and measurement instruments, supported by centralized services. Experiments that were conducted using the AR equipment are as follows:

a. Cardiovascular Regulation at Microgravity.

b. Central Venous Pressure during Microgravity.

c. Determination of Segmental Fluid Content and Perfusion.

d. Left Ventricular Function at Rest and Under Stimulation.

e. Peripheral and Central Hemodynamic Adaptation to Microgravity During Rest, Exercise, and Lower Body Negative Pressure in Humans.

f. Tonometry - Intraocular Pressure in Microgravity.

g. The Central Venous Pressure during Microgravity.

h. Tissue Thickness and Tissue Compliance Along Body Axis Under Microgravity Conditions.

i. Changes in the Rate of Whole-Body Nitrogen Turnover, Protein Synthesis and Protein Breakdown under Conditions of Microgravity.

j. Regulation of Volume Homeostasis in Reduced Gravity with Possible Involvement of Atrial Natriuretic Factor Urodilatin and Cyclic GMP.

k. Effects of Microgravity on Glucose Tolerance.

l. Influence of Microgravity on Endocrine and Renal Elements of Volume Homeostasis.

m. Effects of Spaceflight on Pituitary-Gonad-Adrenal Function in the Human.

n. Adaptation to Microgravity and Readaptation to Terrestrial Conditions.

o. Pulmonary Stratification and Compartment Analysis with Reference to Microgravity.

p. Pulmonary Perfusion and Ventilation in Microgravity Rest and Exercise.

q. Ventilation Distribution in Microgravity.

r. Effects of Microgravity on the Dynamics of Gas Exchange, Ventilation and Heart Rate in Submaximal Dynamic Exercise.

s. Cardiovascular Regulation in Microgravity.

The facility collected scientific data on the cardiovascular system, pulmonary system, and the fluid-shift phenomena. The data will aid in the development of medical diagnostic techniques. A new type of measurement was successfully made, a ballistocardiograph. The investigating team was pleased with the results and the amount of data collected was in excess of that planned.

Biolabor Facility

The Biolabor facility was developed by Germany (MMB/Erno) for use in the Shuttle. The facility is for the conduct of research in electrofusion of cells, cell cultivation, botany experiments, and zoological experiments. The facility is equipped with a microscope, a cell electrofusion control unit, two cell cultivation incubators, a cooler, and two middeck-mounted cooling boxes. The following experiments were performed using this facility.

a. Development of Vestibulocular Reflexes in Amphibia and Fishes with Microgravity Experience.

b. Comparative Investigations of Microgravity Effects on Structural Development and Function of the Gravity Perceiving Organ of Two Water-Living Vertebrates.

c. Structure- and Function-Related Neuronal Plasticity of the Central Nervous System of Aquatic Vertebrates During Early Ontogenetic Development under Microgravity Conditions.

d. Immunoelectron Microscopic Investigation of Cerebellar Development at Microgravity.

e. Gravisensitivity of Cress Roots.

f. Cell Polarity and Gravity.

g. Influence of Gravity on Fruiting Body Development of Fungi.

h. Significance of Gravity and Calcium-Ions on the Production of Secondary Metabolites in Cell Suspensions.

i. Influence of Conditions in Low Earth Orbit on Expression and Stability of Genetic Information in Bacteria. Productivity of Bacteria. Fluctuation Test on Bacterial Cultures.

j. Connective Tissue Biosynthesis in Space: Gravity Effects of Collagen Synthesis and Cell Proliferation of Cultured Mesenchymal Cells.

k. Antigen-Specific Activation of Regulatory T-Lymphocytes of Lymphokine Production. Growth of Lymphocytes under Microgravity Conditions.

l. Enhanced Hybridoma Production under Microgravity.

m. Culture and Electrofusion of Plant Cell Protoplasts under Microgravity: Morphological/Biochemical Characterization.

n. Yeast Experiment HB-L29/Yeast: Investigations on Metabolism.

The biolabor facility performed very well, and the scientific results were very satisfying to the investigating team.

Cosmic Radiation Experiments

a. Biological HZE-Particle Dosimetry with Biostack.

b. Personal Dosimetry: Measurement of the Astronauts Ionizing Radiation Exposure.

c. Measurement of the Radiation Environment Inside Spacelab at Locations which differ in Shielding against Cosmic Radiation.

d. Chromosome Aberration.

e. Biological Response to Extraterrestrial Solar UV Radiation and Space Vacuum.

Unique Support Structure Payloads

The Unique Support Structure was mounted in the payload bay near the Spacelab module, and the structure provided support for additional experiment facilities which were connected to the Spacelab for power and data, but ran independently. The following experiments were located on this structure.

a. Material Science Autonomous Payload (MAUS). This payload was composed of two experiments; one which explored diffusion phenomena of gas bubbles in salt melts (gas bubbles in glass melts and reaction kinetics in glass melts), and the second which performed research on complex boiling processes (pool boiling).

b. Atomic Oxygen Exposure Tray (AOET). This tray was a self-standing facility that performed experiments in the field of material science. The AOET was a quasi-passive sample array of 124 circular or rectangular sample plates mounted in the payload bay such that the samples were facing the incoming atmospheric flow.

c. Galactic Ultrawide-Angle Schmidt System Camera (GAUSS). This instrument was an ultraviolet camera which took about 100 wide-angle (field of view was 145°) photographs of the galaxy and the Earth's atmosphere. The camera's film magazine was reported to be full with over 100 pictures of the Milky Way and the Earth's atmosphere.

d. Modular Opto-Electronic Multispectral Stereo Scanner. This instrument, known as MOMS, was an advanced camera system of Earth observation. The camera provided imaging data from space for photogrammetric mapping and thematic mapping applications. The MOMS tape recorder was filled to its capacity of nearly 5 hours. Data were obtained over the Philippines, Cambodia, Australia, and Africa. The electronic camera system provided three-dimensional topographical exposures that are providing information on the kind as well as the structure of the surface. The investigating team believes that information on geology, building construction, and vegetation will be contained in the data.

Crew Telesupport Experiment

This experiment combined an onboard-computer-based, multi-media documentation file, which included text, graphics, and photographs, with real-time graphical communications between a crew member and the ground station. The experiment demonstrated communications with the Mission Control Center and the Orbiter. Communications were not totally satisfactory with the German facility as the graphics mode could not be successfully demonstrated.

Shuttle Amateur Radio Experiment

The Shuttle Amateur Radio Experiment (SAREX) enabled four of the crew members to have voice contact with students from around the world. Also, as time permitted, amateur radio operators from the general "ham" community were also able to have a contact with the SAREX. Another amateur radio experiment, called SAFEX, was located in the Spacelab module and was operated by the German payload specialists. The SAFEX used a 2 meter/70 cm antenna mounted on the outside of the Spacelab, while the SAREX used a window-mounted antenna in the Orbiter crew station.

The SAREX operations overall were very successful. All school contacts except one acquired good communications with the crew. The remaining school withdrew voluntarily being content with having heard the crew. The SAREX/Spacelab Amateur Funk Experiment (SAFEX) antenna test was successfully completed. In addition, a short voice contact was made with the Mir cosmonauts.

Preliminary data indicated that the SAFEX antenna (located outside the module) performed significantly better than the SAREX antenna (mounted in the crew compartment windows). The SAREX antenna anomaly was suspected to be a cable fatigue failure at the connector interface. Subsequent SAREX operations were performed using the SAFEX antenna. The SAREX transmitter was used for one of the SAFEX passes after a failure of the SAFEX transmitter. Satisfactory operation of the SAFEX transmitter was regained for use in the final operation.

VEHICLE PERFORMANCE

SOLID ROCKET BOOSTERS/REDESIGNED SOLID ROCKET MOTORS

All SRB systems performed as expected. The SRB prelaunch countdown was normal, and no SRB or redesigned solid rocket motor (RSRM) in-flight anomalies have been identified. No SRB or RSRM Launch Commit Criteria (LCC) or Operational Maintenance Requirements and Specifications Document (OMRSD) violations occurred

Power up and operation of all case, igniter, and field joint heaters was accomplished routinely. All RSRM temperatures were maintained within acceptable limits throughout the countdown. For this flight, the low-pressure heated ground purge in the SRB aft skirt was used to maintain the case/nozzle joint and flexible bearing temperatures within the required LCC ranges. At T-15 minutes, the ground purge was changed to high pressure to inert the SRB aft skirt.

Data indicate that the flight performance of both RSRM's was well within the allowable performance envelopes, and the performance was typical of that observed on previous flights. The RSRM propellant mean bulk temperature (PMBT) was 6[illegible]°F at lift-off. A pressure fluctuation was recorded in the left-hand SRB at T + 71.5 seconds. The thrust vector control and rate gyro assembly data were reviewed for specific responses to the spike. Some activity was noted; however, this activity appears to be normal in all aspects.

Both SRB's were successfully separated from the ET at lift-off plus 125.5 seconds, and reports based on visual sightings from the recovery area indicated that the decelerations subsystem performed as expected. Main parachute 3 on the right SRB sustained heavy ribbon damage in two gores. Gore 60 sustained 37 consecutive broken horizontal ribbons (207 through 243, including ripstop ribbon 229). In addition, gore 61 sustained 82 consecutive broken horizontal ribbons (181 through 262 including three ripstop ribbons 205, 229, and 246). Ripstop ribbons 180 and 263 on either side of the damaged region of gore 61 were intact and appeared to contain the damage. This damage was the result of the main parachute canopy 3 rubbing against the aft bipod strut region of the main canopy 3 rubbing against the aft bipod strut of the aft bipod strut region of the frustum. Pink witness paint was found on main parachute 3 canopy 3 in the damaged region.

Both SRB's were observed during descent and were recovered and returned to KSC for disassembly and refurbishment.

RSRM performance is delineated in the table on the following page.

RSRM PROPULSION PERFORMANCE

Parameter	Left motor, 68°F		Right motor, 68°F	
	Predicted	Actual	Predicted	Actual
Impulse gates				
I-20, 10^6 lbf-sec	65.46	64.80	65.83	64.95
I-60, 10^6 lbf-sec	174.57	173.22	175.42	173.64
I-AT, 10^6 lbf-sec	296.80	296.01	297.12	295.87
Vacuum Isp, lbf-sec/lbm	268.50	267.80	268.50	267.40
Burn rate, in/sec @ 60°F at 625 psia	0.3686	0.3677	0.3695	0.3683
Burn rate, in/sec @ 66°F at 625 psia	0.3707	0.3698	0.3716	0.3704
Event times, seconds				
Ignition interval	0.232	N/A	0.232	N/A
Web time[a]	110.00	110.30	119.50	110.30
Separation cue, 50 psia	119.70	120.50	119.20	119.90
Action time	121.80	122.50	121.30	122.20
PMBT, °F	68.00	68.00	68.00	68.00
Maximum ignition rise rate, psia/10 ms	90.4	N/A	90.4	N/A
Decay time, seconds (59.4 psia to 85 K), klbf-sec	2.80	2.70	2.80	2.90
Tailoff imbalance Impulse differential,	Predicted N/A		Actual 324.6[b]	

Notes:
[a] All times are referenced to ignition command time except where noted by the letter a. These items are referenced to lift-off time (Ignition interval).
[b] Tailoff imbalance is equal to left motor minus right motor, and was calculated by Marshall Space Flight Center.

