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STS-56 SPACE SHUTTLE MISSION REPORT

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NSTS-08283

STS-56

SPACE SHUTTLE

MISSION REPORT

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INTRODUCTION

The STS-56 Space Shuttle Program Mission Report provides a summary of the Payloads, as well as the Orbiter, External Tank (ET), Solid Rocket Booster (SRB), Redesigned Solid Rocket Motor (RSRM), and the Space Shuttle main engine (SSME) systems performance during the fifty-fourth flight of the Space Shuttle Program and sixteenth flight of the Orbiter vehicle Discovery (OV-103). In addition to the Orbiter, the flight vehicle consisted of an ET (ET-54); three SSME's, which were designated as serial numbers 2024, 2033, and 2018 in positions 1, 2, and 3, respectively; and two SRB's which were designated BI-058. The lightweight RSRM's that were installed in each SRB were designated as 360L031A for the left SRB and 360L031B for the right SRB.

The STS-56 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 perform the planned operations of the ATLAS-2 payload. The secondary objectives of this flight were to perform the operations of the Shuttle Solar Backscatter Ultraviolet (SSBUV)/A experiment; deploy and retrieve the Shuttle Pointed Autonomous Research Tool for Astronomy-201 (SPARTAN-201) payload; and perform the operations of the Solar Ultraviolet Experiment (SUVE); the Commercial Materials Dispersions Apparatus Assembly (CMIX) experiment; the Physiological and Anatomical Rodent Experiment (PARE); the Space Tissue Loss (STL) experiment; the Shuttle Amateur Radio Experiment-II (SAREX-II); the Hand-Held, Earth-Oriented, Real-time, Cooperative, User-Friendly, Location-Targeting and Environmental System (HERCULES) experiment; the Air Force Maui Optical Site Calibration Test (AMOS); the Cosmic Ray Effects and Activation Monitor (CREAM) experiment; and the Radiation Monitoring Equipment-III (RME-III). In addition to the primary and secondary objectives assigned to STS-56, 13 Development Test Objectives (DTO's) and 15 Detailed Supplementary Objectives (DSO's) were assigned to the flight.

The sequence of events for the STS-56 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. In addition, the Integration and Payload in-flight anomalies are referenced in the applicable sections of the report. Appendix A lists the sources of data, both formal and informal, that were used in the preparation of this document. Appendix B provides the definition of acronyms and abbreviations used in this document. All times given in this report are in Greenwich mean time (G.m.t.) as well as mission elapsed time (MET).

The STS-56 mission was planned as an 8-day mission with an additional day being highly desirable. This additional day capability was determined in real-time based on consumables with mission planning accommodating the longer duration wherever appropriate. A large number of experiments were completed during the mission by the five-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-fourth flight of the Space Shuttle was Kenneth D. Cameron, Col., USMC, Commander; Stephen S. Oswald, Civilian, Pilot; Michael Foale, Ph.D., Civilian, Mission Specialist 1; Kenneth D. Cockrell, Civilian, Mission Specialist 2; Ellen Ochoa, Ph.D., Civilian, Mission Specialist 3. STS-56 was be the second space flight for the Commander, Pilot, and Mission Specialist 1, and the first space flight for Mission Specialist 2 and Mission Specialist 3.

MISSION SUMMARY

The first launch attempt of STS-56 was aborted on April 6, 1993, at T-11 seconds in the countdown. The countdown had proceeded satisfactorily until the T-9 minute hold. At that time, the discussions of the higher than previously experienced temperature on the SSME 1 anti-flood valve had not been completed and the countdown was held for 60 minutes while these discussions were satisfactorily completed. The countdown was picked up at 096:06:23:00 G.m.t., and the countdown continued until the abort was called at T-11 seconds. The abort was called because the hydrogen high-point bleed valve close indication was not on when polled at the T-21 second point in the countdown, and the lack of the indication is a violation of the Launch Commit Criteria (LCC). Analysis of the data showed that the valve had actually closed; however, the closed indication failed to register. Because the valve worked properly during the first countdown as well as during a leak check of the valve after the abort, a decision was made to launch the vehicle on April 8, 1993, with the valve indication masked in the ground launch sequencer (GLS). A confidence check of the valve operation was also performed during the second countdown and the valve again worked properly. After SSME ignition at T-3.5 seconds during the second launch attempt, the high-point bleed valve close indication returned.

The second launch attempt was completed satisfactorily after an exemplary countdown with no unplanned holds. Lift-off occurred on-time at 098:05:28:59.986 G.m.t. (12:29:00 a.m. c.d.t.) on April 8, 1993. All subsystems performed satisfactorily throughout the ascent phase except the flash evaporator system (FES) which shut down at 98:05:33:16 G.m.t. (00:04:16 MET) while operating on the A controller. The crew manually restarted the FES on the primary A controller, and it operated satisfactorily thereafter. The OV-103 FES experienced shutdowns on previous missions because of the mid-point sensor block design, and this occurrence was not unexpected.

A determination of the overall vehicle propulsion performance during ascent was made using vehicle acceleration and preflight propulsion prediction data. First stage ascent performance was satisfactory in all respects. Performance of the SSME's, ET, and the main propulsion system was normal. The average flight-derived SSME specific impulse (Isp) that was determined for the time period between SRB separation and the start of 3g throttling was 452.5 seconds as compared to an average value for that period of 452.83 seconds.

The orbital maneuvering subsystem (OMS) 2 maneuver was satisfactorily performed with ignition at 98:06:06:07.7 G.m.t. (00:00:37:07 MET). The maneuver was 150.63 seconds in duration with a differential velocity (ΔV) of 253.8 ft/sec. The resulting orbit was 160 by 159 nmi.

At 98:06:46:51 G.m.t. (00:01:17:51 MET), the fuel cell 1 oxygen reactant valve indication showed the valve to be closed; however, the fuel cell continued to operate properly, confirming an instrumentation-only failure. Because of this indication, the crew tied busses A and B together. Subsequently, busses A and B were untied and busses A and C were tied to more evenly distribute the electrical loads. This same indication was received on a previous flight of this vehicle (STS-48). Fuel cell 1 will be shut down on the next OV-103 mission (STS-51) as a part of a DTO, because a false close indication would affect the performance of this DTO. The valve has been replaced in preparation for the STS-51 mission.

The payload bay doors were opened as planned with both doors in the open position at 098:07:04:13 G.m.t. (00:01:35:13 MET).

At 098:14:30 G.m.t. (00:09:01 MET), the thermal impulse printer system (TIPS) [(developed to replace both the Text and Graphics System (TAGS) and teleprinter] was not producing an output when the ground was transmitting via the graphics mode (Ku-band). An in-flight maintenance (IFM) procedure to troubleshoot problems with the TIPS was performed. The light indicator showing whether the clock signal was being received by TIPS from the Ku-band signal processor (KUSP) was initially off and then illuminated later. TIPS must receive a clock signal from the KUSP to operate properly. A subsequent TIPS test via Ku-band was successful.

Initially, the Ku-band mode 1 [phase modulation (PM)] channel 3 return link data quality was degraded. Preliminary troubleshooting indicated that mode 1 operated on low-data-rate high-rate multiplexer (HRM) data, but did not operate on high-rate HRM data (Flight Problem STS-56-I-01). The operational data are satisfactory regardless of the data rate being transmitted. Also, the frequency modulation (FM) mode was functioning properly. Much of the equipment in the signal processor is common between the PM and FM modes. As a result of this problem, new custom test formats for formats 27, 28, 29, and 30 were developed; however, no improvement in Ku-band operations was achieved with these formats.

Ku-band downlink was tested in format 11 (32 Mbps) on channel 3 in the PL maximum mode data rate while equipment was powered down to perform an electromagnetic interference test. Channel 3 data were again degraded, and the channel 2 link was good.

A Ku-band payload maximum baseline test was performed from 106:03:00 to 106:04:10 G.m.t. (07:21:31 to 07:22:41 MET). After the Spacelab was reactivated, further troubleshooting was performed in an attempt to narrow the data transmittal problem to a specific payload. Results of these tests indicated that the Ku-band was operating satisfactorily.

The SPARTAN payload was successfully deployed at 101:06:11 G.m.t.(03:00:42 MET). The remote manipulator system (RMS) was used to deploy SPARTAN and the RMS performed nominally. Three reaction control system (RCS) maneuvers were performed for SPARTAN separation and the RCS also performed nominally.

Ku-band radar tracked SPARTAN from 270 feet at 101:06:22 until the system was reconfigured to the communication mode at 101:07:05 G.m.t., when SPARTAN was at 3000 feet. There were no dropouts and the radar was still locked when the system was switched to the communications mode.

The Laser Range and Range Rate Device DTO was performed during the SPARTAN deployment. The Laser Technology Incorporated (LTI) component was used for short-range tracking and performed well. The Mini Eyesafe Laser Infrared Observation Set (MELIOS) was used for longer range (minimum range is specified as 50 m/150 ft). The MELIOS range measurement deviated from the Ku measurement as the Orbiter moved away from the SPARTAN.

A digital autopilot (DAP)/universal pointing discrepancy occurred during Solar Ultraviolet Spectral Irradiance Monitor (SUSIM) operations (Flight Problem STS-56-I-02). The SUSIM experiment attempted to measure electromagnetic activity from the Sun. After the desired pointing configuration with respect to the Sun's limb was established with the DAP in inertial hold, the universal pointing total error in roll started building at a rate of approximately 0.04 degree/minute. This build-up was unexpected as the universal pointing required attitude and inertial hold attitudes should both be held constant. The DAP attitude errors were maintained within deadbands throughout the inertial-hold period.

To begin rendezvous operations for retrieval of the SPARTAN payload, two RCS firings were performed with the left OMS interconnected to the RCS. A nominal slow rate (NSR) maneuver was performed at 102:05:50 G.m.t. (04:00:21 MET) using -X thrusters to achieve a 3.1 ft/sec velocity change. The nominal plane change (NPC) maneuver was performed at 102:07:28 G.m.t. (04:01:59 MET) to achieve a 2.9 ft/sec velocity change. The right OMS was fired to perform a nominal correction (NC1) maneuver at 102:09:40 G.m.t. (04:04:11 MET). The maneuver lasted 8 seconds and achieved a velocity change of 7.1 ft/sec.

A dual supply and waste water dump was performed beginning at approximately 101:19:42 G.m.t. (03:14:13 MET). Thirty-five lb of supply water was dumped; concurrently, 121 lb of waste water was dumped. The RMS wrist camera was used to record video of the water dump from initiation until approximately 75 minutes after dump termination. The video was recorded as an aid in troubleshooting post-dump expulsions (burps) of water from the supply line which have been observed on three OV-103 flights and one OV-104 flight. Data review indicates that two supply water "burps" occurred following the water dump within 1.5 hours of supply water dump valve closure. A review of the video verified water emission associated with the first occurrence, but video was terminated prior to the second occurrence.

A successful rendezvous with the SPARTAN was completed, and the SPARTAN was grappled with the RMS at 103:07:19:45 G.m.t. (05:01:50:45 MET). Final latching of the SPARTAN in the payload bay was completed at 103:08:01:38 G.m.t. (05:02:32:28 MET). Ku-band radar tracking of the SPARTAN during the rendezvous sequence began intermittently at 149,000 ft with solid lock-on achieved at 130,000 ft and held until 90 ft. The LTI device was used for tracking at ranges from 1193 ft with good results. The MELIOS device was also used during rendezvous with satisfactory results. The crew replaced the MELIOS battery after the SPARTAN deployment operations. Low battery voltage was a possible cause of the inaccurate readings during the SPARTAN deployment; however, the crew reported that they had given a low priority to the distance callouts because of the heavy workload during deployment operations.

Following SPARTAN retrieval, the RMS was stowed for the remainder of the mission. The RMS performed nominally throughout the flight.

The flight control system (FCS) checkout was completed satisfactorily at 104:06:55:33 G.m.t. (06:01:26:33 MET). Auxiliary power unit (APU) 1 consumed 13 lb of fuel during the 4 minutes 20 seconds of satisfactory operation. All hydraulics functions were nominal during the checkout, and no water spray cooling was required.

The Freon coolant loop (FCL) 2 flow proportioning valve (FPV) was returned to the interchanger position to aid in cooling the cabin for entry. The water coolant loop 2 temperature controller was returned to the auto position to obtain data on the performance of the water bypass valve with one FPV in Payload and the other in Interchanger.

All landing opportunities for Friday, April 16, were waved-off because of unacceptable weather conditions at KSC. Landing was planned for the first opportunity at KSC on April 17.

An RCS -X orbit adjust firing was performed satisfactorily at 106:06:03:00 G.m.t. (08:00:34:00 MET) using forward thrusters F1F and F2F. The firing duration was 56 seconds and the ΔV was 15 ft/sec. The purpose of the firing was to improve the entry programmed test input (PTI) crossrange opportunity for the second KSC landing opportunity on April 16.

The RCS hot-fire test was subsequently performed at 106:06:19:40 G.m.t. (08:00:50:40 MET). The data review from the test showed that thruster L3L had a low chamber pressure (16 psia) for the first 240 ms of the first 400 ms pulse. The second pulse was nominal. Possible causes are being evaluated; however, no concern existed for the continued operation of this thruster.

The crew reported a glob of water of about two ounces was on a portion of the water loop 2 inlet line to the cabin heat exchanger that had no insulation. The water was most probably the result of condensation, as there were no indications of a leak.

The cell performance monitor (CPM) differential voltage readings for fuel cell 1 substack 3 demonstrated a trend whereby the readings increased during reactant purging and gradually decreased between purges. The increase during purges was a few millivolts larger with each succeeding purge. Analysis of the data pointed to plugging of the reactant ports in one or more of the cells of substack 3. Since the performance of the fuel cell was otherwise normal, no additional purges of that fuel cell were made. Because of fuel cell shutdown operations planned for fuel cell 1 on the next flight of this vehicle, the decision was made to replace this fuel cell.

Both payload bay doors were closed nominally by 107:07:59:54 G.m.t. (08:02:30:54 MET). The deorbit maneuver was performed at 107:10:34:25.3 G.m.t. (09:05:05:25.3 MET). The maneuver was approximately 208.2 seconds in duration and the ΔV was 378.7 ft/sec. Entry interface occurred at 107:11:05:53 G.m.t. (09:05:36:53 MET). All programmed test inputs (PTI's) were performed as planned.

Main landing gear touchdown occurred at the Shuttle Landing Facility on concrete runway 33 at 107:11:37:19 G.m.t. (09:06:08:19 MET) on April 17, 1993. Nose landing gear touchdown occurred 15 seconds after main gear touchdown with the Orbiter drag chute being deployed satisfactorily at 107:11:37:30.8 G.m.t. The drag chute was jettisoned at 107:11:38:00 G.m.t. with wheels stop occurring at 107:11:38:22 G.m.t. Preliminary indications are that the rollout was normal in all respects. The flight duration was 9 days 6 hours 8 minutes 24 seconds. All three APU's were powered down by 107:11:53:20 G.m.t. The crew completed the required postflight reconfigurations and departed the Orbiter landing area at 107:12:48 G.m.t.

PAYLOADS

The payloads carried on STS-56 consisted of the ATLAS-2; the SPARTAN-201; the SUVE; the HERCULES; the RME-III; the CREAM; the AMOS; and the SAREX-II. In addition, more than 30 investigations were flown as a part of the Commercial Materials Dispersion Apparatus (MDA) Instrumentation Technology Associates (ITA) experiments. Three in-flight anomalies were identified from the Payloads data and these anomalies are discussed in the appropriate area of the Payloads section of this report.

ATLAS-2

The primary payload for STS-56 was the second in NASA's series of Atmospheric Laboratory for Applications and Science-2 (ATLAS-2) Spacelab missions, which consisted of remote-sensing laboratory studies of the Sun's energy output and Earth's middle-atmosphere chemical make-up, and how these factors affect levels of ozone. Ozone depletion has been a serious environmental concern since the 1970's, and in the mid-1980's British scientists observed significant ozone depletion of the Antarctic. Scientists from five nations participated directly with the U. S. in the ATLAS-2 mission, underscoring the worldwide importance of atmospheric and solar research. In addition to the United States, investigators represented Belgium, Germany, France, The Netherlands, and Switzerland.

The open, U-shaped pallet-type reusable Spacelab equipment provided by the European Space Agency (ESA) in 1981 as it contribution to the Space Shuttle Program had six instruments mounted on it in the payload bay. A seventh instrument was mounted in two get-away special (GAS) canisters on the walls of the payload bay. These seven instruments were divided into two major areas of science - atmospheric and solar. A teacher's guide entitled, Atmospheric Detectives, was developed for use with middle school students to complement and teach science objectives of the ATLAS-2 mission.

Activation of the ATLAS-2 payload was completed at 098:09:19:00 G.m.t. (00:03:50 MET). The ATLAS-2 provided data on the composition and chemical processes of the middle atmosphere. It measured atmospheric constituents, solar radiation, and total solar irradiance. The night launch provided the ATLAS-2 scientists a unique opportunity to make detailed measurements in the Arctic stratosphere. Additionally, atmospheric data were collected over 94 percent of the Earth. The solar observations provided scientists with information on the solar energy that drives Earth's climate system, and the photochemistry of ozone in the stratosphere. The data collected will ultimately be placed in the Earth Observing System Data Information System archives at Goddard Space Flight Center where it will be available to atmospheric scientists around the world.

The ATLAS II and Spacelab were both able to take advantage of the weather-added day in space. Five of the seven ATLAS-2 experiments were repowered to gather data during that extra day. As a result, the final ATLAS-2 power down occurred at 107:05:33 G.m.t. (09:00:04 MET). All Principal Investigators for the ATLAS-2 experiments considered the mission to have been very successful.

Atmospheric Science

Atmospheric Trace Molecule Spectroscopy.- The Atmospheric Trace Molecule Spectroscopy (ATMOS) experiment identified the distribution, by altitude, of 30 to 40 different gases between 6 and 85 miles (10 and 140 kilometers) above the Earth's surface. This experiment made most of its measurements in the Southern Hemisphere during the first mission (ATLAS-1) it was flown, and to focus on the Northern Hemisphere during the ATLAS-2 mission required the night launch. This experiment was sponsored by the Jet Propulsion Laboratory of the United States.

A problem with the transmission of high-rate data initially caused some loss of all experiment data; however, the problem was overcome with the use of a new downlink format. This format allowed the data team to maximize the use of the high data rate recorder (HDRR) to provide near-real-time data evaluation during the mission. Additionally, the new ATMOS recorder that was located in the payload bay was used to record over 100 sunrise/sunset observations, which made the ATMOS experiment a major success. This recorder will be used on all future ATLAS missions.

The ATMOS instrument experienced an anomaly with the loss of one phase of the three-phase cooler compressor on flight day 3. Preliminary indications were that ice crystal contamination in the expansion area of the compressor caused the anomaly. The cooling capacity of the instrument was unaffected and the instrument performed well for the remainder of the mission.

Millimeter Wave Atmospheric Sounder.- The Millimeter Wave Atmospheric Sounder (MAS) experiment measured water vapor, ozone and chlorine monoxide (a key compound that contributes to ozone loss), as well as temperature and pressure in the middle atmosphere. This experiment was sponsored by the Institute for Aeronomy of Germany.

The MAS science team was able to overcome an early-mission problem with the pointing system by modifying the onboard software. Preliminary analyses of these data show high quality chlorine monoxide, ozone, and water vapor profile information. Data were collected in both the northern and southern hemispheres.

Initial analysis by the MAS team shows that the MAS data are of better quality than from the ATLAS-1 mission. These data will provide better spatial resolution for the chlorine monoxide, ozone, and water vapor profile information.

Shuttle Solar Backscatter Ultraviolet Spectrometer.- The Shuttle Solar Backscatter Ultraviolet (SSBUV) Spectrometer experiment, mounted in two gas canisters on the walls of the payload bay, measured ozone concentrations by comparing solar ultraviolet radiation with that scattered back from the Earth's atmosphere. This experiment was sponsored by the Goddard Space Flight Center (GSFC) of the United States.

The minimum observing requirements were exceeded by more than 100 percent. Preliminary analysis of the data shows a decrease in northern mid-latitude ozone. These data are consistent with recent analysis of satellite data. The instrument also observed sulfur dioxide concentrations over urban and industrial areas of the eastern United States, Europe, and eastern Asia. The additional day of operations provided the instrument with the unique opportunity to measure nitric oxide gamma bands, which will provide information of mesospheric nitric oxide. The additional time also allowed the instrument to measure how much ultraviolet radiation is actually reaching the Earth.

After initial data evaluation, the Principal Investigator team has reported that all of the observational objectives for the flight were met and many were exceeded. The instrument performance, data acquisition, and operations went exceedingly well, and scientific observations were conducted that have never been accomplished, such as that of tropospheric sulfur dioxide.

Solar Science

Solar Spectrum.- The Solar Spectrum (SOLSPEC) Measurement experiment studied the distribution of solar energy by wavelength (infrared to ultraviolet). This experiment was sponsored by the National Center for Scientific Research of France.

Remote operation of the SOLSPEC instrument from the Brussels, Belgium control center was very successful. SOLSPEC collected correlative data with a similar instrument aboard the free-flying European Carrier Satellite (EURECA). As a result, solar variability studies were conducted because the solar activity decreased between the ATLAS-1 and ATLAS-2 flights. The investigation team has expressed extreme satisfaction over the operation of the instrument and the scientific return the measurements have provided.

Solar Ultraviolet Irradiance Monitor.- The Solar Ultraviolet Irradiance Monitor (SUSIM) experiment concentrated on the Sun's ultraviolet radiation which undergoes wider variations than other wavelengths. This experiment was sponsored by the Naval Research Laboratory of the United States.

The SUSIM instrument collected solar data and sunrise/sunset occultation during each of the solar pointing orbits. This primary solar science objective was performed to make comparisons with the SUSIM instrument on the Upper Atmosphere Research Satellite (UARS). These comparisons will allow scientist to make the necessary corrections to the UARS data that are essential for tracking subtle changes in the atmospheric condition and the solar energy which influences them. The SUSIM also met a secondary objective by capturing the sunrise/sunset occultations to obtain ozone profiles.

The SUSIM investigation team considers the ATLAS-2 flight to be clearly the most successful mission for the SUSIM instrument. The data are being used to obtain ozone density profiles, as well as compare and validate the performance of previous SUSIM flights.

Active Cavity Radiometer and Solar Constant.- The Active Cavity Radiometer (ACR) and the Solar Constant (SOLCON) experiments each made direct and precise independent measurements of the total energy Earth receives from the Sun. The ACR experiment was sponsored by the Jet Propulsion Laboratory of the United States, and the SOLCON experiment was sponsored by the Belgian Royal Institute of Meteorology of Belgium.

The ACR experiment had two premission goals and both were met. The instrument made correlative measurements with UARS and performed as many solar constant measurements as the mission allowed. The ACR instrument performance was outstanding as reported by the Principal Investigators. The investigators believe that the quality measurements obtained will allow the most stable and best ever calibrations with the UARS data.