EXTERNAL TANK

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

Typical ice/frost formations for the April atmospheric environment were observed on the ET during the countdown. Normal quantities of ice or frost were present on the LO_2 and LH_2 feedlines and on the pressurization line brackets, and some frost or ice was present along the LH_2 protuberance air load (PAL) ramps. These observations were acceptable based on criteria given in NSTS-08303. There was no observed ice or frost on the acreage of the LO_2 and LH_2 tank barrel.

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

ET separation was confirmed, and main engine cutoff (MECO) occurred within expected tolerances. ET entry and breakup was nominal and the impact point was approximately 83 nmi. uprange of the preflight predicted point.

Photographs taken after ET separation revealed approximately six divots in the intertank to LH_2 tank flange closeout, numerous small "popcorn" type divots in the intertank acreage area, three areas of missing foam 6 to 8 inches long from the stringer tops, four divots from the forward area of the LH_2 tank insulation below the intertank splice closeout, and the +Y jack-pad closeout was missing. None of these items were a cause for an in-flight anomaly because they were typical of previously observed items and anomaly investigations.

SPACE SHUTTLE MAIN ENGINES

The initial launch attempt for the STS-55 mission experienced an on-pad abort about 3 seconds prior to the planned lift-off. The Space Shuttle main engine (SSME) oxidizer preburner (OPB) purge pressure exceeded the maximum redline value because one of the five check valves in the purge system leaked and the monitor detected combustion product pressure which exceeded the 50-psia redline (Flight Problem STS-55-E-01). After replacement of all three SSME's and the performance of the necessary prelaunch systems and payloads verification, the launch of STS-55 was rescheduled for April 24, 1993. An investigation team was formed and the team determined that the failure was due to a small piece of NITRIL Buna-N O-ring material being caught in the sealing surface of the check valve. The O-ring material was built into the valve during manufacture. Interim action was taken to clear all subsequent flights by running purge cycles followed by reverse leak checks on all check valves prior to the next flight.

For the successful launch, all SSME parameters were normal throughout the prelaunch countdown and were typical of prelaunch parameters observed on previous flights. Engine "READY' was achieved at the proper time, all LCC were met, and engine start and thrust buildup were normal.

Flight data indicate that SSME performance during mainstage, throttling, shutdown and propellant dump operations was normal. High pressure oxidizer turbopump (HPOTP) and high pressure fuel turbopump (HPFTP) temperatures were well within specification throughout engine operation. No failures were noted, nor were any SSME significant problems identified. MECO occurred 510.24 seconds after lift-off.

During ascent, SSME 3 HPFTP experienced coolant liner pressure fluctuations with up to 110-psi shifts (Flight Problem STS-55-E-02). Shifts of this magnitude have been observed in the development program, but are outside of the return-to-flight data base. The pressure shifts also violated the specifications of 300-psid maximum, as determined by the coolant liner pressure minus the main combustion chamber hot gas injection pressure plus 100 psid.

This problem is not considered a constraint to flight since all other flight HPFTP's meet the requirements of the specification and do not exhibit the fluctuations observed during flight.

SHUTTLE RANGE SAFETY SYSTEM

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

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

ORBITER SUBSYSTEMS

Main Propulsion System

The overall performance of the main propulsion system (MPS) was as expected with no anomalies identified. The LO_2 and LH_2 loading was performed as planned with no stop flows or reverts. Also, there were no OMRSD or LCC violations.

Throughout the period of preflight operations, no significant hazardous gas concentrations were detected. The maximum hydrogen concentration level in the Orbiter aft compartment (occurred shortly after the start of LH_2 circulation pumps) was approximately 90 ppm, which is the lowest maximum reading for this Orbiter vehicle.

A comparison of the calculated propellant loads at the end of replenish versus the inventory loads resulted in a loading accuracy of +0.006 percent for the LH_2 and 0.020 percent for LO_2.

Ascent MPS performance was completely normal. Data indicate that the LO_2 and LH_2 pressurization systems performed as planned, and that all net positive suction pressure (NPSP) requirements were met throughout the flight. The GO_2 fixed orifice pressurization system performed as predicted, and the GH_2 pressurization system performed nominally. Evaluation of the flow control valve data also revealed nominal operation.

During ascent, the MPS pneumatic helium pressure decayed 80 psi from 4240 psia at lift-off to 4160 psia at MECO, (Flight Problem STS-55-V-12), which is one data bit (20 psi) below the OMRSD File 9 requirement of +20/-60 psi. Analysis showed that when combined with the temperature change during the T-0 to MECO time frame, a leak of approximately 3,000 scim was present. Postflight, when the system was pressurized, a blowing leak was noted at the actuation port of the 4-inch disconnect opening solenoid, and the leak was equivalent to approximately 3,000 scim's. The leak was determined to be caused by an undertorqued B-nut at the actuation port. The anomaly had no impact on the mission.

The liquid hydrogen (LH2) 4-inch External Tank/Orbiter (ET/Orbiter) disconnect valve closed slowly when commanded following the on-pad abort on March 22, 1993 (Flight Problem STS-55-V-01A). The close command was sent and the open indicator was lost, but the closed indicator was not received until nearly 11 minutes later when the LH_2 topping valve was opened. Troubleshooting included ambient cycling, pressure decays, boroscope inspections, external inspections, and replacement of the actuator. None of these efforts could explain the problem.

After the successful launch, the LH_2 4-inch ET/Orbiter disconnect valve did not close within the specification requirement of 2.8 seconds after MECO. However, the disconnect valve did close at ET/Orbiter umbilical retraction 10.4 seconds after MECO (Flight Problem STS-55-V-01B). Umbilical camera footage at ET separation showed no anomalous venting that would be indicative of either the ET or Orbiter disconnect being stuck open. The crew reported what appeared to be an abnormal amount of venting from the aft left side of the vehicle. However, data do not indicate any source of unusual venting. Video of the umbilical after landing revealed that the actuator push-rod was extended out in the fully open position. It should have been retracted up into the vehicle after the close command was issued. Tests were being conducted as this was written to determine the cause of the disconnect-valve closure anomalies.

During the first launch attempt, the SSME 2 helium bottle pressure reached 4,510 psia, and the LCC limit is 4,500 psia. The pressure remained constant for over one hour with bottle temperatures falling. The cause of the problem was a 50 psia bias in the SSME 2 pressure transducer and a 30 psia bias between the facility regulator set point and the actual delivered pressure. The ground source was switched from secondary to primary, and all Orbiter bottle pressures then dropped approximately 30 psia. As a result, the SSME 2 pressure was reduced to 4480 psia, the LCC violation was cleared, and no waiver was required.

Reaction Control Subsystem

The performance of the RCS was nominal throughout the flight. In addition to the 4,861.7 lbm of RCS propellants consumed during the mission, 7.65 percent of the left OMS propellants and 7.43 percent of the right OMS propellants were consumed during RCS/OMS interconnect operations.

The RCS hot-fire test was performed at 125:11:06 G.m.t. (08:20:16 MET). Data review indicated that all thrusters performed as expected. The RCS was used during entry to complete six programmed test inputs in addition to the normal attitude-control functions.

At 117:18:38 G.m.t. (01:03:48 MET), the heater for RCS thruster L4D failed on (Flight Problem STS-55-V-06). The heater was controlled manually from the flight deck for the remainder of the flight. The switch controlling the thruster L4D heater also controlled the heaters on five other thrusters. The oxidizer and fuel injector tube upper temperatures were limited to 160°F (operational) and 185°F (non-operational), and injector tube lower temperature was limited to 60°F. This failure did not impact operations on this flight.

The upper temperature limits were consistent with the procedures used for STS-49 and STS-50 thruster heater failures. The upper limit was set to protect the Teflon seats of the valve from cold flowing due to valve closing forces. The lower limit protects from valve leakage due to Teflon shrinkage at cold temperatures.

During the course of the mission, three vernier thruster L5D firings had erratic chamber pressure. The chamber pressure data were indicative of gas bubbles passing through the thruster. At the time of these occurrences, the RCS was interconnected to the right OMS. The most likely cause was a small isolated pocket of gas trapped in the crossfeed line during

Orbital Maneuvering Subsystem

The OMS performed satisfactorily throughout the flight. Two maneuvers were performed for a total firing time of 313.7 seconds on each OMS engine. Propellant usage totaled 14,069 lb for the OMS with 8769 lbm of oxidizer and 5290 lbm of fuel used.

Ignition for the OMS-2 maneuver occurred at 116:15:29:54.96 G.m.t. (00:00:39:54.96 MET). The maneuver was 140.4 seconds in duration and the differential velocity (ΔV) was 222.2 ft/sec. The orbit achieved as a result was 162.9 by 160.2 nmi.

The deorbit maneuver was performed at 126:13:29:20 G.m.t. (09:22:39:20 MET). The maneuver was approximately 173 seconds in duration and the ΔV was 290.2 ft/sec.

During the deorbit maneuver, both the right OMS oxidizer and fuel tank pressures decreased about 5 psi over a 73-second period to 245.5 psia for the oxidizer and 243.0 psia for the fuel. The specification for these pressures is 252 psia +5/-7 psia. Following the maneuver, the oxidizer and fuel tank ullage pressures returned to normal lock-up pressures. This condition was not seen on STS-52 when the pressures did not recover to normal lock-up values following the maneuver. A decay was noted during the STS-50 deorbit maneuver; however, the lowest value observed was within specification limits. On STS-55, the right OMS helium tank pressure rate of decay decreased when the propellant tank pressures decreased, indicating that the flow demand had decreased. This condition is indicative of a helium flow problem to the propellant tanks. Postflight testing was performed to isolate the problem area as this report was written.

The right orbital maneuvering engine (OME) low-pressure system was leaking at a rate of approximately 37 scch. The pressure decreased to 300 psia before repressurization was initiated, and the repressurization appeared to fix the leak. A similar signature was seen on STS-52 (Flight Problem STS-52-V-07); however, on STS-52 the leak continued throughout the flight and several repressurizations were performed. Troubleshooting at that time failed to isolate the cause of the anomaly and the decision was made to fly as-is. A review of data throughout the mission indicates that a small (less than 10 scch) leak may still be present.