The SOLCON experiment was very successfully controlled from Brussels, Belgium. The SOLCON Principal Investigator team are presently studying their data in Belgium. Preliminary solar irradiance measurements show close agreement with data received from the EURECA. The science team also reports that very stable calibration was achieved between the SOLCON instrument and the instruments on the UARS.

Shuttle Pointed Autonomous Research Tool for Astronomy-201

The SPARTAN-201 was a free-flying payload that studied the velocity and acceleration of the solar wind and observed aspects of the Sun's corona. In measuring these phenomena, two telescopes, a White Light Coronagraph (WLC) and an Ultraviolet Coronal Spectrometer (UVCS), were used. A comparison of the data from the two telescopes will for the first time allow scientists to measure the temperatures and electron and proton densities in the solar corona.

The SPARTAN payload was deployed using the RMS during the third day of the mission at 101:06:11:33 G.m.t. (03:00:42:33 MET). The crew performed a separation maneuver using the RCS and separated the Orbiter to a distance of about 172 miles behind the SPARTAN-201. A successful rendezvous with the SPARTAN was completed, and the SPARTAN was grappled with the RMS at 103:07:20:05 G.m.t. (05:01:51:05 MET). Final latching of the SPARTAN in the payload bay was completed at 103:08:01:38 G.m.t. (05:02:32:28 MET) in preparation for its return to the Earth.

The SPARTAN-201 was removed from the payload bay and was shipped to GSFC. Initial evaluation of the science data tapes has revealed excellent data. Data are continuing to be evaluated as the SPARTAN-201 is prepared for its next flight on the STS-63 mission.

Solar Ultraviolet Experiment

The SUVE provided data on the extreme ultraviolet solar radiation as it affects the Earth's ionosphere. The SUVE was housed in a single GAS canister in the payload bay. The experiment was designed, managed, and built by students at the University of Colorado.

A total of 22 orbits of solar radiation data were collected with the SUVE instrument during the four data-take periods. The data collected represents more than 16 times the minimum requirements.

Hand-Held, Earth-Oriented, Real-Time, Cooperative, User-Friendly, Location-Targeting and Environmental System

The HERCULES experiment provided a modified Nikon camera and a geolocation device which enabled the crewperson to determine in real-time the latitude and longitude of Earth images. STS-56 was the second flight of this experiment that was developed by the Department of Defense Space Test Program.

The HERCULES experiment obtained over 13 disks with over 400 images of data during the mission. Initially, the HERCULES experiment experienced some problems with the playback/downlink unit (PDU) retaining power (Flight Problem STS-56-P-02). The PDU was swapped with a PGSC, but the geolocation information was lost. After determining that the power cable was the cause of the power problem, the cable was repaired and the PDU was brought back on line. The experiment operated satisfactorily for the remainder of the mission.

During an attempted HERCULES inertial measurement unit (HIMU) alignment on flight day 6, two HERCULES attitude processor (HAP) failures occurred, and in each case this resulted in the loss of the alignment (Flight Problem STS-56-P-03). Loss of the HAP results in the loss of geolocation capability. The HAP was reset and a subsequent alignment was successful. The error data were saved for postflight analysis.

Radiation Monitoring Equipment-III

The Radiation Monitoring Equipment-III (RME-III) experiment was used to measure the exposure of ionizing radiation on the Space Shuttle. RME-III displayed the dose rate and the total accumulated radiation dose to the operator. The RME-III was flown under the direction of the Department of Defense Space Test Program, and was flown in conjunction with other radiation experiments on this flight.

The RME-III was set up on flight day 1 and collected ionizing radiation data throughout the mission. The instrument was moved to different preplanned crew cabin locations, and operations were nominal. The units were stowed for entry as planned.

Cosmic Radiation Effects and Activation Monitor

The CREAM experiment was designed to collect cosmic ray energy loss spectra, neutron fluxes, and induced radioactivity data. The instruments were set up on flight day 1, and the data were collected by the active and passive monitors placed at specific locations throughout the Orbiter cabin. The active monitor collected data on real-time spectral data, whereas, the passive monitors collected data that was analyzed during the postflight period. The CREAM experiment was a Department of Defense experiment and was flown under the direction of the Space Test Program.

Air Force Maui Optical Site

The AMOS is an electro-optical facility located on the island of Maui in the Hawaiian Islands. This experiment observed primary RCS thruster firings and water dumps as the Orbiter flew over the tracking site. No hardware was required onboard the Space Shuttle for this experiment. The RCS firing on flight day 8 was observed with both visible and infrared instruments.

Shuttle Amateur Radio Experiment-II

The SAREX-II provided public participation in the space program, supports educational initiatives and demonstrated the effectiveness of making contact between the Space Shuttle and amateur "ham" radio stations on the ground.

SAREX-II provided very satisfactory communications on seven of the past Space Shuttle missions, and was used very successfully on this mission by all five crew members. SAREX enabled the first Orbiter to MIR contact on April 10, 1993, at 100:23:02 G.m.t. (02:17:32 MET). The crew also contacted all scheduled schools that were located in the United States, Britain, Portugal, South Africa, and Australia. The amateur television portion of SAREX experienced some success with the crew confirming receipt of some of the color-fast scan and some of the slow-scan video transmissions.

Commercial Materials Dispersion Apparatus ITA Experiments

In excess of 30 separate investigations were conducted with the Commercial Materials Dispersion Apparatus (MDA) Instrumentation Technology Associates (ITA) experiments. These experiments enabled the gathering of data for determining how microgravity can aid research in drug development and delivery, biotechnology, basic cell biology, protein and inorganic crystal growth, bone and invertebrate development, immune deficiencies, manufacturing processes, and fluid sciences.

The CMIX hardware consists of four MDA mini-laboratories, which are housed in a commercial refrigerator/incubator module. Each of the mini-labs was a brick-sized automated device that could bring as many as 100 separate samples of multiple fluids and/or solids into contact at precisely timed intervals. In addition, live cell investigations were conducted in 10 bioprocessing modules (BPM's), which contain 60 to 100 times more fluid volume than the MDA's. A listing of the experiments contained in the CMIX is as follows:

a. Bone cell differentiation
b. Immune cell response
c. Diatoms
d. Mouse bone marrow cells
e. Nerve/muscle cell interactions
f. Phagocytosis
g. Live cell investigations
h. Collagen reconstitution

i. Microencapsulation
j. Urokinase protein crystal growth
k. Bacterial aldolase and rabbit muscle aldolase protein crystal growth
l. HIV reverse transcriptase
m. RNA protein crystal growth
n. Methylase protein crystal growth
o. Lysozyme protein crystal growth
p. DNA-Heme protein crystal growth
q. Brine shrimp development
r. Cell research
s. Mustard seed germination
t. Fish egg hatching
u. Heart cells in culture
r. Mushroom spore generations
s. Mustard-spinach seed germination
t. Other investigations

All CMIX operations were on time and nominal. The BPM's were set up, activated, sampled, and restowed with no problems or anomalies. The materials dispersion apparatuses (MDA's) were activated and deactivated according to schedule.

Space Tissue Loss Experiment

The objective of the STL experiment was to validate models of muscle, bone, and endothelial cell biochemical and functional loss induced by microgravity stress; to evaluate cytoskeleton, metabolism, membrane integrity and protease activity in target cells; and to test tissue loss pharmaceuticals for efficacy.

Initialization of the STL experiment occurred four hours into the mission. The temperatures rose to 4-5 degrees above the normal operating temperature of 37°F (Flight Problem STS-56-P-01). On flight day 4, after moving the experiment to the airlock to obtain cool air from the "elephant trunk", the STL temperature was successfully dropped to nominal. Operations continued as planned from that location. The unit was stowed back in its locker for entry; however, the temperature began rising again and the unit was moved to a new locker location and the "elephant trunk" cooling was re-established at the new location. The STL temperature then went lower than normal, so the "elephant trunk" was removed and stowed for entry.

Physiological and Anatomical Rodent Experiment

The PARE is a series of experiments that are designed to determine whether exposure to microgravity results in physiological or anatomical changes in rodents. The PARE consists of rodents contained within an animal enclosure module (AEM), which occupies one middeck locker with a modified locker door.

The PARE operations were nominal, except for the day/night light on one of the two AEM's that was discovered to have lost power. The power was recycled and as a result, the light was restored to its operational mode.

VEHICLE PERFORMANCE

SOLID ROCKET BOOSTERS/REDESIGNED SOLID ROCKET MOTORS

All SRB systems performed as expected, except the hold down post (HDP) debris containment device on HDP 5. The SRB prelaunch countdown was nominal. No SRB or redesigned solid rocket motor (RSRM) Launch Commit Criteria (LCC) or Operations and 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 limits. At T-15 minutes, the purge was changed to high pressure to inert the aft skirt.

The plunger and spring from the left SRB aft skirt (HDP 5) debris containment device exited the device at lift-off (Flight Problem STS-56-B-1). An investigation concluded that during the process of sealing the exit bore in the containment device at lift-off, the plunger was struck by the frangible nut halves, in turn breaking off four sections of the plunger flange at the edges of the flange cutouts. The plunger then impacted the spherical washer causing the remaining edges of the plunger flange to fail. The failure provided enough clearance for the plunger and spring to exit the debris containment device and lodge in the mobile launch platform (MLP) support post. This incident has been identified as a random occurrence (1 out of 240 containment device uses) with a low probability (0.99998 probability of no HDP debris impact) of debris impact to the vehicle, and therefore, this condition is not considered a safety-of-flight issue.

Data indicate that the flight performance of both RSRM's were well within the allowable performance envelopes, and the performance was typical of the performance observed on previous flights. The RSRM propellant mean bulk temperature (PMBT) was 66°F at lift-off. Both SRB's were successfully separated from the ET 125.8 seconds after lift-off and were recovered and returned to KSC for disassembly. The table on the following page presents the RSRM performance values.

During the disassembly process, a small axial scratch (0.04 inch) was observed at the 55.8-degree location on the left RSRM aft dome boss primary sealing surface (Flight Problem STS-56-M-1). The scratch was 0.58 inch from the forward edge of the aft dome boss inside diameter. Raised metal was detected. No damage was found on any of the nozzle-to-case joint O-rings, and a preflight check provided a positive verification of the joint sealing capability. The minimum O-ring footprint of 0.116 inch at 14.49 percent squeeze yields a 35-percent violation of the minimum O-ring footprint.

Also during the SRB post-recovery disassembly and inspection, a pair of pliers were found in the left-hand SRB skirt.

RSRM PROPULSION PERFORMANCE

Parameter	Left motor, 68°F		Right motor, 68°F	
	Predicted	Actual	Predicted	Actual
Impulse gates				
I-20, 10^6 lbf-sec	65.00	64.77	65.15	64.94
I-60, 10^6 lbf-sec	173.56	173.32	173.94	173.24
I-AT, 10^6 lbf-sec	296.82	295.96	297.11	296.08
Vacuum Isp, lbf-sec/lbm	268.5	267.8	268.5	267.4
Burn rate, in/sec @ 60°F at 625 psia	0.3672	0.3672	0.3674	0.3676
Burn rate, in/sec @ 66°F at 625 psia	0.3688	0.3687	0.3690	0.3691
Event times, seconds				
Ignition interval	0.235	N/A	0.235	N/A
Web time[a]	110.80	110.80	110.70	110.60
Separation cue, 50 psia	120.60	120.60	120.50	120.80
Action time	122.70	123.00	122.60	123.10
PMBT, °F	66.00	66.00	66.00	66.00
Maximum ignition rise rate, psia/10 ms	90.4	N/A	90.4	N/A
Decay time, seconds (59.4 psia to 85 K)	2.80	3.20	2.80	3.00

Tailoff imbalance	Predicted	Actual
Impulse differential, klbf-sec	N/A	398.95b

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

The 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 MSFC OMRSD or LCC violations 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 liquid oxygen (LO_2) and liquid hydrogen (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 per NSTS 08303. No ice or frost was observed on the acreage of the LO_2 or the 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 ullage pressure slump was 13.9 psid. ET separation was confirmed after a nominal main engine cutoff (MECO).