The oxidizer gauging system performance was nominal; however, both fuel probes exhibited anomalous behavior similar to that noted on STS-50 and STS-52. The cause of the anomalous behavior of the gaging system is still being investigated; however, the probes will not be replaced until the next Orbiter Maintenance Down Period (OMDP) for this vehicle.

Power Reactant Storage and Distribution Subsystem

The power reactant storage and distribution (PRSD) subsystem performed nominally throughout the flight. The five-tank-set configuration supplied 2950.5 lb of oxygen to the fuel cells, 129.8 lb to the environmental control and life support system (ECLSS), and 371.6 lb of hydrogen for the fuel cells. Cryogenics remaining at landing were adequate for an additional 39 hours of flight at the average power level of 17.9 kW.

The depletion of the PRSD tank sets 4 and 5 was completed. The quantities in hydrogen tanks 4 and 5 reached 1.1 percent and 1.5 percent, respectively. The hydrogen consumables redline for tank depletion is 2.5 percent. The tank depletion was discontinued well within the tank hardware temperature limits (-120°F actual vs. 160°F fluid limit; 67°F actual vs. 200°F limit for the heater). Depletion of oxygen tanks 4 and 5 was discontinued when a heater temperature reached 250°F (tank heater limit is 350°F). The oxygen fluid temperature reached 100°F vs. the 160°F limit. Quantities remaining in oxygen tanks 4 and 5 settled at 6.8 percent and 6.3 percent, respectively, with an oxygen consumables redline for tank depletion of 6.5 percent. The cryogenics consumables margin was improved by depleting tank sets 4 and 5 since actual residual quantities were lower than predicted.

Fuel Cell Powerplant Subsystem

The fuel cells performed nominally in meeting all electrical requirements of the flight. The fuel cells provided 4296 kWh of electrical energy during the flight at an average power level of 17.9 kW and electrical load average of 584 amperes. The total oxygen consumed in the generation of the electricity was 2950.5 lb, total hydrogen consumption was 371.6 lb, and 3,322.1 lb of water were produced.

Four purges of the fuel cells were performed during the mission. STS-55 was the first mission that performance decay was slow enough to reach the desired goal of 72 hours between purges. The reactant purity analysis revealed that the cryogenics loaded into the tanks was extremely clean, which is the major contributing factor to the 72-hour fuel cell purge interval achieved on this mission.

At 117:06:52 G.m.t. (00:16:02 MET), the fuel cell 2 oxygen-flow meter failed off-scale low (Flight Problem STS-55-V-05). This was the first off-scale-low failure of the -01 configuration sensors. Fuel cell flow meter failures have no mission impact as other indications of fuel cell reactant flow rates are available.

The fuel cell 2 alternate water line temperature went up to 130°F, which was above the operating range of the heater. The cause of this condition was warm fuel cell water leaking at specification levels past the alternate water line check valve. This condition did not affect the flight in any manner.

Auxiliary Power Unit Subsystem

The APU subsystem performed nominally throughout the flight with no in-flight anomalies noted. However, three minor problems occurred and are discussed in the following paragraphs. The table on the following page shows the APU run times and fuel consumption by APU serial number and position.

Flight Phase	APU 1 (S/N 407)		APU 2 (S/N 403)		APU 3 (S/N 402)	
	Time, min:sec	Fuel consumption, lb	Time, min:sec	Fuel consumption, lb	Time, min:sec	Fuel consumption, lb
On-pad abort	5:45	16	5:45	20	5:45	17
Ascent	21:11	48	21:11	54	21:11	56
FCS checkout	5:09	15	-----	--	-----	--
Entry[a]	59:00	102	80:39	158	59:01	120
Total[a]	91:05	181	107:35	232	85:57	193

Notes:
[a] The APU's ran for 15 minutes 4 seconds after landing (touchdown).

The APU 1 seal cavity drain system pressure decayed from about 16 psia to 2.5 psia over a six-day period and remained at 2.5 psia for the remainder of the mission. Relief valve leakage is believed to be the cause, and this leakage has been seen on previous missions. All relief valves were checked during postflight activities to verify normal OMRSD operations.

Early activation (5 to 10 minutes) of the tank/fuel line/water system heaters on APU 2 was required after ascent to avoid violating the lower fault detection annunciation (FDA) limit of 48°F. Systems 1 and 3 reached 49°F and nominal heater performance was observed. An evaluation is now underway to determine if the lower FDA can be lowered to avoid future occurrences.

APU 1 had one gearbox repressurization during entry about four minutes prior to landing. Additionally, the lubrication oil outlet pressure violated the lower FDA limit of 25 psia twice after APU start for entry [126:13:46:14 G.m.t. (09:22:56:14 MET) and 126:13:46:35 (09:22:56:35 MET)], and once later during entry. The pressure then increased to approximately 30 $\pm$ 5 psia for the remainder of the mission, and all lubrication oil system temperatures were nominal throughout entry. The APU is known to leak GN_2 past the turbine carbon seal, but it does not leak beyond the specification limit. This APU will be flown one more mission before being removed because of gas generator valve module (GGVM) life limits.

Hydraulics/Water Spray Boiler Subsystem

Overall hydraulics/water spray boiler (WSB) subsystem performance was nominal except for the unexpected response of hydraulics system 3 main pump drain temperature to circulation pump operations, a momentary freeze-up and subsequent over-cool by APU 1 lubrication oil during ascent, and an over-cool of WSB 3 during entry. Hydraulics and WSB performance during the on-pad abort and the launch scrub was nominal.

WSB 2 operations during the first launch attempt in March revealed a small internal leak in the GN_2 regulator. The allowable internal leakage through a WSB regulator is 0.5 sccm (approximately 0.05 psi/day with 2420-psi inlet pressure and 118 lb of water). Calculation of the internal leakage seen during this launch attempt showed approximately 23 sccm (1.1 psi/hr). The internal leak repeated again on the second launch attempt, and it was calculated to be 3.793 psi/hr; however, the leak was not present during the final launch countdown. As a result of these problems, the regulator will be replaced during the turnaround process.

The freeze-up of WSB 3 during ascent resulted in the lubrication oil return temperature reaching 277°F before the core temperature indicated spraying. The flight specification upper limit is 275°F. The elevated temperatures induced high-rate spraying that in turn caused an over-cooling condition where the temperature reached 229°F. Following this, the temperature stabilized at 252°F, as required. The freeze-up lasted approximately 60 seconds, and the condition did not affect flight operations.

The prolonged bottom-to-Sun attitude resulted in numerous circulation pump cycles because of low fluid temperatures in the rudder/speedbrake return lines. To conserve power, the rudder/speedbrake return line temperature set points for the circulation pump control were lowered by 5°F.

The hydraulic system 3 main pump drain temperature exhibited an unusual signature. The temperature was responding rapidly to each circulation pump run during on-orbit operations. Because the main pump does not operate on-orbit, the temperature in the line should be relatively constant. A similar signature was observed in the STS-50 data. Hydraulic systems 1 and 2 main pump case drain temperature measurements did not respond to circulation pump operations. The system 3 drain temperature was also over 20°F cooler during entry. It was determined from postflight inspections that the sensor had been bonded to the hydraulic system 3 filter module high pressure outlet line, which was the wrong line. The sensor was moved to the correct location.

Review of the on-orbit hydraulic system pump 1 operations indicated that pump 1 on-times were considerably greater than either pump 2 or pump 3 for the same temperature differential increase. Data review and analysis showed that unlike systems 2 and 3, system 1 hydraulic fluid was flowing through the rudder/speedbrake power drive unit (PDU), and this accounted for the longer circulation pump operations.

During entry, WSB 3 had an out-of-specification over-cooling condition with the temperature going from 252°F to 226°F. The specification allows only a 15°F drop from steady-state for over-cooling to take place. Violation of this requirement normally requires a lubrication oil hot flush; however, since this was an Improved APU (IAPU) and since IAPU's are not contamination generators, the hot-flush was waived.

Electrical Power Distribution and Control

The electrical power distribution and control (EPDC) subsystem performed nominally throughout the mission.

At approximately 116:16:48:32 G.m.t. (00:01:58:32 MET), the -Y and -Z star tracker doors were opened. Concurrently and as expected, the forward motor control assembly (FMCA) 2 operational status (OP STAT) measurement (V76X2122E) went from 1 to 0 showing relay operation. Both doors opened with dual motor drive time and automatic inhibit of the ac relays from the limit switches occurred. At the completion of that sequence, the measurement should have returned to 1; however, it did not (Flight Problem STS-55-V-03). The measurement indicated 0 for the remainder of the flight. This measurement reflects the status of left/right (L/R) vent door 1 and 2, L/R air data probe motor 2, -Y star tracker motor 2 close, and -Z star tracker motor 2 open relays. A data review indicated that the -Z star tracker motor 2 open relay caused the OP STAT 2 indication to remain at 0. The star tracker doors were fully open allowing normal operations. This problem represented no mission impact.

During postflight operations at Dryden Flight Research Facility (DFRF) in preparation for ferrying back to KSC, the star tracker doors were cycled open. Data indicated that the doors opened, but that the operational status indication still did not revert back to its 1 state. The test verified a problem existed in the K16 relay. Further troubleshooting performed at KSC identified the anomaly as the K16 relay failed in the closed position.

Environmental Control and Life Support System

The environmental control and life support system (ECLSS) performed nominally throughout the mission. Two anomalies were noted during the mission and these are discussed in the following paragraphs.

The atmospheric revitalization subsystem (ARS) performed satisfactorily. The air and water coolant loops performance was normal. The CO_2 partial pressure was maintained below 6.0 mmHg. The cabin air temperature and relative humidity peaked at 80.5°F and 45.6 percent, respectively. The avionics bays 1, 2, and 3 air outlet temperatures peaked at nominal levels of 103.3°F, 104.5°F, and 89.5°F, respectively. The avionics bays 1, 2, and 3 water coldplate temperatures peaked at nominal levels of 89.5°F, 92.0°F, and 82.0°F, respectively.

The regenerable carbon dioxide removal system (RCRS) performed in an excellent manner with no problems identified.

The cabin pressure control systems were both used to maintain cabin total pressure and oxygen partial pressure nominally following the depletion of the Spacelab nitrogen.

The active thermal control system (ATCS) performance was nominal except for the shutdown of the FES.