Post-separation ET photographs taken from the Orbiter in support of DTO 312 showed approximately 12 divots in the intertank-to-LH_2 tank flange closeout and approximately 9 areas of missing foam up to two feet in length from the -Z side of the intertank acreage thermal protection system (TPS) application (Flight Problem STS-56-T-01). An investigation team was formed to determine the cause and corrective action for the occurrence of divots in the intertank TPS application.

ET separation occurred 532.884 seconds after lift-off. ET entry and breakup occurred approximately 74 nmi. uprange of the preflight predicted point and within the predicted footprint.

SPACE SHUTTLE MAIN ENGINES

All SSME parameters were normal throughout the prelaunch countdown and were typical of prelaunch parameters observed on previous flights, except for the SSME-1 (2024) LO_2 anti-flood valve (AFV) skin temperature measurement. During propellant loading for both the launch scrub on April 6 and the launch on April 8, the AFV skin temperature measurement on SSME-1 read approximately 60°F warmer than expected on channels A and B (Flight Problem STS-56-E-1). This did not cause an LCC or OMRSD violation, but a concern for debonded skin temperature sensors was raised. It was considered safe to proceed with the countdown and launch after an LCC deviation was created to monitor the AFV skin temperature and gaseous oxygen (GO_2) interface temperature for small temperature changes during the final seconds of the countdown to assure that the AFV was not leaking.

Engine "ready" was achieved at the proper time, all LCC were met, and engine start and thrust buildup was normal.

Flight data indicated that the SSME performance during mainstage, throttling, shutdown and propellant dump operations was normal. Engine cutoff times from the time of engine start were 520.64, 520.77, and 520.89 seconds for SSME 1, 2, and 3, respectively. The high pressure oxidizer turbopump (HPOTP) and high pressure fuel turbopump (HPFTP) temperatures appeared to be well within specification throughout engine operation. The Isp was rated as 452.50 seconds based on trajectory data. SSME MECO occurred at 514.312 seconds after lift-off.

SHUTTLE RANGE SAFETY SYSTEM

All 24 of the Shuttle Range Safety System (SRSS) performed successfully. The 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 were turned off at the appropriate times. All SRSS measurements indicated that the system operated as expected throughout the countdown and flight.

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

ORBITER SUBSYSTEMS PERFORMANCE

Main Propulsion System

The overall performance of the main propulsion system (MPS) was as expected with the exception of the LH_2 high point bleed valve position indicator failure discussed in the following paragraph.

The countdown on the first launch attempt was picked up at T-9 minutes and was scrubbed at T-11 seconds when the MPS LH_2 high-point bleed valve (PV22) closed position indicator failed off (did not indicate closure of the valve during the T-21-second poll), and this is an LCC violation (Flight Problem STS-56-V-01). Analysis of the data showed that the valve had actually closed; however, the closed indication was never transmitted. This was based on the loss of open power, loss of the open indicator, and the immediate temperature rise shown by the downstream facility transducer. During the LH_2 drain, the valve was cycled five times to monitor indicators and temperatures. The closed indication was never received, but the downstream temperature showed nominal performance for each cycle (rising to an off-scale high temperature of -408.8°F in about 8 seconds). The valve was successfully cycled again during the loading for the second launch attempt, but again the valve-closed indication was not received. As a result, an LCC waiver was approved to mask out the PV22 closed position indicator in the GLS. During the second launch attempt which lead to a successful launch, the high-point bleed valve (PV22) closed indication returned at T-3.5 seconds during the engine start sequence. The valve also worked properly during the vacuum inerting and showed a nominal response.

Throughout the period of preflight operations, no significant hazardous gas concentrations were detected. The maximum hydrogen concentration level in the Orbiter aft compartment (which occurred shortly after the start of the LH_2 recirculation pumps) was approximately 147 ppm (corrected), which compares favorably with previous data for this vehicle.

A comparison of the calculated propellant loads at the end of replenish versus the inventory loads resulted in a nominal loading accuracy of +0.01 percent for LH_2 and +0.06 percent for LO_2.

Ascent MPS performance was completely normal in all respects. 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 and GH_2 pressurization systems performed as predicted. Evaluation of the flow control valve data revealed no problems.

The MPS helium system performed as expected and met all requirements during powered flight, propellant dumping, and vacuum inerting operations. During entry, helium consumption was nominal with approximately 58.0 lb used.

Reaction Control Subsystem

The RCS operated satisfactorily throughout the mission with 4656.1 lbm of propellants used during the mission. The RCS was interconnected to the OMS while on-orbit and 8.26 percent of the left OMS propellants and 6.92 percent of the right OMS propellants were used by the RCS. The RCS performed 10 firings during the mission in support of the mission objectives.

The RCS was used to impart pitch, yaw, and roll maneuvers in support of DTO 251 (Entry Aerodynamic Control Surfaces Test) during entry. The forward RCS was dumped to near zero late in the entry phase as planned.

Rendezvous operations for retrieval of the SPARTAN payload were completed with RCS maneuvers. Two RCS firings were performed with the left OMS interconnected to the RCS. A nominal slow rate (NSR) maneuver was performed at 102:05:50 G.m.t. (04:00:21 MET) using -X thrusters to achieve a 3.1 ft/sec velocity change. Nominal plane change (NPC) was performed at 102:07:28 G.m.t. (04:01:59 MET) to achieve a 2.9 ft/sec velocity change.

An RCS -X orbit adjust firing was performed satisfactorily at 106:06:03:00 G.m.t. (08:00:34:00 MET) using forward thrusters F1F and F2F. The firing duration was 56 seconds and the ΔV was 15 ft/sec. The purpose of the firing was to improve the entry PTI crossrange opportunity for the second KSC landing opportunity on April 16.

During the RCS hot-fire test performed at 106:06:19:40 G.m.t. (08:00:50:40 MET) following the flight control system checkout, the chamber pressure for the first pulse of thruster L3L was low (approximately 16 psia) for approximately the first 240 ms of the 400 ms pulse. The second pulse was nominal. The chamber pressure recovered fully and the thruster operated nominally for the remainder of the mission.

During deorbit preparations, the oxidizer and fuel temperatures for RCS vernier thruster L5D was 30 to 40°F warmer than the other vernier thrusters. This behavior was interpreted as a failed-on 10W thruster heater (Flight Problem STS-56-V-13). The thruster was also exhibiting slower cooling than the other thrusters when the heaters were turned off prior to entry. Data evaluation revealed that the L5D injector temperatures were off-scale high for the majority of the mission. The thruster will be replaced during turnaround operations.

Orbital Maneuvering Subsystem

The OMS performance was very satisfactory throughout the mission with three maneuvers performed as planned. The total firing time for the left OMS engine was 356.1 seconds and for the right OMS engine was 364.1 seconds. A total of 15861 lb of propellants were used during the mission. The RCS was interconnected to the OMS while on-orbit and 8.26 percent of the left OMS propellants and 6.92 percent of the right OMS propellants were used by the RCS.

Inlet pressures, chamber pressures, and regenerative jacket temperatures for both engines were as expected. OMS firing times and propellant consumption were consistent with predictions.

The right OMS was fired to perform a nominal correction (NC1) maneuver at 102:09:40 G.m.t. (04:04:11 MET). The maneuver lasted 8 seconds and achieved a velocity change of 7.1 ft/sec.

During propellant loading, it was noted that the left-hand fuel gage was biased high, and this is indicative of a problem in the aft probe or the totalizer. This bias did not affect mission operations.

The following table presents the pertinent parameters for each firing.

OMS firing	Engine used	Time, G.m.t./MET	Firing duration, sec	ΔV, ft/sec
2	Both	98:06:06:08.2 G.m.t. 00:00:37:18.2.MET	148.8	253.6
3	Right	102:09:39:37.5 G.m.t. 04:04:10:37.5 MET	8.0	6.8
Deorbit	Both	107:10:34:25.5 G.m.t. 08:05:05:25.5 MET	208.1	378.7

Power Reactant Storage and Distribution Subsystem

The power reactant storage and distribution (PRSD) subsystem operated nominally with 29.1 hours of mission extension capability remaining based on an average power level of 15.7 kW. The vehicle was flown in the four-tank set configuration. A total of 2485.1 lb of oxygen, including the 69.7 lb used by the crew, was consumed. Also 304.2 lb of hydrogen was used.

A test was conducted to determine the minimum amount of unusable oxygen and hydrogen by driving the tank 4 heaters to the Shuttle Operational Data Book (SODB) limits. The limits are defined at 350°F for the oxygen heater, 200°F for the hydrogen heater, and 160°F for the oxygen and hydrogen fluid. The oxygen tank fluid reached 160°F with a residual quantity of 5.5 percent instead of the 6.5 percent at normal operating conditions and a heater temperature of 250°F before deactivating the oxygen tank heater. The hydrogen tank 4 quantity reached a minimum of 0.7 percent instead of the normal 2.5 percent residual quantity without reaching either the heater or the fluid temperature limits. The hydrogen tank 4 heaters were deactivated when the heater temperature reached 160°F and the fluid temperature reached 0°F. This test demonstrated that by raising the heater and fluid temperatures to near the SODB limits of the hydrogen and oxygen tanks, more usable cryogenics could be depleted from the tanks. Thus, the fuel cell subsystem could have an extra amount of cryogenics for power generation.

Fuel Cell Powerplant Subsystem

The fuel cell powerplant subsystem operated nominally throughout the mission, supplying 3497 kWh of electrical energy. In generating this amount of electricity, the fuel cells also produced 2719.6 lb of water.

At 98:06:46:51 G.m.t. (00:01:17:51 MET), the fuel cell 1 oxygen reactant valve indication showed the valve to be closed; however, the fuel cell continued to operate properly, confirming an instrumentation-only failure (Flight Problem STS-56-V-02). Because of this indication, the crew tied busses A and B together. Subsequently, busses A and B were untied and busses A and C were tied together to more evenly distribute electrical loads. The oxygen reactant valve was closed during postlanding operations for fuel cell shut down. Subsequently, the reactant valve was opened for inerting the fuel cells and the indicator worked properly. The valve panel that has the anomalous valve will be replaced during the next turnaround. Fuel cell 1 will be shut down on the next OV-103 mission (STS-51) as a part of a DTO, because a false close indication would affect the performance of this DTO. This same indication was received on a previous flight of this vehicle (STS-48).

Six fuel cell purges were performed during the mission at 24, 67, 115, 160, 191, and 215 hours MET. The flight rule for fuel cell purging for this mission was to purge every 72 hours or when a 0.2 V degradation was reached by any fuel cell. A voltage decay of 0.2 V was noted every other day on fuel cell 1, necessitating a purge prior to the 72-hour goal. Fuel cell 1 reached the 0.2 volt voltage decay limit earlier than planned because the reactant inerts were above historical levels of facility reactants, although the levels were well within specification. In addition, fuel cell 1 supplied 33 percent more power than either fuel cell 2 or fuel cell 3 due to the Orbiter load distribution.