At 118:15:27 G.m.t. (02:00:37 MET), the FES experienced an over-temperature shutdown. The FES was deactivated until normal supply water pressure of 30 psia was restored. At 118:23:47 G.m.t. (02:08:57 MET), with GN_2 pressure restored, a FES water dump was initiated. After 5 minutes of stable operation, the FES again experienced an over-temperature shutdown. The crew cycled the FES and it immediately shut down without reaching its control band. All shutdowns occurred on the primary A controller. The shutdowns were attributed to ice formation in the topping core while operating at low supply-water pressure. The ice was successfully removed using a flush procedure about 14 hours after the last FES shutdown. The radiators were bypassed to increase the Freon inlet temperature to the FES and then the secondary controller was cycled several times to flush the ice from the core. A momentary drop in the right topping duct temperatures indicated that some ice passed through the duct. The FES was operated on the primary controller B for about an hour before the FES and the duct heaters were deactivated to conserve power for the remainder of the mission. The radiators were deployed at 119:14:50 G.m.t. (03:00:00 MET) to provide additional heat rejection since the FES was no longer being operated. The radiators were stowed at 125:00:10 G.m.t. (08:10:00 MET), and the FES primary B controller was used for supplemental cooling. The primary A controller was selected for two water dumps, starting at 125:19:30 G.m.t. (09:04:40 MET) and 125:20:53 G.m.t. (09:06:03 MET), and the controller operation was nominal, therefore, exonerating any controller malfunction as a cause of the earlier shutdowns.

The FES duct and nozzle heaters were activated on system B in preparation for FES activation and radiator stowage. The FES was activated in primary B controller at 125:00:20 G.m.t. (08:09:50 MET) and demonstrated proper operation. The radiators were stowed shortly thereafter. The primary A controller was selected at 126:02:28 G.m.t. (09:11:38 MET) for a FES water dump that lasted approximately 67 minutes. Controller operation was nominal throughout this period.

The radiator cold soak provided cooling during entry through touchdown plus 13 minutes when the ammonia boiler system (ABS) primary A control was selected. Evaporator outlet temperatures were maintained to a nominal 36°F. This was the first use of the system A ammonia boiler since its installation during the OMDP. The ABS had an under-temperature condition during KSC checkout; however, special procedures were developed for this vehicle, and these allowed the ABS to control temperatures nominally.

The supply water and waste management systems performed adequately throughout the mission. Supply water was managed through the use of the FES and overboard dump system. Twelve supply water dumps were performed at a rate of 1.47 percent/minute (2.42 lb/min). The supply water dump line temperature was maintained between 76°F and 107°F with the use of the line heater.

The waste-water liquid pressure increased by 13 psig to 22 psig during the first 5 hours of the mission. A concern was expressed with respect to the tank bellows being stuck; however, an increase in waste-tank quantity had accompanied several of the waste liquid-pressure increases due to urine/fan separator use. Furthermore, past data indicated that the bellows in the OV-102 vehicle waste tank exerted more force when compared with other vehicles, thus requiring a higher liquid pressure to fill the tank. At the time of this occurrence, no limits were being violated with the differential pressure within the 10-psid life cycle pressure limit across the bellows.

At 117:02:24 G.m.t. (00:11:34 MET), about three hours into a FES water dump, the gaseous nitrogen regulator pressure in the common manifold for the supply and waste water tanks dropped to 6 psig. The FES water dump was terminated 11 minutes later to prevent any anomalous FES operation. Troubleshooting and malfunction-procedure workarounds pinpointed a probable leak in the nitrogen system that pressurizes the water tanks. The water alternate pressure valve was opened and all water tanks were pressurized with cabin air. A FES supply water dump was subsequently completed successfully.

At approximately 118:02:12 G.m.t. (01:11:22 MET), the crew reported that a puncture was found in the wall of the waste water tank (Flight Problem STS-55-V-04). Subsequent video was downlinked showing the puncture and deformation of the waste water tank wall. The crew reported no signs of liquid leakage, thus indicating that the tank bellows was still intact. As a result of the gaseous nitrogen leak, the CWC was placed in use for holding the waste water. Four waste water dumps from the CWC were successfully performed throughout the flight. An IFM procedure to isolate the GN_2 leak from the water tank pressurization system was completed successfully at 118:23:34 G.m.t. (02:08:44 MET), and all supply water tanks were repressurized to 16 psig. The postflight investigation showed that an existing dent in the tank wall jammed one side of the bellows, eventually forcing a rulon tab on the bellows through the tank wall.

The crew noted that odors were being given off by the CWC, but no leakage was evident. Following a successful waste water dump, the crew was instructed to place the CWC in the Extended Duration Orbiter (EDO) wet trash volume. The crew configured the EDO wet trash volume and connected the vent to provide continuous compartment venting.

The waste collection system (WCS) performed satisfactorily throughout the mission. No anomalies or problems with the WCS were identified.

Smoke Detection and Fire Suppression Subsystem

All smoke detection system parameters remained within nominal ranges throughout the mission. The use of the fire suppression system was not required.

Airlock Support System

The airlock support system was not used to support an extravehicular activity (EVA) during this flight. All airlock system parameters remained within normal ranges throughout the flight. The tunnel adapter EVA hatch thermal cover came loose apparently during ascent (Flight Problem STS-55-V-09). The Thermal Control Section of the report contains a discussion of this anomaly.

Avionics and Software Support Subsystems

The integrated guidance, navigation and control subsystem performance was nominal throughout the flight. None of the identified problems impacted the flight.

The IMU's performed satisfactorily. However, approximately 9 hours before the planned launch on April 24 (second attempt) while changing the mode of the IMU 2 (model KT-70) from standby to operate, an IMU 2 platform-fail built-in test equipment (BITE) indication was received (Flight Problem STS-55-V-02). Several mode cycles between standby and operate were made and the failure was not repeated. As a result of the initial failure indication and the uncertainty of the possible recurrence of the failure, a decision was made to replace the IMU and reschedule the launch.

Prior to the transition to operational sequence (OPS) 2, a roll-rate build-up was noted. Data analysis showed the negative roll direction rate build-up was caused by thrust from operating the FES hi-load evaporator while in free drift. The direction and roll rate attained are consistent with the calculated roll rate based on venting. Although unusual during this time period, the vehicle was in free drift attitude to satisfy a payload requirement.

The data processing system hardware and flight software performed adequately. At 123:23:35:39 G.m.t. (07:08:45:39 MET), the crew entered an Item 18 Execute to initiate the MMU 1 checkpoint. Thirteen seconds later, Off/Busy MMU 1 and Checkpoint Fail fault messages were annunciated by GPC 4, and GPC 4 logged a single I/O error plus other indications (Flight Problem STS-55-V-10). The crew cycled the MMU power in accordance with normal malfunction procedures and the checkpoint was satisfactorily completed on a subsequent attempt. The failure history of MMU 1 as well as the software interfaces were investigated in an effort to determine the cause of this occurrence. MMU 1 was used throughout the rest of the mission without a recurrence of this anomaly.

At 124:12:59 G.m.t. (07:22:09 MET), GPC 4 annunciated an input/output error on CRT 4 (Flight Problem STS-55-V-11). The crew reported that the CRT 4 display electronics unit (DEU) BITE flag was tripped and that CRT 4 was blank. Due to power conservation requirements, CRT 4 had been taken to "standby" a number of times prior to the annunciation. In addition, the CRT also had been displaying extended lines on the antenna display prior to the annunciation. The crew performed a malfunction procedure, but the CRT was not recovered. CRT 4 was powered down and remained powered down for the rest of the mission. Due to the signature, it is believed that the problem resides in the DEU.

The FCS performed nominally. The FCS checkout was completed at approximately 125:10:50 G.m.t. (08:20:00 MET), and the data review indicated that the checkout was nominal.

The displays and controls subsystem performed satisfactorily. Likewise, the operational instrumentation (OI) and the modular auxiliary data system (MADS) performed in a nominal manner.

Communications and Tracking Subsystem

The performance of the communications and tracking subsystem was nominal. At 117:00:12 G.m.t. (00:10:22 MET), an anomaly with closed circuit television (CCTV) camera A was noted. The downlink video was severely degraded and had horizontal multicolored lines running through the picture, coupled with cyclic blooming. These conditions are indicative of a power supply failure. The camera was powered down and not used for the rest of the mission. The camera was removed and troubleshooting will be performed at Johnson Space Center (JSC).

First noted at 117:19:00 G.m.t. (01:05:10 MET), camera D had slightly degraded video. The camera exhibited a slight jitter in its video image throughout the mission. The camera was removed and troubleshooting will be performed at JSC.

At 121:03:49 G.m.t. (04:12:59 MET), Mission Specialist 2 reported a headset problem. Transmissions were intermittent on wireless crew communications system (WCCS) crew remote unit (CRU) serial number 1037 (Flight Problem STS-55-V-13).

The batteries were changed, but this did not resolve the problem. Both the PTT ICOM and PTT XMIT buttons were used, and transmissions were intermittent using both buttons. When pressure was applied to the PTT ICOM and PTT XMIT buttons, the CRU appeared to work properly. The faulty unit has been returned to JSC for troubleshooting.

At 123:20:11 G.m.t. (07:05:21 MET), the crew reported that the VCCS B audio interface unit (AIU) had failed in the RF transmit mode, but was still operating in the hard-line (HL) mode (Flight Problem STS-55-V-14). The crew also indicated that the audio terminal unit (ATU) to which the B unit was connected was operating correctly. The cause of this failure is unknown. The AIU was returned to JSC for troubleshooting.

At 124:04:24 G.m.t. (07:13:34 MET) while configured for two-way Ku-band communications during a Tracking and Data Relay Satellite (TDRS) handover, the Ku-band fail-safe circuit was disabled via a stored program command (SPC). A second command that was intended to reenable the fail-safe circuit was incorrect and inadvertently turned the Ku-band to "standby". As a result, communications with the Orbiter were lost for about 80 minutes. Communications were regained after the crew reactivated the Ku-band system.

The TIPS began operating satisfactorily. Following a problem earlier in the mission when a TIPS message sent via Ku-band was not received onboard, a procedure was developed to correct the problem. The EBIA must be powered on for TIPS to operate in the Ku-band mode. The EBIA and the TAGS operate from the same remote power controller (RPC); when the TAGS is powered off by ground command, the EBIA is also powered off. A procedure was developed to keep the EBIA on while TAGS is powered off to enable TIPS to receive messages via Ku-band. This TIPS configuration operated well until late in the mission when it was turned off to save paper for possible future graphics requirements.