Late in the flight, the cell performance monitor (CPM) differential voltage readings for fuel cell 1 substack 3 demonstrated a trend whereby the readings increased during reactant purging and gradually decreased between purges (Flight Problem STS-56-V-12). The increase during purges was a few millivolts larger with each succeeding purge. Analysis of the data pointed to plugging of the reactant ports in one or more of the cells of substack 3. Since the performance of the fuel cell was otherwise normal, no additional purges of that fuel cell were made. Because of fuel cell shutdown operations planned for fuel cell 1 on the next flight of this vehicle, the decision was made to replace this fuel cell during turnaround operations.

Auxiliary Power Unit Subsystem

The APU subsystem performed nominally throughout the mission, and no problems or in-flight anomalies were recorded. The table on the following page presents the APU run times and fuel consumption by APU serial number and position.

Approximately 3 minutes after APU shutdown following ascent, the system 1 fuel test line temperature 1 violated the lower fault detection annunciator (FDA) limit of 48°F, requiring the early activation of the fuel/tank/line/water system A heaters. The test line temperatures returned to the normal range once the heaters began to cycle. This is a recurring problem, and efforts are underway to resolve this condition.

Flight Phase	IAPU 1 (S/N 405)		IAPU 2 (S/N 406)		IAPU 3 (S/N 404)	
	Time, min:sec	Fuel consumption, lb	Time, min:sec	Fuel consumption, lb	Time, min:sec	Fuel consumption, lb
Launch Scrub	5:39	19	5:39	19	5:39	18
Ascent	21:41	54	21:41	59	21:41	54
FCS checkout	4:20	13				
Entry[a]	60:01	118	83:42	168	60:02	133
Total[a]	91:41	204	111:02	246	87:22	205

Notes:

[a] The IAPU's ran for 16 minutes 7 seconds after landing (touchdown).

After ascent, all three APU fuel service line temperature measurements cycled higher than the initial FDA limit, requiring the upper FDA limit of 100°F to be raised in real time to 140°F for all three APU's to prevent nuisance alarms. This condition occurred on the previous flight of this vehicle after the sensors were relocated without changing the FDA limits. Efforts are underway to raise the FDA limits.

Hydraulics/Water Spray Boiler Subsystem

The hydraulics/water spray boiler subsystem performed very satisfactorily. Operations during ascent and on-orbit were nominal with no circulation pump operations during the mission. Also, no spray cooling was experienced during the FCS checkout because the APU was operated for less than 5 minutes.

Prior to the first launch attempt, the WSB 2 core temperature lagged those of WSB 1 and 3 while the APU's were running. This lag of the WSB 2 core temperature behind those of WSB's 1 and 3 was also repeated during the STS-56 launch. When WSB water boiling occurred shortly after launch, the WSB 2 core temperature caught up with systems 1 and 3.

WSB 1 displayed a slight undercooling condition (268°F lubrication oil return temperature) and overcooling condition during ascent. However, temperatures remained well within the allowable limits.

WSB 2 had a minor overcooling condition of APU lubrication oil return after SSME repositioning during entry. This was a 20°F temperature drop that recovered after one minute, and this is a violation of the in-flight checkout requirements. The condition is a repeat of the WSB 2 system problem that occurred during the entry phase of STS-53.

Electrical Power Distribution and Control Subsystem

The electrical power distribution and control (EPDC) subsystem performed nominally throughout the mission with no problems noted. Because the fuel cell 1 oxygen reactant valve indication showed the valve to be closed, main buses A and B were tied together as a precautionary measure and to ensure that a main bus would not be lost. Later in the flight, buses A and B were untied and buses A and C were tied together to more evenly distribute the electrical loads. This configuration was maintained until after the deorbit maneuver when the buses were untied for entry and landing.

Environmental Control and Life Support Subsystem

The environmental control and life support subsystem (ECLSS) performed nominally throughout the mission.

The active thermal control subsystem (ATCS) performance was satisfactory throughout the mission. The FES primary A controller shut down during ascent at 98:05:33:16 G.m.t. (00:00:04:16 MET) as the FES was entering its control band. The FES was successfully restarted using the primary A controller. This shutdown was similar to ascent shutdowns experienced on this vehicle during STS-41 and STS-48. The temperature oscillations which triggered the shutdown logic in the controller are attributed to a unique midpoint temperature sensor manifold which is a known condition.

The radiator coldsoak provided cooling during entry through touchdown plus 14 minutes when ammonia system A was activated using the secondary controller. Before system A was activated, Freon cooling loop 2 was switched to bypass flow to increase its flowrate and the temperature entering the ammonia boiler. These procedures were specifically developed for the ammonia boilers on OV-102 and OV-103 to preclude under-temperature operation below 31°F. The procedures proved effective as the ammonia boiler controlled the temperature to 36.5°F. System A had provided 37 minutes of cooling when the ground cooling was initiated.

The atmospheric revitalization subsystem performed nominally throughout the mission. During the redundant component check, the pressure control system was switched from system 1 to system 2. Both systems exhibited normal operation.

The supply water and waste water subsystems performed adequately for the duration of the mission. All in-flight checkout requirements were performed and satisfied.

Supply water was managed through the use of the overboard dump system and the flash evaporator system. One supply water dump was performed at an average dump rate of 1.63 percent/minute (2.74 lb/min). This dump was simultaneous with waste water dump 2. The supply water dump line temperature was maintained between 63 and 92°F throughout the mission with the operation of the line heater.

Waste water was gathered at approximately the predicted rate. Three waste water dumps were performed at an average dump rate of 1.88 percent/min (3.11 lb/min). The waste water dump line temperature was maintained between 56 and 88°F throughout the mission, while the vacuum vent line temperature was between 59 and 80°F.

A simultaneous supply and waste water dump was performed, beginning at approximately 101:19:42 G.m.t. (03:14:13 MET) and was viewed with the RMS wrist CCTV camera. A total of 35 lb of supply water was dumped; concurrently, 121 lb of waste water was also dumped. RMS video, using the wrist camera, was recorded from initiation of the dump until approximately 75 minutes after the supply dump was terminated. The video was recorded as an aid in troubleshooting post-dump expulsions (burps) of water from the supply line which have been observed on three OV-103 and one OV-104 flights. Data indicate that two supply water "burps" occurred following the water dump within 1.5 hours of supply water dump valve closure. A review of the video verified water emission associated with the first occurrence, but the video was terminated prior to the second occurrence. This "burping" phenomenon was confirmed to occur on STS-53, STS-48, and STS-44, and is suspected to have occurred on previous flights of OV-103 and OV-104. A resolution to this condition continues to be developed.

The water loop 2 interchanger bypass valve was slow in closing in the automatic (controller) mode when compared with other vehicles (>75 seconds from full bypass to full closed) (Flight Problem STS-56-V-08); however, its performance matches that observed on two previous flights of OV-103 (STS-53 and STS-42). The valve closed at a slower rate when in the controller mode, whereas, in the manual mode, the closing time for the valve did not exceed the SODB limits of 60 $\pm$ 15 seconds. As a result, the controller is suspected to be the cause of the problem.

The Freon coolant loop (FCL) 2 FPV was returned to the interchanger position to aid in cooling the cabin for entry. The water coolant loop 2 temperature controller was returned to the auto position to obtain data on the performance of the water bypass valve with one FPV in Payload and the other in Interchanger.

The crew reported a glob of water about two ounces in size was on a portion of the water loop 2 inlet line to the cabin heat exchanger that was uninsulated. The water was most probably the result of condensation, as there were no indications of a leak.

The waste collection system (WCS) performed normally throughout the mission. This flight was the first for the phase I fan separator design modifications, which were intended to minimize the possibility of flooding in flight. The crew reported that the WCS system operated properly. The WCS fan separator will receive a detailed inspection upon return to the vendor.

Smoke Detection and Fire Suppression Subsystem

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

Airlock Support System

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

The crew reported that the hardware for one of the DTO's was placed in the airlock for better cooling.

Avionics and Software Subsystems

The integrated guidance, navigation and control subsystem operated nominally. Six PTI maneuvers were performed during entry in support of DTO 251 - Entry Aerodynamic Control Surfaces Test. The aileron trim excursion noted was like that seen on STS-50 and is believed to have been caused by asymmetric boundary layer transition.

A digital autopilot (DAP)/universal pointing discrepancy occurred during SUSIM operations. After the desired pointing configuration with respect to the Sun's limb was established with the DAP in inertial hold, the universal pointing total error in roll started building at a rate of approximately 0.03 degree/minute (Flight Problem STS-56-I-02). This build-up was unexpected as the universal pointing required roll attitude and the inertial hold attitudes to both be held constant. The DAP errors were maintained within deadbands throughout the inertial hold period.

The investigation of this DAP anomaly included audits of the software code, which showed no problems with the software. In addition, Software Production Facility (SPF) tests were performed in an attempt to recreate the anomaly, which could not be done. These audits and SPF tests showed that the software was not the cause of the anomaly. A workaround was developed for use during the subsequent SUSIM operations requiring universal pointing.

The flight control system performed nominally throughout the mission. The FCS checkout was completed satisfactorily at 104:06:55:33 G.m.t. (06:01:26:33 MET). During the switch checkout portions of the FCS checkout, indications were received that a power transient occurred within the ascent thrust vector control (ATVC) channel 4 electronics and caused it to fail (Flight Problem STS-56-V-09). The ATVC 4 power switch was cycled and power was restored to the unit. This anomaly did not affect the successful completion of the mission.

Performance of the inertial measurement unit, star tracker, data processing system (DPS) hardware and software, and displays and controls was satisfactory.

Communications and Tracking Subsystem

The network signal processor (NSP) 2 uplink command capability was intermittent in the low-frequency mode (Flight Problem STS-55-V-03). Troubleshooting of the ground equipment was performed and no problems were found. The command capability was switched to NSP 1 and the intermittent command problem cleared; however, communications continued to be degraded. Operations were continued on NSP 1 until about 27 hours MET when NSP 2 was reselected. Both occurrences of degraded communications took place after several hours of nominal use of the respective NSP's on low frequency (Flight Problem STS-56-V-03). A switch to high frequency alleviated the problem. Later in the mission, the S-band system operated in the low-frequency mode for over 54 hours without any observed abnormal communications problems. This signature is similar to an STS-52 low-frequency in-flight anomaly in which the cable between the preamplifier and the switch assembly for the low-frequency path had a fault.

At 098:14:30 G.m.t. (00:09:01 MET), the TIPS associated with DTO 660 was not producing an output when the ground was transmitting via the graphics mode

(Ku-band). The TIPS was producing garbled output when the ground was transmitting text (S-band); some characters were not being received clearly and were being replaced with question marks which is the normal procedure for the TIPS. However, after troubleshooting, the TIPS began working with the Ku-band system.

The TAGS was powered down to conserve power. A few hours after one successful test message was received onboard, the crew reported that none of the subsequent uplink messages were in the TIPS output tray. The crew took the TIPS down and set it up again, and the TIPS passed the self-test, but again no messages were received onboard. The test messages were received in the ground laboratory, which indicates that the ground system was operating properly. The TAGS was repowered for receiving uplink messages. At 100:11:00 G.m.t. (02:05:31 MET), the crew began reconfiguring the TIPS in preparation for additional testing. An in-flight maintenance (IFM) procedure to troubleshoot problems with the TIPS was performed. TIPS must receive a clock signal from the KUSP to operate properly. The light indicator showing whether the clock signal is being received by TIPS from the Ku-band signal processor (KUSP) was initially off and then illuminated later. A subsequent TIPS test via Ku-band was successful; however, the TIPS again failed to receive messages following the one successful transmission.

The TIPS operation through S-band audio performed well after the addition of a 10-dB attenuator in the delta modulation voice system ground equipment. A troubleshooting plan for TIPS Ku-band data transmissions was developed and sent to the crew to be performed as time permitted.

After troubleshooting, five transmissions of graphics through the Ku-band to the TIPS were attempted with the first three being received and the last two not being received. Preliminary analysis indicated that the TIPS cable may have been faulty; however a continuity test showed that the cable was satisfactory for use. In addition, the cable was attached to the TAGS, and the TAGS operated properly with this cable. The TIPS cable was reconnected to the TIPS and operations through the Ku-band were satisfactory. Operation of the TIPS in the text mode through the S-band continued to be very satisfactory.

Early during flight day 6, the crew reported that the TIPS was operating properly both on the S-band and the Ku-band. However, a few hours later, a TIPS uplink message was attempted via the Ku-band, and a second message was attempted about an hour later. Neither message was received onboard, and it was recommended that the TIPS be turned off. After 45 minutes, the TIPS was again powered up and an S-band message was successfully uplinked. The TIPS was again powered off for approximately 15 minutes, powered back up, and a Ku-band message was sent but was not received onboard.

On flight day 7, a decision was made that no more TIPS/Ku-band mode troubleshooting would be performed during the mission. Another test was performed with a message uplinked via the portable audio data modem (PADM). The crew was then able to view the file on the payload general support computer (PGSC) and print the file on the TIPS printer. The initial printout was twice the normal size so the crew scaled subsequent printouts to 50 percent for better readability.

The Ku-band mode 1 [phase modulation (PM)] channel 3 return link data quality was degraded (Flight Problem STS-56-V-04). Preliminary troubleshooting indicated that mode 1 operated on low-data-rate high-rate multiplexer (HRM) data, but did not operate on high-rate HRM data. The operational data are satisfactory regardless of the data rate being transmitted. Also, the frequency modulation (FM) mode was functioning properly. Much of the equipment in the signal processor is common between the PM and FM modes. As a result of this problem, new custom test formats 27, 28, 29, and 30 were developed; however, no improvement in Ku-band operations were achieved with these formats. Ku-band downlink was tested in format 11 (32 Mbps) on channel 3 in the payload maximum mode data rate while equipment was powered down to perform an electromagnetic interference test. Channel 3 data were again degraded, and the channel 2 link was good.

A Ku-band payload maximum baseline test was performed from 106:03:00 to 106:04:10 G.m.t. (07:21:31 to 07:22:41 MET). After the Spacelab was reactivated, further troubleshooting was performed in an attempt to narrow the data transmission problem to a specific payload. Results of these tests indicated that the Ku-band was operating satisfactorily.

The Ku-band system passed a self-test at 101:05:32 G.m.t. (03:00:03 MET). Ku-band radar tracked SPARTAN from 270 feet at 101:06:22 G.m.t. until the system was reconfigured to the communication mode at 101:07:05 G.m.t., when SPARTAN was at 3000 feet. There were no dropouts and the radar was still locked when the system was switched to the communication mode.

Following receipt of the last page of an uplink message at 104:17:17 G.m.t. (06:11:48 MET), the crew reported that the TAGS showed a developing (DVLP) indication without a page advance command from the ground. One page advance was performed and TAGS continued to show DVLP indication until a power cycle was performed. The TAGS showed a jam after the power cycle and the DVLP indication changed back to the normal ready status.

The TAGS troubleshooting was performed by the crew. The paper transport door was opened and accordioned paper was found and partially removed at the cutter bar. Since the TAGS power was still on (not in accordance with the malfunction procedure), the lower booster rollers fed the remaining paper into the developer. The paper was threaded into the lower paper path, causing a jam in the developer (Flight Problem STS-56-V-11). As a result, the TAGS was shut down and printed matter was uplinked via the TIPS text mode (S-band) for the remainder of the mission. Graphics capability existed by uplinking via the PADM to the PGSC and then printing on the TIPS.

At 104:07:56 G.m.t. (06:02:27 MET), the Commander reported that his headset interface unit (HIU) had failed (Flight Problem STS-55-V-10). The Commander used a spare HIU for the remainder of the mission.

At 104:12:18 G.m.t. (06:06:49 MET), a CCTV camera was indicating an over-temperature condition. At 105:06:41 G.m.t. (07:01:12 MET), the keel camera (PL2) was shut off and the over-temperature message went away.

The operational instrumentation (OI) performance was satisfactory.

At 107:09:03 G.m.t. (08:03:34 MET), the modular auxiliary data system (MADS) did not begin recording when commanded (Flight Problem STS-56-V-14). About six minutes after the command was sent, the MADS recorder began recording, and the recorder operated satisfactorily for the remainder of the mission.

Structures and Mechanical Subsystems

All structures and mechanical subsystems performed nominally and the main landing gear tires were considered to be in good condition following a KSC landing.

STS-56 was the seventh flight of the drag chute system. The drag chute was deployed as planned prior to nose wheel touchdown and all operations were nominal. The drag chute was jettisoned as planned 29 seconds after deployment. The following table shows where the components of the drag chute system were found.

Event/component	Location from runway threshold and centerline of runway, ft
Mortar cover	4960 & 147 East
Sabot	4980 & 23 West
Door	5065 & 7 West
Pilot chute	5030 & 0
NLG touchdown	5587 & 0
Main chute	9005 & 70 East
Wheel stop	10603 & 0

The drag chute configuration for this flight was 90-percent reefed, which data have shown to be more stable than the baseline parachute. Operation of this parachute validated the Ames Research Center wind tunnel results relative to parachute stability.

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

Aerodynamics, Heating and Thermal Interfaces

The ascent aerodynamics were nominal except for the wind shear that was encountered at lift-off plus 65 seconds at Mach 1.55. This wind shear resulted in alpha and beta excursions. A sudden increase in aerodynamic loads on the wing was identified as a possible forcing function that induced an oscillation in the elevon actuator primary pressure reading.

The entry aerodynamics were nominal with the control surfaces responding as expected except that there was an apparent recurrence of the aileron trim phenomena that occurred on STS-50. The entry aerodynamics were affected by the six PTI's performed in support of DTO 251, in addition to the two body flap maneuvers that were performed.

LANDING AND BRAKING PARAMETERS

Parameter	From threshold, ft	Speed, keas	Sink rate, ft/sec	Pitch rate, deg/sec
Main gear touchdown	1182	205.6	~3.0	n/a
Nose gear touchdown	5587	143.8	n/a	2.92

Braking initiation speed	130.9 knots (keas)
Brake-on time	33.6 seconds (not sustained)
Rollout distance	9,519 feet
Rollout time	63.2 seconds
Runway	33 (concrete) at KSC
Orbiter weight at landing	207,851 lb (landing estimate)

Brake sensor location	Peak pressure, psia	Brake assembly	Energy, million ft-lb
Left-hand inboard 1	1248	Left-hand outboard	16.21
Left-hand inboard 3	1272	Left-hand inboard	17.90
Left-hand outboard 2	1284	Right-hand inboard	12.77
Left-hand outboard 4	1092	Right-hand outboard	10.96
Right-hand inboard 1	1116		
Right-hand inboard 3	1044		
Right-hand outboard 2	948		
Right-hand outboard 4	936		

Tire location	No. 1 pressure, psia	No. 2 pressure, psia	Temperature, °F
Left-hand outboard	351.4	351.4	36.7
Left-hand inboard	350.9	350.2	36.7
Right-hand inboard	325.1	324.3	7.3
Right-hand outboard	327.9	327.9	7.3
Left-hand nose gear	334.1	334.9	41.9
Right-hand nose gear	332.1	332.1	41.9

Vehicle heating data showed structural temperatures higher on the right side of the vehicle and that is consistent with asymmetric boundary layer transition. The performance of DTO 251 did not affect the control of the vehicle.

Thermal Control Subsystem

The thermal control subsystem (TCS) performed satisfactorily throughout the mission with no out-of-limits temperatures noted.

A loose thermal blanket on the aft bulkhead (Xo 1307) was observed at 101:17:05 G.m.t. (03:11:36 MET) during video downlink of the payload bay (Flight Problem STS-56-V-05). Thermal data were assessed to determine the effects of the unsnapped thermal blanket on Orbiter subsystems. The preliminary assessment indicated that this condition would not pose an over-temperature concern to the OMS fuel high point bleed line on the aft bulkhead during the remaining planned top-Sun attitudes, since thermal blankets cover this line.

L5D aft vernier thruster oxidizer feedline temperature (V42T2560A) was consistently high and peaked at 196°F, which is higher than normal but below SODB limits. The Reaction Control Subsystem section of this report discusses this anomaly in greater detail.

Aerothermodynamics

The aerothermodynamics were nominal with acreage heating within limits and local heating normal. The structural temperature rise was near the limit of experience with the right wing temperature rise greater than the left wing. In addition, the TPS damage was near the limit of experience with several hits greater than 0.3-inch depth on the lower right forward fuselage.

Thermal Protection Subsystem

The thermal protection subsystem (TPS) performance was satisfactory. Based on structural temperature response data, the entry heating was higher than average. In particular, temperature rises on the lower aft centerline and the lower right wing were the largest ever measured on OV-103 (approximately 25°F higher than average). The overall boundary layer transition from laminar flow to turbulent flow was earlier than normal. The transition occurred at 1000 seconds after entry interface on the forward side of the vehicle (X/L=0.3), and at 980 seconds after entry interface on the aft right portion of the vehicle (X/L=0.6). Also, transition was asymmetrical from right to left on the vehicle. Transition occurred 140 seconds later on the left side of the vehicle than on the right side.

A total of 156 hits were experienced during the mission. Of these 156, 36 had a major dimension greater than one inch. The total number of hits was near the average of all missions, whereas the number of hits 1 inch or larger was greater than average when compared with previous missions.

The distribution of hits on the lower surface does not suggest a single source of ascent debris, but indicates a shedding of ice and TPS debris from random sources. The table on the following page shows the the number of hits in each area of the vehicle.

The largest tile damage site measured 9.0 by 2.0 by 0.2 inches (included two tiles) and was located on the lower surface of the right-hand wing leading edge extension (glove area). The shallow depth of 0.2 inch is indicative of an impact by low-density material, such as ET insulation. Also, one unusually large impact measuring 4.0 inches long by 2.5 inches wide by 1.3 inches deep was found on th lower right wing aft of the main landing gear door.

Reusable carbon carbon (RCC) nose cap performance was nominal. The gap filler between the nose cap and the adjacent tiles was severely breached for

Vehicle surface	Hits > 1 inch	Total hits
Lower surface	18	94
Upper surface	2	23
Right side	0	0
Left side	0	0
Right OMS pod	1	4
Left OMS pod	15	35
Total	36	156

approximately 10 inches on the lower surface. (This nose cap gap filler was replaced and this required removal of the forward RCS module and extension of the nose cap.) The primary nose landing gear door (NLGD) thermal barrier was in good condition, and no NLGD tiles were damaged. The main landing gear door (MLGD) thermal barriers were in excellent condition except for two minor tears/frays. The ET door thermal barriers were also in good condition. However, it was noted that the barriers appeared to have experienced higher than normal heating. The left-hand RCC panels 6 and 9 showed bubbling and blistering (seen on previous flights). A gap filler o the body flap was damaged with its outer fabric fused to the adjacent tile's surface, which is indicative of high heating.

All three dome-mounted heat shield blankets sustained minor damage. Base heat shield peppering was less than average. Two tiles on the right side trailing edge of the vertical stinger were damaged, apparently from drag chute deployment.