A review of the postlaunch lightning data at KSC revealed a RF signal that was detected by the LDAR system during ascent between 47 and 50 seconds MET. Orbiter data showed simultaneous electromagnetic disturbance being registered on UHF receiver 4. The LDAR was tuned to 63 MHz and the UHF receiver operated at 243 MHz, indicating that the interference was broadband in nature.

Structures and Mechanical Subsystems

All mechanically actuated subsystems performed nominally. The drag chute was flown for the eighth time during the Space Shuttle Program. The drag chute was deployed as planned before nose gear touchdown and was jettisoned 25.69 seconds later. The drag chute trailed straight behind the vehicle in the reefed configuration, but trailed off to one side after disreef. All drag chute operations were nominal. The crew reported no steering corrections were required because of the drag chute.

Evaluation of the entry heating damage to the elevon cove of the right wing following the STS-56 mission, during which the alternate elevon schedule was used in support of Development Test Objective (DTO) 251, has shown that the heating was outside the thermal design base and previous flight experience. This resulted in a concern being raised about performing DTO 251 with the alternate elevon schedule during the STS-55 entry. The alternate elevon schedule allowed up-elevon deflection of 10° and more if aileron trim is required. The evaluation showed that if an early transition occurred following entry interface as it did on STS-56 (coupled with the fact that this Orbiter is approximately 20,000 lb heavier than the STS-56 Orbiter), the damage to the elevon cove may have been greater than that seen on STS-56. As a result, a decision was made by the MMT to use the automatic elevon schedule which required a maximum of 7° up elevon. No elevon cove damage was found during postflight inspections.

The landing and braking data are presented in the following table.

LANDING AND BRAKING PARAMETERS

Parameter	From threshold, ft	Speed, keas	Sink rate, ft/sec	Pitch rate, deg/sec
Main gear touchdown	1895	217.4	~3.5	n/a
Nose gear touchdown	7288	160.2	n/a	3.92

Braking initiation speed	94.6	knots (keas)
Brake-on time	29.0	seconds (sustained)
Rollout distance	10,095	feet
Rollout time	60.9	seconds
Runway	22	(concrete) at EAFB
Orbiter weight at landing	227,279	lb (landing estimate)

Brake sensor location	Peak pressure, psia	Brake assembly	Energy, million ft-lb
Left-hand inboard 1	936	Left-hand outboard	10.15
Left-hand inboard 3	912	Left-hand inboard	13.03
Left-hand outboard 2	816	Right-hand inboard	16.16
Left-hand outboard 4	864	Right-hand outboard	18.67
Right-hand inboard 1	1332		
Right-hand inboard 3	1320		
Right-hand outboard 2	1344		
Right-hand outboard 4	1344		

Aerodynamics, Heating, and Thermal Interfaces

The ascent and entry aerodynamics were nominal. DTO 251 - Part 5, (Entry Aerodynamics Control Surfaces Test - Alternate Elevon Schedule was performed during entry; however, the DTO was modified to use the automatic elevon schedule due to thermal concerns resulting from damage seen in the elevon cove area of OV-103 after STS-56.

Evaluation of the integrated heating showed that all heating had been within nominal limits. The thermal interfaces all performed satisfactorily and within the experience base.

Thermal Control Subsystem

The thermal control subsystem performed nominally with all temperatures being maintained within limits.

At 117:22:33 G.m.t. (01:07:43 MET), the heater for RCS thruster L4D failed on (Flight Problem STS-55-V-06). The heater was controlled manually for the remainder of the flight. The injector upper temperature was limited to 160°F (operational) and 185°F (non-operational). The injector lower temperature was limited to 60°F. The switch controlling the thruster L4D heater also controls the heaters on five other thrusters. This failure did not impact operations on this flight.

Downlink video showed the tunnel adapter extravehicular activity (EVA) hatch thermal cover to be open approximately 80 degrees (Flight Problem STS-55-V-09). This same problem was noted on STS-40 (Flight Problem STS-40-V-09). Thermal analysis indicated that this anomaly would have no mission impact.

The hydraulic system 3 main pump case drain temperature measurement (V58T0385A) exhibited an unusual signature (Flight Problem STS-55-V-07). The Hydraulics/Water Spray Boiler Subsystem contains a more detailed discussion of this anomaly.

The forward fuselage structural temperature violated the entry interface limit of 61°F, reaching 65°F just prior to entry interface. The violation was the result of the attitude the vehicle was in during the one-orbit delay of landing because of weather. A data review indicates that the loads, which include mechanical and thermal loads, experienced during entry were lower than the certified loads. Therefore, this violation was of no impact to the flight or the vehicle.

Aerothermodynamics

During entry, early boundary layer transition was experienced on the lower surface, occurring at Mach 13 which is about 1070 seconds after entry interface. Normal transition occurs between Mach 9 and 6, and between 1100 and 1300 seconds after entry interface. Two gap fillers, protruding about 1/4 inch beyond the outer mold line aft of the nose landing gear doors, are suspected of being the cause of the early transition.

Local heating during entry was nominal with postflight analysis of the data continuing. DTO 251 was modified to avoid abnormal heating that was experienced in the elevon cove area on STS-56.

Acreage heating rise was near the structural temperature limit of experience on the aft fuselage, and the left and right wings.

Thermal Protection Subsystem

Based on structural temperature response data, the thermal protection subsystem performed satisfactorily and prevented heating damage effectively throughout ascent and entry. The overall boundary layer transition from laminar to turbulent flow was symmetric, but occurred earlier than normal.

The TPS sustained 143 hits of which 13 had a major dimension of one inch or greater. Of the total hits, the lower surface had 128, the upper surface 6, the right side 1, the left side 3, the right OMS pod 5 and the left OMS pod had zero. A comparison of these numbers with statistics from previous missions indicates that the total number of hits and hits greater than one inch were both near average. No TPS damage was attributed to material from the wheels, tires, or brakes.

The reusable carbon carbon (RCC) performance was nominal, with small pores with type-A coating-bubbling evident. The nose landing gear door (NLGD) thermal barriers were in good condition, with minor fraying noted. Both aft outboard corner tiles were damaged and will be scrapped. Four protruding Ames gap fillers were noted on the lower surface. Two were located just aft of the NLGD on the left side just off of the centerline. The third was on the left-hand side, inboard of the main landing gear door (MLGD). The fourth was located on the left-hand inboard elevon. The MLGD thermal barriers sustained damage at five locations. The ET door thermal barriers were in good condition.

Base heat shield peppering was nominal. However, one tile that was located between SSME's 2 and 3 was damaged beyond repair. All three dome-mounted heat shield blankets were in good condition. Also, an unusual elliptically shaped area of residue was noted on SSME 3 heat shield at the 4 o'clock position, and it covered an area approximately 6 inches by 9 inches. Chemical samples were taken and the analysis indicates that the residue was primarily ammonium nitrate. The source of the residue is unknown.

Eleven pieces of tile material were found on the runway after landing, and these matched the damage to the three tiles on the lower right edge of the vertical tail stinger. This area has been damaged on previous missions where the drag chute was flown.

A infrared spot radiometer was used to measure the surface temperatures on several areas of the Orbiter in accordance with OMRSD requirements. Twenty minutes after landing, the nosecap RCC temperature was 160.1°F. Fifty-two minutes after landing, the right-hand wing leading edge RCC panel no.9 was 78.2°F, and fifty-five minutes after landing, RCC panel no. 17 was 82.3°F.

FLIGHT CREW EQUIPMENT/GOVERNMENT FURNISHED EQUIPMENT

The flight crew equipment/government furnished equipment operated satisfactorily throughout the mission with the exception of the payload general support computer (PGSC).

The crew reported on flight day 8 that the PGSC deorbit program would not accept a request for only KSC or Edwards landing sites (Flight Problem STS-55-V-16). The crew also observed that the state vector input screen would not accept new data after old data had been deleted. After exiting to the main menu and returning, the problems did not recur. The PGSC was sent to JSC for troubleshooting.

CARGO INTEGRATION

The cargo integration hardware operated without anomaly throughout the mission. Areas of support included the analysis and confirmation of primary Orbiter refrigerator/freezer (ORF) troubleshooting. A suit fan power cable was modified on-orbit for use during the ORF troubleshooting. The primary ORF was shut down for the remainder of the mission, and the backup ORF was activated and functioned properly.

New hardware provided for this flight consisted on two Orbiter aft flight deck ORF instrumentation harnesses which performed properly.

DEVELOPMENT TEST OBJECTIVES AND DETAILED TEST OBJECTIVES

A total of 11 development test objectives and 10 detailed supplementary objectives were assigned to the STS-55 mission. Nine of the 11 DTO's were completed as planned, one (DTO 251) was modified during the mission, and one (DTO 805) was not accomplished. All 10 of the DSO's were completed satisfactorily.

DEVELOPMENT TEST OBJECTIVES

DTO 236 - Ascent Wing Aerodynamic Distributed Loads Verification - This DTO was satisfactorily completed, and the results of the analyses will be published in a separate document. STS-55 was the seventh flight of this DTO.

DTO 251 - Entry Aerodynamic Control Surfaces Test - Alternate Elevon Schedule - The Mission Management Team (MMT) decided to adjust the DTO 251 elevon schedule to the automatic elevon schedule rather than the alternate schedule. In addition, the aileron trim limit for the body flap sweep was expanded as a result of an increase in the end-of-mission Y-axis center of gravity. This DTO was manifested seven times on previous Space Shuttle flights.

DTO 301D - Ascent Structural Capability Evaluation - The data for this DTO was collected and it has been given to the sponsor for evaluation. The results of the evaluation will be reported in a separate document. STS-55 was the forty-first flight of this DTO.

DTO 307D - Entry Structural Capability - Data were collected for this DTO, and the data have been given to the sponsor for evaluation. The results of the evaluation will be reported in a separate document. STS-55 was the thirty-fourth flight of this DTO.

DTO 312 - ET TPS Performance (Methods 1 and 2) - The crew was able to expose one roll of 70-mm film, which contained 34 ET photographs of excellent quality, using the hand-held Hasselblad camera and the 250-mm lens. The crew was also able to expose one roll of good quality 16-mm film with 950 frames (39.6 seconds elapsed time) of photographs for evaluation. In addition, one roll of 16-mm film and one roll of 35-mm film were exposed with the umbilical well cameras. STS-55 was the twenty-ninth flight of this DTO during the Space Shuttle Program.

No major anomalies were observed. Four marks/divots were visible on the LH_2 tank surface (+Z axis to the left of the forward ET/Orbiter attachment bipod) and other marks/divots were seen along the LH_2 tank/intertank closeout. Two marks/divots were also observed on the LH_2 tank/intertank closeout interface on the far side of the ET (-Z axis).