No TPS damage was attributed to material from the wheels, tires, or brakes.

Elevon cove inspections revealed six tile slumps, four on the right-hand side and two on the left-hand side. The most severe slumping occurred on tiles adjacent to the outboard center hinge point, where strain isolation pad (SIP) charring and discoloration of carrier panel koropan was also found. This is the first tile slumping found in this area of the vehicle since the elevon cove TPS was redesigned prior to STS-26. The increased local heating and SIP charring is believed to be attributed to the extreme up-elevon schedule flown as a part of DTO 0251 - Entry Aerodynamic Control Surfaces Test- Alternate Elevon Schedule; however, a connection between this DTO and the early/asymmetric transition is difficult to prove. This DTO has been performed on three previous flights, none of which indicated increased heating. However, on one of those flights (STS-50), asymmetric transition was suspected due to a aileron trim anomaly. Surface thermocouple data to support this conclusion are not available on OV-102.

All three ET/Orbiter separation devices (EO-1, -2, and -3) appeared to have functioned properly. All ET/Orbiter umbilical separation ordnance retention shutters were closed properly. No flight hardware was found on the runway below the umbilical doors.

Orbiter windows 3 and 4 exhibited moderate hazing. Only a very light haze was visible on the other windows. Some streaks were visible on windows 3 and 4. Surface wipes were taken from each window for laboratory analysis.

A portable Shuttle thermal imager (STI) was used to measure the TPS surface temperatures of three areas on the Orbiter in accordance with Space Shuttle documentation. Ten minutes after landing, the Orbiter nosecap reusable carbon carbon (RCC) was 202°F. Twenty minutes after landing, the right-hand wing leading edge RCC panel 9 was 102°F and panel 17 was 97°F.

FLIGHT CREW EQUIPMENT/GOVERNMENT FURNISHED EQUIPMENT

All flight crew equipment/government furnished equipment operated satisfactorily and supported the mission as required.

REMOTE MANIPULATOR SYSTEM

The RMS operated in an excellent manner throughout the mission with no anomalies or problems identified. STS-56 was the tenth flight of the serial number 201 arm, and the first flight of the serial number 403 end effector. The prime RMS activity was the deployment and retrieval of the SPARTAN-201 payload. For most of the mission, the RMS was positioned in a port-side, forward parked configuration that placed it out of the field of view of the ATLAS-2 experiments.

Approximately 6 1/2 hours into the mission, a successful RMS checkout was performed per standard procedures. Because of time constraints to begin ATLAS-2 operations, two steps of the checkout were deferred until later in the mission: the manual augmented mode test and the operator-commanded auto-sequence test.

On flight day 4 (03:00:42 MET), the RMS deployed the SPARTAN-201. The payload was not equipped with telemetry, but the execution of the planned "pirouette" maneuver after release indicated that the preprogrammed onboard control system was operating properly. On flight day 6 (05:01:50 MET), the SPARTAN-201 was retrieved by the RMS and returned to the payload bay for return to Earth.

Since there is no ground-based training facility that fully models the berthing of a release-engage mechanism (REM), some concern existed premission that the difficulty of the task was not fully evaluated. The difficulty involved the precise positioning and alignment needed to receive three ready-to-latch indications. The berthing of the SPARTAN-201 into the REM was accomplished in 8 minutes in an excellent manner. The maneuver was facilitated by the use of a berthing camera located on the keel of the payload bay, plus a video camera located on the SPARTAN mission peculiar experiment support structure (MPESS).

The RMS wrist camera was used during the mission to monitor a supply and waste water dump on flight day 5. The data from this camera provided the engineering community the first positive indications of the water-expulsion phenomenon that occurs after a supply water dump.

The RMS was cradled at 105:11:49 G.m.t. (07:06:20 MET) after successfully meeting all requirements placed on the system during the flight. Because of the mission extension and the need to conserve power, the RMS heaters were turned off during much of the final flight day. No negative effects were observed and temperatures did not go much lower than those observed during the periods of heater activation.

INTEGRATION

Hardware provided for integration of the cargo into the vehicle performed nominally throughout the flight. No new mission-unique integration hardware was manifested for this flight.

Two Integration in-flight anomalies were identified from the data. These anomalies are discussed in the appropriate section of this report.

DEVELOPMENT TEST OBJECTIVES/DETAILED SUPPLEMENTARY OBJECTIVES

Thirteen Development Test Objectives (DTO's) were assigned to the STS-56 mission. Of these, 11 were performed, and the results are discussed in the following paragraphs.

DEVELOPMENT TEST OBJECTIVES

DTO 251 - Entry Aerodynamic Control Surfaces Test - All six of the planned PTI's were performed in support of this DTO. The maneuvers did not impact the entry operations. High aileron trim (1.8 degrees) was experienced and it was similar to that seen on STS-50 during performance of this DTO. Data have been given to the sponsor and the results will be published in a separate report.

DTO 301D - Ascent Structural Capability Evaluation - Data were recorded on onboard recorders for this data-only DTO. The data have been given to the sponsor for evaluation, and the analyses and results will be published in separate documentation.

DTO 305D - Ascent Compartment Venting Evaluation - Data were recorded on onboard recorders for this data-only DTO. The data have been given to the sponsor for evaluation, and the analyses and results will be published in separate documentation.

DTO 306D - Descent Compartment Venting Evaluation - Data were recorded on onboard recorders for this data-only DTO. The data have been given to the sponsor for evaluation, and the analyses and results will be published in separate documentation.

DTO 308D - Vibration and Acoustic Evaluation - Data were recorded on onboard recorders for this data-only DTO. The data have been given to the sponsor for evaluation, and the analyses and results will be published in separate documentation.

DTO 312 - ET TPS Performance (Method 3) - This DTO was successfully accomplished with the acquisition of many excellent views of the ET. The two film rolls contained 74 pictures that were taken with the Nikon F4 camera and a 300-mm lens. Detailed findings from this DTO will be reported in the JSC STS-56 Photographic/Television Analysis Final Report.

Excellent sunlit views were acquired of most of the ET surface except the side toward the Orbiter (+Z axis). The pictures were acquired several minutes later than usual because the night launch increased the time before the tank entered daylight.

Apparent damage to the ET TPS on the intertank acreage was observed in the pictures. The unusual markings or divots seen on the photography has resulted in the declaration of an in-flight anomaly (Flight Problem STS-56-T-01). The following items were noted during the screening:

a. Six or more light-colored marks or divots were visible on the intertank TPS on the -Z axis or far side of the ET. Marks or divots are also visible on the liquid hydrogen/intertank flange closeout. A light-colored mark is visible on the ET TPS near the right SRB/ET aft attachment as seen on the -Z axis views. An unusual looking dark area or shadow is associated with this mark. Approximately five marks or divots are visible on the liquid hydrogen/intertank closeout flange on the -Y axis of the ET. Detailed analysis of the photography revealed 11 divots that were between 18 and 26 inches in size.

b. Bright marks are visible on the aft ET/Orbiter attachment bracing. These bright marks may be reflections of sunlight of normal protuberances on the attachment bracing.

c. The TPS on the ET nose and aft dome appeared normal. The booster separation motor (BSM) burn scars on the liquid oxygen tank appeared typical of previous missions.

The crew noted one problem in that the manifesting of this DTO was very late in the flow, requiring changes to the cameras as late as the day before launch, which impacted the crew and their preparations for the flight.

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

DTO 520 - Edwards Lakebed Runway Bearing Strength and Rolling Friction Assessment for Orbiter Landings - This DTO was not accomplished as the vehicle landed at KSC.

DTO 521 - Orbiter Drag Chute System - This DTO was accomplished during the landing and rollout phase as planned.

DTO 653 - Evaluation of the MK I Rowing Machine - This DTO was accomplished and all operations were nominal. Results of this DTO will be published in separate documentation.

DTO 656 - PGSC Single Event Upset Monitoring - This DTO was accomplished and the results are being evaluated by the sponsor. The results of the analyses will be published in separate documentation.

DTO 700-2 - Laser Range and Range Rate Device - The Laser Range and Range Rate Device DTO was performed during the SPARTAN deployment. The long-range laser for this DTO provided range data during the SPARTAN deployment that varied differently from the Ku-band radar data. The LTI component was used for short-range tracking and performed well. The MELIOS was used for longer range (minimum range is specified as 50 m/150 ft). The MELIOS range measurement deviated from the Ku-band measurement as the Orbiter moved away from the SPARTAN.

During rendezvous with the SPARTAN, the LTI device was used for tracking at ranges from 1193 ft with good results. The MELIOS device was also used during rendezvous with satisfactory results. The crew replaced the MELIOS battery after the SPARTAN deployment operations. Low battery voltage was a possible cause of the inaccurate readings during the SPARTAN deployment; however, the crew stated that the callouts were given a low priority because of the heavy workload, and this may have contributed to the inaccuracies.

DTO 700-6 - The global positioning system (GPS) data were not being displayed on the portable computer in support of DTO 700-6. An IFM troubleshooting procedure was performed; and the system began working properly. After about two hours, the system again stopped working.

DTO 805 - Crosswind Landing Performance - This DTO was not performed as crosswinds were not of sufficient magnitude to meet the minimum requirements of this DTO.

DETAILED SUPPLEMENTARY OBJECTIVES

A total of 15 DSO's were assigned to the STS-56 mission. The following paragraphs list the number and title of each DSO, as well as any preliminary results that were available at the time of publication.

DSO 321 - Frequency Interference Measurement - Approximately 4 hours of data were recorded on flight day 2. After operating for 11 hours on flight day 7, the unit experienced a power failure and was stowed after unsuccessfully attempting to restore power. Results of this DSO will be published in separate documentation.

DSO 322 - Human Lymphocyte Locomotion in Microgravity - The bioreactor for this DSO initially encountered problems in initiating operations because of excessive temperatures. The bioreactor was moved to the airlock for cooling using the "elephant trunk", and operations became nominal. The time of operations was extended because of the delay in activation. Upon completion, the bioreactor was stowed in its original locker for entry, and satisfactory temperatures were maintained.

DSO 469 - In-Flight Radiation Dose-Distribution [Tissue Equivalent Proportional Counter (TEPC) only] - This DSO equipment operated nominally throughout the mission. The unit was stowed for entry at 106:00:34 G.m.t. (07:19:05 MET)

DSO 476 - In-Flight Aerobic Exercise - All planned exercises were completed and the ergometer was reported to be very quiet.
DSO 485 - Inter Mars TEPC (no data during ascent or descent) - This DSO was accomplished and the data have been given to the sponsor for analysis. The results of the analyses will be reported in separate documentation.

DSO 488 - Measurement of Formaldehyde Using Passive Dosimetry - All operations associated with this DSO were nominal. The analyses and results will be reported in separate documentation.

DSO 603B - Orthostatic Function During Entry, Landing, and Egress - This DSO was accomplished and the data have been given to the sponsor for analysis. The analyses and results will be reported in separate documentation.

DSO 605 - Postural Equilibrium Control During Landing/Egress - This DSO was accomplished and the data are being evaluated by the sponsor. The results of the analyses will be reported in separate documentation.

DSO 617 - Evaluation of Functional Skeletal Muscle Performance Following Space Flight - This DSO was completed and the data are being evaluated by the sponsor. The results of the analyses will be reported in separate documentation.

DSO 624 - Pre and Postflight Measurement of Cardiorespiratory Responses to Submaximal Exercises - This DSO was accomplished and the data are being evaluated by the sponsor. The results of the analyses will be reported in separate documentation.