The LH_2 4-inch ET/Orbiter disconnect valve closed slowly, 11 seconds after the command was sent. The valve normally requires one second to close. All of the DTO photography were viewed specifically to determine if any venting from the ET umbilicals could be detected. No signs of venting from the ET were observed.

DTO 521 - Orbiter Drag Chute System (nose in the air deployment after initiation of derotation with crosswind $\leq$ 10 knots and touchdown near the runway centerline) - This DTO was flown as planned and the data are being analyzed by the sponsor. The results of the analysis will be published in a separate document. STS-55 was the eighth flight of this DTO.

DTO 623 - Cabin Air Monitoring - The data for this DTO have been given to the sponsor for evaluation. The results of the evaluation will be reported in a separate document. STS-55 was the thirteenth flight of this DTO.

DTO 660 - Thermal Impulse Printer Demonstration - The TIPS performed satisfactorily once the Ku-band transmission anomaly was understood to be a configuration problem. The EBIA was required as a timing source for the TIPS; however, the EBIA was physically located in the TAGS unit and whenever the TAGS was powered down, the timing source was lost and this resulted in the loss of TIPS operations. Procedures were corrected to enable the EBIA to operate when the TAGS was powered off, and the TIPS operated exceptionally well after this procedural change. STS-55 was the second flight of DTO 660.

DTO 663 - Acoustical Noise Dosimeter Data - Data were collected for this DTO, and the data have been given to the sponsor for evaluation. The results of the evaluation will be published in a separate document. STS-55 was the eighth flight of this DTO.

DTO 665 - Acoustical Noise Sound Level Data - Data were collected for this DTO, and the data have been given to the sponsor for evaluation. The results of the evaluation will be published in a separate document. STS-55 was the third flight of this DTO.

DTO 805 - Crosswind Landing Performance - This DTO was not performed because crosswinds were not of significant magnitude during the landing of the Orbiter. STS-55 was the sixteenth flight of this DTO.

DETAILED SUPPLEMENTARY OBJECTIVES

DSO 323 - Evaluation of Samples Obtained from the Urine Monitoring System (Configuration 1 and 3) - All samples were obtained in accordance with the timeline. The crew reported that some of the early samples were foamy which is indicative of low-volume levels. The samples have been given to the sponsor for evaluation. The results of the evaluation will be published in a separate document.

DSO 486 - Physical Examination in Space - This DSO was performed twice with two video downlinks of the activities that will also serve as partial fulfillment of DSO 802 - Educational Activities. Mission Specialist 2 (Dr. Harris) demonstrated a physical examination of Mission Specialist 1 (Major Precourt) to the Mayo Clinic. The video downlinks have been given to the sponsor for evaluation, and the results will be reported in a separate publication.

DSO 603 - Orthostatic Function During Entry, Landing, and Egress - This DSO was performed as an EDO buildup medical evaluation. Data were collected for this DSO during the desired periods, and the data have been given to the sponsor for evaluation. The results of the evaluation will be reported in a separate publication.

DSO 617 - Evaluation of Skeletal Muscle Performance Following Space Flight - Data for this DSO were collected during postflight medical examinations and tests. The data have been given to the sponsor for evaluation and reporting of the results of the evaluation.

DSO 618 - Effects of Intense Exercise During Space Flight on Aerobic Capacity and Orthostatic Function - Data from the Pilot's exercise period on the day prior to entry were downlinked successfully after initial difficulties caused by an apparent loose connection which the crew corrected. The data are being evaluated by the sponsor, and the results of this evaluation will be reported in a separate publication.

DSO 625 - Measurement of Blood Volume Before and After Space Flight - Data for this DSO were collected during the normal preflight and postflight activities. The data are being evaluated by the sponsor and the results of that evaluation will be published separately.

DSO 802 - (Educational Activities (Objectives 1 and 2 - with 2 being highly desirable) - Videos of the flight operations have been provided to develop educational videos (Objective 1). Objective 2, live downlink of educational activities, was accomplished in conjunction with DSO 486.

DSO 901 - Documentary Television - Numerous activities were video-taped or transmitted in real-time during the mission. Video tapes of these activities are being evaluated.

DSO 902 - Documentary Motion Picture Photography - Numerous activities were photographed and will, as an adjunct, be evaluated in support of this DSO.

DSO 903 - Documentary Still Photography - Numerous still pictures were taken of Earth scenes as well as activities in the crew compartment.

PHOTOGRAPHY AND TELEVISION ANALYSES

LAUNCH PHOTOGRAPHY AND VIDEO ANALYSIS

On launch day, 24 of the expected 24 video views of the launch were screened and no in-flight anomalies were noted. Also during the course of the mission, 54 of the expected 55 launch films were also examined with no anomalies noted.

ON-ORBIT PHOTOGRAPHY AND VIDEO ANALYSIS

No on-orbit photographic or video analysis requirements existed for this mission. However, a detailed discussion and analysis of DTO 312 photography is presented in the DTO section of this report.

LANDING PHOTOGRAPHY AND VIDEO ANALYSIS

On landing day, seven videos plus NASA Select were screened, and no anomalous events or circumstances were noted. All drag chute deployment and jettison activities were taped and all appeared to be nominal.

TABLE I.- STS-55 SEQUENCE OF EVENTS

(a) On-Pad Abort

Event	Description	Actual time, G.m.t.
APU activation	APU-1 GG Chamber Pressure	081:14:46:10.50
	APU-2 GG Chamber Pressure	081:14:46:11.64
	APU-3 GG Chamber Pressure	081:14:46:12.74
SRB HPU activation	LH HPU System A Start Command	081:14:50:32
	RH HPU System A Start Command	081:14:50:32
Main engine start	SSME-3 Start Command to EIU	081:14:50:53.437
	SSME-2 Start Command to EIU	081:14:50:53.557
	SSME-1 Start Command to EIU	081:14:50:53.677
Main engine stop	SSME-3 Shutdown	081:14:50:54.956
	SSME-2 Shutdown	081:14:50:56.259
	SSME-1 Shutdown	081:14:50:57.526
APU Deactivation	APU-1 GG Chamber Pressure	081:14:51:52.70
	APU-2 GG Chamber Pressure	081:14:51:53.55
	APU-3 GG Chamber Pressure	081:14:51:55.09

(b) Mission Timeline

Event	Description	Actual time, G.m.t.
APU activation	APU-1 GG chamber pressure	116:14:45:11.24
	APU-2 GG chamber pressure	116:14:45:12.12
	APU-3 GG chamber pressure	116:14:45:12.95
SRB HPU activation[a]	LH HPU system A start command	116:14:49:33.843
	LH HPU system B start command	116:14:49:33.683
	RH HPU system A start command	116:14:49:33.523
	RH HPU system B start command	116:14:49:33.363
Main propulsion System start[a]	Engine 1 start command accepted	116:14:49:54.292
	Engine 2 start command accepted	116:14:49:54.404
	Engine 3 start command accepted	116:14:49:54.524
SRB ignition command (lift-off)	SRB ignition command to SRB	116:14:50:00.017
Throttle up to 100 percent thrust[a]	Engine 1 command accepted	116:14:50:04.029
	Engine 2 command accepted	116:14:50:04.036
	Engine 3 command accepted	116:14:50:04.037
Throttle down to 72 percent thrust[a]	Engine 1 command accepted	116:14:50:27.069
	Engine 2 command accepted	116:14:50:27.077
	Engine 3 command accepted	116:14:50:27.077
Maximum dynamic pressure ($\bar{q}$)	Derived ascent dynamic pressure	116:14:50:53

[a]MSFC supplied data

TABLE I.- STS-55 SEQUENCE OF EVENTS (Continued)

Event	Description	Actual time, G.m.t.
Throttle up to 104 percent thrust[a]	Engine 1 command accepted	116:14:50:56.669
	Engine 2 command accepted	116:14:50:56.677
	Engine 3 command accepted	116:14:50:56.678
Both SRM's chamber pressure at 50 psi[a]	LH SRM chamber pressure mid-range select	116:14:52:00.537
	RH SRM chamber pressure mid-range select	116:14:52:00.857
End SRM action[a]	RH SRM chamber pressure mid-range select	116:14:52:02:207
	LH SRM chamber pressure mid-range select	116:14:52:02.537
SRB separation command	SRB separation command flag	116:14:52:05
SRB physical separation[a]	LH rate APU A turbine speed LOS	116:14:52:05.497
	RH rate APU A turbine speed LOS	116:14:52:05.497
Throttle down for 3g acceleration[a]	Engine 3 command accepted	116:14:57:32.165
	Engine 1 command accepted	116:14:57:32.195
	Engine 2 command accepted	116:14:57:32.204
3g acceleration	Total load factor	116:14:57:37.8
Throttle down to 67 percent thrust[a]	Engine 3 command accepted	116:14:58:23.686
	Engine 1 command accepted	116:14:58:23.716
	Engine 2 command accepted	116:14:58:23.725
Engine Shutdown[a]	Engine 3 command accept	116:14:58:30.287
	Engine 1 command accept	116:14:58:30.316
	Engine 2 command accept	116:14:58:30.325
MECO	Command flag	116:14:58:30
	Confirm flag	116:14:58:31
ET separation	ET separation command flag	116:14:58:49
OMS-1 ignition	Left engine bi-prop valve position	Not performed - direct insertion trajectory flown
	Right engine bi-prop valve position	
OMS-1 cutoff	Left engine bi-prop valve position	
	Right engine bi-prop valve position	
APU deactivation	APU-1 GG chamber pressure	116:15:06:21.47
	APU-2 GG chamber pressure	116:15:06:22.39
	APU-3 GG chamber pressure	116:15:06:22.73
OMS-2 ignition	Right engine bi-prop valve position	116:15:29:53.9
	Left engine bi-prop valve position	116:15:29:53.9
OMS-2 cutoff	Right engine bi-prop valve position	116:15:32:14.4
	Left engine bi-prop valve position	116:15:32:14.2
Payload bay door open	PLBD right open 1	116:16:18:18
	PLBD left open 1	116:16:19:39

[a] MSFC supplied data.

TABLE I.- STS-55 SEQUENCE OF EVENTS (Concluded)

Event	Description	Actual time, G.m.t.
Flight control system checkout		
APU start	APU-1 GG chamber pressure	125:10:20:01.71
APU stop	APU-1 GG chamber pressure	125:10.25:10.52
Payload bay door close	PLBD left close 1	126:09:21:31
	PLBD right close 1	126:09:23:51
APU activation for entry	APU-2 GG chamber pressure	126:13:24:19.58
	APU-1 GG chamber pressure	126:13:45:57.11
	APU-3 GG chamber pressure	126:13:45:58.43
Deorbit maneuver ignition	Right engine bi-prop valve position	126:13:29:20.3
	Left engine bi-prop valve position	126:13:29:20.1
Deorbit maneuver cutoff	Right engine bi-prop valve position	126:13:32:13.5
	Left engine bi-prop valve position	126:13:32:13.4
Entry interface (400K)	Current orbital altitude above reference ellipsoid	126:13:58:35
Blackout ends	Data locked at high sample rate	No blackout
Terminal area energy management	Major mode change (305)	126:14:23:48
Main landing gear contact	LH MLG tire pressure	126:14:29:59
	RH MLG tire pressure	126:14:29:59
Main landing gear weight on wheels	LH MLG weight on wheels	126:14:29:59
	RH MLG weight on wheels	126:14:30:00
Drag chute deploy	Drag chute deploy 1 CP Volts	126:14:30:14.9
Nose landing gear contact	NLG tire pressure	126:14:30:17
Nose landing gear weight on wheels	NLG WT on Wheels -1	126:14:30:18
Drag chute jettison	Drag chute jettison 1 CP Volts	126:14:30:40.6
Wheels stop	Velocity with respect to runway	126:14:31:04
APU deactivation	APU-3 GG chamber pressure	126:14:44:57.23
	APU-1 GG chamber pressure	126:14:44:58.91
	APU-2 GG chamber pressure	126:14:44:59.67

TABLE II.- STS-55 PROBLEM TRACKING LIST

Number	Title	Reference	Comments
STS-55-V-01	LH_2 4-Inch ET/Orbiter Disconnect (PD3) A) Slow Closure Following Pad Abort	081:14:51 G.m.t. UA-2-A022 IM KB2654	The 4-inch ET/Orbiter disconnect valve closure was slow following the pad abort. Closure did not occur until the topping valve was closed 10 minutes 42 seconds after command (s/b a maximum of 2.8 seconds). Replaced actuator and LV51 vent check valve. Visual inspection of 4-inch boot, plate gap, insulation, and valve mechanism showed no anomalies. Initial testing of actuator showed no problems. Valve performance has been nominal at MECO for four flights.
	B) Did Not Close at MECO	116:14:58 G.m.t. IM 55RF05	The LH_2 4-inch disconnect did not close when commanded at MECO. The valve did close at MECO plus 10 seconds when the Orbiter umbilical plate pulled back in preparation for ET separation. KSC: Troubleshooting is continuing. The PD3, LV50, and LV51 valves will be replaced and sent to Rockwell-Downey for further troubleshooting.
STS-55-V-02	IMU 2 Platform Fail BITE Indication	114:04:42 G.m.t. PR GNC-2-14-0094 IM 55RF01	During moding from standby to operate for the April 24 launch attempt, IMU 2 (KT-70) showed a platform fail BITE indication. Several subsequent STDBY/OPERATE cycles failed to indicate a problem. Problem believed to be with the DC/DC1 card. Scrubbed launch and replaced IMU. KSC: No further KSC action is required.
STS-55-V-03	FMCA 2 OPS STAT 2 Did Not Invert	116:16:48 G.m.t. IM 55RF06 IPR 58V-0007	OPS STAT 2 did not return to a "1" when -Z star tracker door opened. Door drive time and currents were nominal. This could be an indicator problem or a failed closed relay (K16). KSC: Troubleshooting indicated a failed closed relay. FMCA 2 has been replaced.
STS-55-V-04	Waste Water Tank GN_2 Leak	117:16:50 G.m.t. PR ECL-2-14-0083 CAR 55RF02	The wall of the waste water tank was punctured causing a loss of pressurization of all water tanks. There was no liquid leak. The waste tank was isolated from the GN_2 pressurization system by IFM. This allowed the repressurization of the remaining water tanks. A plan for removal, inspection, and failure analysis of the waste tank was developed. KSC: Removed and replaced tank and sent tank to Rockwell-Downey for failure analysis.
STS-55-V-05	Fuel Cell 2 O_2 Flow Sensor Failed Off-Scale Low LEVEL III CLOSURE	117:06:51 G.m.t. IPR 58V-0002 IM55RF03	The fuel cell 2 O_2 flow sensor failed off-scale low. This was the first off-scale low failure of the -01 sensors. The failure was no impact to the mission. KSC: Troubleshooting confirmed flow sensor failure. Will fly as-is.
STS-55-V-06	RCS L4D Primary Heater Failed-On	117:22:23 G.m.t. PR LP05-04-0071 IM 55RF04	At approximately 117:19:05 G.m.t., it was observed that the heater on primary thruster L4D had failed-on. The flight deck switch for this heater controls the heater on five other thrusters. The heaters were managed manually. The thruster was replaced. KSC: Replace thruster.

TABLE II.- STS-55 PROBLEM TRACKING LIST

Number	Title	Reference	Comments
STS-55-V-07	Anomalous Hydraulic System Main Pump Case Drain Temperature	118:05:12 G.m.t. IPR 58V-0008 IMRF5510	The hydraulic system 3 main pump case drain temperature (V58T0385A) exhibited an unusual signature. The temperature responded to hydraulic system 3 circulation pump runs. The signature may indicate a wiring problem or a failed check valve in the filter module. KSC: Troubleshooting determined that the sensor was bonded to the wrong hydraulic line. The sensor will be moved to the proper location.
STS-55-V-08	FES Shutdowns.	118:15:30 G.m.t. 118:23:59 G.m.t. 119:00:06 G.m.t.	Several FES shutdowns were experienced while on the primary A controller. The first FES shutdown occurred after a 2.5-hour FES water dump at cabin pressure. Two other shutdowns occurred with the water tanks pressurized. Theory is that ice formed in the core during the dumps at cabin pressure and caused the shutdowns. A FES topping core flush was performed successfully. KSC: No special testing is required other than spray nozzle inspection during normal postflight OMRSD inspections.
STS-55-V-09	Loose Thermal Cover On Tunnel Adapter Hatch	117:00:30 G.m.t. PR TCS-?-15-2052 IMRF5511	Downlink video showed that the tunnel adapter EVA hatch thermal cover was open. Thermal impact for this mission was minimal. For top Sun attitudes near the nominal EOM, predictions indicated that the hatch may exceed the 113°F touch temperature limit. The crew was informed of this condition. The same problem was seen on STS-40 (STS-40-V-09). KSC: Troubleshooting will be performed to determine problem cause.
STS-55-V-10	MMU 1 SM Checkpoint Fail	123:23:35 G.m.t. PR DIG-2-15-0172 IM 55RF08	At 123:23:35 G.m.t., the crew entered an "ITEM 18 EXEC" to "SM SPEC 60" to initiate an MMU 1 checkpoint. Thirteen seconds later, "OFF/BUSY MMU 1" and "S60 CHECKPT FAIL" fault messages were annunciated by GPC 4. GPC 4 logged a single input/output error and an operational code indicating an MMU OFF/FAIL during an MMU utility write. The crew power cycled the MMU per the malfunction procedure and successfully retried the SM checkpoint. The MMU performed nominally for the remainder of the mission. KSC: Replace MMU.
STS-55-V-11	CRT 4 Failure	124:12:59 G.m.t. PR DIG-2-15-0171 IM 55RF07	During a power-up of CRT 4, GPC 4 annunciated an "I/O ERROR CRT 4" message. The crew reported that the DEU BITE flag was tripped and that CRT 4 was blank. The crew performed a power cycle, but the CRT was not recovered. CRT 4 remained powered down for the remainder of the of the mission. DEU 4 has been replaced.
STS-55-V-12	MPS Pneumatic Helium Pressure Decay During Ascent	116:14:58 G.m.t. IPR 58V-0006	During ascent, the MPS pneumatic Helium system pressure decayed 80 psi (1 bit below the maximum allowable of 60 psi per OMRSD DV41AZO.150). Suspect internal leak with CV4 fill check valve or with valves in the interconnect system. Troubleshooting will consist of a test similar to File III requirement V41AZO.150, and the performance of every flow requirements V41AZO.100 and V41AZO.110. Troubleshooting found an audible leak at the LV50 outlet B-nut.

TABLE II.- STS-55 PROBLEM TRACKING LIST

Number	Title	Reference	Comments
STS-55-V-13	MS2 WCCS Leg Unit (SN 1037) Problem LEVEL III CLOSURE	121:03:51 G.m.t. DR BH330154	Mission Specialist 2 reported a problem with the WCCS leg unit (SN 1037) Push-to-talk on both intercom and air-to-ground was clipping. A battery replacement was unsuccessful in correcting the problem. The unit was returned to the JSC FEPC facility for troubleshooting.
STS-55-V-14	WCCS B Wall Unit Problem LEVEL III CLOSURE	123:20:11 G.m.t. DR BH330151	The crew reported that the WCCS B wall unit had failed in the radio frequency (RF) mode, but the unit still worked in the hardline mode. The crew also indicated that the ATU that the unit B was connected to was operating correctly. The unit was returned to the JSC FEPC facility for troubleshooting.
STS-55-V-15	Right OMS Propellant Tanks Pressure Decrease	126:13:33 G.m.t. IPR 58V-0017	The right OMS oxidizer and fuel tanks ullage pressure decreased 5 psi during the last 70 seconds of the deorbit firing (firing duration was 2 minutes 53 seconds). The specification is 245 psi minimum and the fuel tank pressure dropped to 243 psi. The right OMS helium tank showed a decrease in it pressure decay rate when the propellant tank pressures decreased. The signature is indicative of a helium flow problem to the propellant tanks. KSC: Will troubleshoot for this condition.
STS-55-V-16	SPOC PGSC Data Input LEVEL III CLOSURE	126:00:00 G.m.t.	The crew reported at the MOD/MER Crew Debriefing that on flight day 8 the SPOC deorbit program would not accept a request for only KSC and EDW landing sites. The crew also observed that the SPOC state vector input screen would not accept new data after old data had been deleted. After exiting to the SPoC main menu and returning, the problems did recur. The PGSC has been returned to JSC for troubleshooting.

TABLE III.- MSFC ELEMENTS PROBLEM TRACKING LIST

Problem	Element	Description	Comments/Status
1. STS-55-E-1 ME-3 Oxidizer Preburner Purge Redline Exceedance and Resulting On-Pad Abort	Space Shuttle Main Engine	During the first launch attempt (March 24, 1993) of STS-55, a redline exceedance of the oxidizer preburner purge system occurred at engine start +1.44 seconds on ME-3 (E-2011). The anomaly resulted in an on-pad abort of the mission by the RSLS.	The noted purge redline was established to protect against a failure of the fuel preburner Augmented Spark Ignition (ASI) purge check valve (possible criticality 1 condition). The unwanted mixture of oxidizer with hydrogen-rich hot gas, coupled with a possible ASI line failure could result in over-pressurization of the Orbiter aft compartment. The redline uses two pressure transducers upstream of the five oxidizer check valves. Of these five check valves in the oxidizer purge system, four have orifices upstream of the valves which restrict leakage flow and are considered criticality 3 (no threat to flight safety). A joint NASA/Rocketdyne team has investigated the problem and determined the cause to be contamination of the oxidizer preburner (OPB) ASI check valve. Contamination in the form of a piece of nitrile (buna-n) O-ring (0.146 inch by 0.046 inch by 0.018 inch) was found inside of the check valve during the destructive disassembly. This material was introduced into the valve during the manufacturing process. The O-ring is a part of the equipment used to clean the check valve prior to it being welded into the final assembly. Since manufacturing of this valve, procedures have been developed to revise the checkout tool installation sequence and to inspect the O-ring for damage after use. The O-ring has an area outside of the sealing surface which can be a trap for contamination. This area is downstream of the poppet flow holes and upstream of the valve flow control area. The contamination was found in this region. Combined reverse flow check data, showing consistently higher readings than the database, support this conclusion. The corrective actions addressing this issue fall into the following three groups. Near Term Plan Establish a new combined reverse leak check with a combined allowable leakage of <7 scim (was <50 scim). Failure of this criteria requires isolation leak checks to find the individual leaking valve. Any valve with a leak value >5 scim would be replaced. Individual check valve isolation leakage sum must match combined leakage within 3 scim or additional cycles would be required. Combined leak checks with >11 scim and with no isolated valve found >5 scim, and combined leakage not within the 3 scim limit shall cause all check valves to be replaced in that system. Eight consecutive successful checks will be conducted on new valves or systems which had check valves or lines replaced since the last hot-fire. These additional requirements improved the probability of finding a contaminated check valve. This is the rationale for flight until a new screening method is developed. Note: STS-56, STS-55, and STS-57 were cleared for flight by accounting for at least eight consecutive leak check cycles using data from engine build to present. Any valve(s) which did not have at least eight were required to have enough cycles completed at KSC to bring them to that total. This work was completed per Rocketdyne Action Requests (RAR).

TABLE III.- MSFC ELEMENTS PROBLEM TRACKING LIST

Problem	Element	Description	Comments/Status
STS-55-E-1 (Continued)			<u>Long Term Plan</u> Reverse flush the valve/line assembly at the component level. Perform the eight leak check cycles at the component level to eliminate these checks at KSC. Eliminate or minimize all potential sources of contamination from build and test equipment, and make procedures for use of this equipment reflect this intent. Revise procedurs to inspect and provide for protection of orifice plate alignment pins. Make leak check and installation procedures consistent at all sites. These procedures should be sensitive to accuracy of 1 scim. Require one combined leak check with the preceeding purge for each engine flow. <u>Assess Redesign Options</u>. The following measures are presently being evaluated as redesign options. Desensitize system for leakage in an attempt to delete the redline. Change the system/software to reduce susceptibility for redline shutdown. Eliminate the need for alignment pins in any system susceptible to contamination. Evaluate NDT processes and filters to assure system cleanliness. In conclusion, this problem was caused by contamination trapped under the seat of the OPB ASI check valve. It was introduced into the valve at manufacture and was not detected until the abort. The additional reverse leak check valve cycles on the oxidizer check valves should provide confidence for the present that the valves are not contaminated. Other corrective actions will be considered for the long term, as well as options regarding possible redesign improvements.
2. STS-55-E-2 ME-3 HPFTP Coolant Liner Pressure Fluctuations.	Space Shuttle Main Engine	During ascent of the STS-55 mission, the ME-3 (E-2029) HPFTP MCC coolant liner pressure exhibited (at (104 percent) erratic behavior.	Although coolant liner pressure shifts of the discussed magnitude have been observed on the engine testing and development program, this permutation falls outside the return-to-flight database (30 flights). The pressure shifts also violated the RL00461 (green run) specification of 300 psid (maximum), which is determined between the coolant liner pressure minus the MCC hot gas injection pressure, plus 100 psid. Conversely, the 400-psid redline margin was maintained throughout the flight. This HPFTP (unit no. 4015) had accumulated two starts and 935 seconds prior to the STS-55 mission. The unit was acceptance tested and then flew on STS-49 (May 7, 1992). The coolant liner pressure was normal and steady during the test and STS-49 flight. The pressure during STS-55, however, exhibited perturbations as high as 110 psid. This magnitude of pressure change is at the upper end of experience with the enlarged coolant liner discharge orifices. A pressure change of up to 113 psi has been observed on the engine development program. HPFTP flight unit 2026 experienced a 70-psi change on the STS-26R mission. This was the maximum flight experience value on coolant liner ΔP prior to STS-55. The most likely cause for the noted perturbations is hot-gas leakage by the mount-ring static seals. The

TABLE III.- MSFC ELEMENTS PROBLEM TRACKING LIST

Problem	Element	Description	Comments/Status
STS-55-E-2 (Continued)			phenomenon is well understood and is considered a benign condition. The static seals degrade over time due to the turbopump installation deflections and the operational environment. The pump-end outer diameter seal typically degrades prior to the inner diameter seal. The installation deflections overload the seal then cracks form from the hydrogen environment embrittlement (HEE). The operational deflections reduce the compression on the pump-end inner diameter seal. Fretting then reduces the sealing capability. Perturbations in the coolant liner pressure will also occur if the inner seal degrades prior to the outer seal. Experience has shown that replacement of the static seals restores the pressure to normal levels and behavior. There has been extensive successful turbopump operation with the enlarged orifice configuration. There have been 110 builds tested for 626 starts amd 252.872 seconds. The maximum pressure change observed was 113 psi with a 122 psi margin to the redline. The three Endeavour (STS-57) HPFTP units have exhibited normal and steady coolant liner pressures during their respective tests and flights (each unit has flown twice). The anomalous HPFTP unit 4015 has been returned to Rocketdyne for disassembly and investigation/analysis. The problem report has been deferred for STS-57 within the Level III MSFC PRACA tracking system, pending the results of disassembly. The in-flight anomaly closure submittal is expected soon for Level II PRCB approval. Deferred.

DOCUMENT SOURCES

In an attempt to define the official as well as the unofficial sources of data for this STS-54 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

ACRONYMS AND ABBREVIATIONS

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

ABS	ammonia boiler system
AIU	audio interface unit
AOET	Atomic Oxygen Exposure Tray
APU	auxiliary power unit
AR	Anthrorack
ARS	atmospheric revitalization system
ATCS	Active thermal control system
ATU	audio terminal unit
BITE	built in test equipment
CCTV	closed circuit television
CRT	cathode ray tube
CRU	crew remote unit
CWC	contingency water carrier
DEU	display electronics unit
DFRF	Dryden Flight Research Facility
DSO	Detailed Supplementary Objective
DTO	Development Test Objective
ΔV	differential velocity
EAFB	Edwards Air Force Base
EBIA	encryption bypass isolation assembly
ECLSS	Environmental Control and Life Support System
EDO	Extended Duration Orbiter
ELLI	ellipsoid heating facility
EPDC	electrical power distribution and control subsystem
ESA	European Space Agency
ET	External Tank
EVA	extravehicular activity
FCS	flight control system
FDA	fault detection and annunciation subsystem
FES	flash evaporator system
FMCA	forward motor control assembly
GAS	getaway special
GAUSS	Galactic Ultrawide-Angle Schmidt System Camera
GFE	Government Furnished Equipment
GFQ	gradient furnace with quenching
GGVM	gas generator valve module
GH_2	gaseous hydrogen
G.m.t.	Greenwich mean time
GPC	general purpose computer
HL	hardline
HOLOP	Holographic Optics Laboratory
HPFTP	high pressure fuel turbopump
HPOTP	high pressure oxidizer turbopump
HPT	high precision thermostat
HPU	hydraulic power unit
IAPU	improved auxiliary power unit
IFM	in-flight maintenance
IMU	inertial measurement unit

I/O	input/output
Isp	specific impulse
JSC	Johnson Space Center
keas	knots estimated air speed
KSC	Kennedy Space Center
kWh	kilowatt hours
LCC	Launch Commit Criteria
LESC	Lockheed Engineering and Sciences Company
LH_2	liquid hydrogen
LO_2	liquid oxygen
L/R	left/right
MADS	modular auxiliary data system
MAUS	Material Science Autonomous Payload
MECO	main engine cutoff
MEDEA	Material Sciences Experiment Double Rack for Experiment Modules and Apparatus
MET	mission elapsed time
Mir	Russian Space Station
MLG	main landing gear
MLGD	main landing gear door
MMT	Mission Management Team
MMU	mass memory unit
MOMS	Modular Opto-Electronic Multispectral Stereo Scanner
MPS	main propulsion system
MSFC	George C. Marshall Space Flight Center
NASA	National Aeronautics and Space Administration
NLG	nose landing gear
NLGD	nose landing gear door
NPSP	net positive suction pressure
NSTS	National Space Transportation System
OI	operational instrumentation
OMDP	Orbiter Maintenance Down Period
OMRSD	Operations and Maintenance Requirements and Specifications Document
OMS	orbital maneuvering subsystem
OPB	oxidizer preburner
OPS	operations sequence
OP STAT	operational status
ORF	Orbiter refrigerator/freezer
PAL	protuberance air load
PDU	power drive unit
PGSC	payload general support computer
PLBD	payload bay door
PMBT	propellant mean bulk temperature
ppm	parts per million
PRSD	power reactant storage and distribution
PTI	programmed test input
RCC	reinforced carbon carbon
RCRS	regenerable carbon dioxide removal system
RCS	reaction control subsystem
REM	release-engage mechanism
RF	radio frequency
RKGM	reaction kinetic in glass melts
ROTEX	Robotics Experiment
RPC	remote power controller

RSRM	Redesigned Solid Rocket Motor
S&A	safe and arm
SAFEX	Spacelab Amateur Funk Experiment
SAREX-II	Shuttle Amateur Radio Experiment-II
SPC	stored program command
SRB	Solid Rocket Booster
SRM	Solid Rocket Motor
SRSS	Shuttle Range Safety System
SSME	Space Shuttle main engine
TAGS	text and graphics system
TDRS	Tracking and Data Relay Satellite
TIPS	thermal impulse printer system
UHF	ultrahigh frequency
USAF	U. S. Air Force
USS	unique support structure
WCCS	wireless crew communications system
WCS	Waste Collection System
WL	Werkstofflabor
WSB	water spray boiler