DSO 626 - Cardiovascular and Cerebrovascular Response to Standing Before and After Space Flight - This DSO was accomplished and the data are being analyzed by the sponsor. The results of the analyses will be reported in separate documentation.

DSO 802 - Educational Activities (Objective 1) - This DSO was accomplished.

DSO 901 - Documentary Television - This DSO was accomplished during the course of performing regular video documentation. The results are being evaluated.

DSO 902 - Documentary Motion Picture Photography - This DSO was accomplished.

DSO 903 - Documentary Still Photography - This DSO was accomplished.

PHOTOGRAPHY AND TELEVISION ANALYSES

LAUNCH PHOTOGRAPHIC AND VIDEO ANALYSIS

On launch day, 24 of the 24 expected videos were received and screened. In addition, during the course of the mission 51 of the 54 expected launch films were reviewed. No potential in-flight anomalies were observed in any of the launch films or video.

ON-ORBIT PHOTOGRAPHIC AND VIDEO ANALYSIS

The results of the analysis of the photography taken in support of DTO 312 are contained in the Detailed Test Objectives section of this report.

A white debris object was seen on video during the SPARTAN-201 capture. Measurements of the size and velocity of this object were made. The diameter of the RMS end effector was used for scale to determine the size of the object.

The diameter of the RMS end effector is 13.6 inches without the thermal blanket material. The object was seen to pass in front of the RMS arm. As a result, a maximum-size estimate of the object was made assuming the debris to be at the same distance as the arm. The dimension of the object was determined to be 2 by 3 inches. The velocity of the debris was 1.15 ft/sec with respect to the Orbiter.

LANDING PHOTOGRAPHIC AND VIDEO ANALYSIS

On landing day, 17 videos plus the NASA Select video were received and screened. The screening of two of the videos showed several pieces of debris appear to fall from the nose wheel well at nose landing gear door opening. The debris traveled along the underside of the Orbiter and toward the left wing.

Video coverage of the drag chute deployment was also obtained. The deployment appeared to be as expected; however, the Orbiter deviated slightly from the runway centerline in a westward direction at the time the drag chute disreefed.

TABLE I.- STS-56 SEQUENCE OF EVENTS

Event	Description	Actual time, G.m.t.
APU activation	APU-1 GG chamber pressure	098:05:24:11.84
	APU-2 GG chamber pressure	098:05:24:12.77
	APU-3 GG chamber pressure	098:05:24:13.60
SRB HPU activation[a]	LH HPU system A start command	098:05:28:32.166
	LH HPU system B start command	098:05:28:32.326
	RH HPU system A start command	098:05:28:32.486
	RH HPU system B start command	098:05:28:32.646
Main propulsion System start[a]	Engine 3 start command accepted	098:05:28:53.410
	Engine 2 start command accepted	098:05:28:53.530
	Engine 1 start command accepted	098:05:28:53.648
SRB ignition command (lift-off)	SRB ignition command to SRB	098:05:28:59.986
Throttle up to 100 percent thrust[a]	Engine 1 command accepted	098:05:29:04:048
	Engine 2 command accepted	098:05:29:04:050
	Engine 3 command accepted	098:05:29:04:050
Throttle down to 89 percent thrust[a]	Engine 3 command accepted	098:05:29:21:170
	Engine 2 command accepted	098:05:29:21:170
	Engine 1 command accepted	098:05:29:21:209
Throttle down to 69 percent thrust[a]	Engine 3 command accepted	098:05:29:28.370
	Engine 2 command accepted	098:05:29:28.371
	Engine 1 command accepted	098:05:29:28.409
Maximum dynamic pressure (q)	Derived ascent dynamic pressure	098:05:29:53
Throttle up to 104 percent thrust[a]	Engine 1 command accepted	098:05:30:01.009
	Engine 2 command accepted	098:05:30:01.971
	Engine 3 command accepted	098:05:30:01.971
Both SRM's chamber pressure at 50 psi[a]	RH SRM chamber pressure mid-range select	098:05:31:00.666
	LH SRM chamber pressure mid-range select	098:05:31:00.906
End SRM action[a]	LH SRM chamber pressure mid-range select	098:05:31:03.256
	RH SRM chamber pressure mid-range select	098:05:31:03.286
SRB separation command	SRB separation command flag	098:05:31:07
SRB physical separation[a]	LH rate APU A turbine speed LOS	098:05:31:05.866
	RH rate APU A turbine speed LOS	098:05:31:05.866
Throttle down for 3g acceleration[a]	Engine 3 command accepted	098:05:36:30.617
	Engine 2 command accepted	098:05:36:30.621
	Engine 1 command accepted	098:05:36:30.652
3g acceleration	Total load factor	098:05:36:30.5
Throttle down to 67 percent thrust[a]	Engine 3 command accepted	098:05:37:28.218
	Engine 2 command accepted	098:05:37:28.222
	Engine 1 command accepted	098:05:37:28.252
Engine Shutdown[a]	Engine 3 command accept	098:05:37:34.298
	Engine 2 command accept	098:05:37:34.302
	Engine 1 command accept	098:05:37:34.332

[a] MSFC supplied data.

TABLE I.- STS-56 SEQUENCE OF EVENTS (Continued)

Event	Description	Actual time, G.m.t.
MECO	Command flag	098:05:37:34
	Confirm flag	098:05:37:35
ET separation	ET separation command flag	098:05:37:53
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	098:05:45:52.07
	APU 2 GG chamber pressure	098:05:45:53.44
	APU-3 GG chamber pressure	098:05:45:54.40
OMS-2 ignition	Right engine bi-prop valve position	098:06:06:07.8
	Left engine bi-prop valve position	098:06:06:07.7
OMS-2 cutoff	Right engine bi-prop valve position	098:06:08:37.4
	Left engine bi-prop valve position	098:06:08:37.2
Payload bay door open	PLBD right open 1	098:07:02:54
	PLBD left open 1	098:07:04:13
SPARTAN-201 Deploy	Voice call	101:06:11:33
OMS-3 ignition	Right engine bi-prop valve position	102:09:39:37.0
	Left engine bi-prop valve position	Not applicable
OMS-3 cutoff	Right engine bi-prop valve position	102:09:39:45.4
	Left engine bi-prop valve position	Not applicable
SPARTAN-201 Grapple	Voice call	103:07:20:05
Flight control system checkout		
APU start	APU-1 GG chamber pressure	104:06:55:33.27
APU stop	APU-1 GG chamber pressure	104:06:59:53.15
ATLAS-2 Powerdown	Voice Call	107:05:33
Payload bay door close	PLBD right close 1	107:07:57:16
	PLBD left close 1	107:07:59:54
APU activation for entry	APU-2 GG chamber pressure	107:10:29:27.82
	APU-1 GG chamber pressure	107:10:53:08.45
	APU-3 GG chamber pressure	107:10:53:09.65
Deorbit maneuver ignition	Left engine bi-prop valve position	107:10:34:25.3
	Right engine bi-prop valve position	107:10:34:25.4

TABLE 1.- STS-56 SEQUENCE OF EVENTS (Concluded)

Event	Description	Actual time, G.m.t.
Deorbit maneuver cutoff	Right engine bi-prop valve position	107:10:37:53.7
	Left engine bi-prop valve position	107:10:37:53.8
Entry interface (400K)	Current orbital altitude above reference ellipsoid	107:11:05:53
Blackout ends	Data locked at high sample rate	No blackout
Terminal area energy management	Major mode change (305)	107:11:31:01
Main landing gear contact	LH MLG tire pressure	107:11:37:19
	RH MLG tire pressure	107:11:37:19
Main landing gear weight on wheels	LH MLG weight on wheels	107:11:37:24
	RH MLG weight on wheels	107:11:37:23
Drag chute deploy	Drag chute deploy 1 CP Volts	107:11:37:30.8
Nose landing gear contact	NLG tire pressure	107:11:37:34
Nose landing gear weight on wheels	NLG WT on Wheels -1	107:11:37:34
Drag chute jettison	Drag chute jettison 1 CP Volts	107:11:38:00.0
Wheels stop	Velocity with respect to runway	107:11:38:22
APU deactivation	APU-3 GG chamber pressure	107:11:53:09.35
	APU-1 GG chamber pressure	107:11:53:10.08
	APU-2 GG chamber pressure	107:11:53:11.53

TABLE II.- STS-56 PROBLEM TRACKING LIST

Number	Title	Reference	Comments
STS-56-V-01	MPS LH_2 High Point Bleed Valve (PV-22) Failed To Indicate Closed	096:06:31 G.m.t. IM 56RF01 IPR 51V-0002	MPS LH_2 high point bleed valve (PV-22) failed to indicate closed, and caused a launch countdown termination at T-11 seconds. Subsequent testing showed the valve cycled with no response from the closed indication. During the second launch attempt, closed indication returned at T-3.5 seconds and then operated normally when the valve was cycled for vacuum inerting. KSC: Troubleshoot aft wiring; replace if required.
STS-56-V-02	Fuel Cell 1 O_2 Reactant Valve False Close Indication	098:06:46 G.m.t. CAR 48RF03 UA-3-A0023	The fuel cell 1 oxygen reactant valve indicated closed at 098:06:46:54 G.m.t. Buses A and B were tied together initially. Later buses A and C were tied together. The fuel cell continued to operate properly confirming an instrumentation-only failure. This anomaly is a Repeat of Flight Problem STS-48-V-03 (OV-103). The proper indication occurred after the valve cycled postlanding for fuel cell shutdown shutdown/inerting. KSC: Troubleshoot wiring and replace oxygen manifold 1 panel after deservicing.
STS-56-V-03	Low Frequency Uplink Command Difficulty	098:14:57 G.m.t. IM 56RF04 IPR 51V-0005	Degraded communications were observed on NSP 2 and on NSP 1. Both occurrences were after several hours of nominal use of the respective NSP's. Low frequency is a common denominator, switching to high frequency cleared up problem. Switched back to low frequency on flight day 7. KSC: Measure coaxial cable temperatures and verify connector torques.
STS-56-V-04	High Data Rate Downlink Problems TRANSFERRED TO WA	098:12:30 G.m.t. IPR 51V-0003	Downlink data quality degraded on both Ku-band channels 2 and 3 when when 32 Mbps or 48 Mbps data were put on the Ku-band channel 3 in Payload Max (PL MAX) mode (PM mode). When 2 Mbps data were put on channel 3 in PL MAX mode, data quality was intermittent. Bldg 45 chit approved to delay removal of ATLAS payload.
STS-56-V-05	Aft Bulkhead Thermal Blanket Loose	101:17:15 G.m.t. IM 56RF02 PR TCS-3-17-1673	Payload bay thermal blanket on the aft bulkhead was partially detached. KSC: Evaluate postlanding.
STS-56-V-06	Universal Pointing Total DAP Error Buildup TRANSFERRED TO WA	099:13:30 G.m.t.	During execution of the SUSIM Alignment Procedure Part B, there was an unexpected change in roll attitude while the DAP was in the Inertial mode. While holding this attitude, roll total errors indicated a change in roll attitude of approximately -0.03 deg/min; however, DAP errors remained within the 0.033 deg/min deadband. The problem was repeated and a workaround of using DAP auto mode was proven successful. KSC: No action required.
STS-56-V-07	Deleted.		

TABLE II.- STS-56 PROBLEM TRACKING LIST

Number	Title	Reference	Comments
STS-56-V-08	Water Bypass Valve Controller Slow LEVEL III CLOSURE	099:03:54 G.m.t.	The water loop 2 interchanger bypass valve was slow closing when in the controller mode. The valve is closing with the specification requirements when closed manually. This performance matches the data of STS-53 and STS-42. KSC: No KSC action required.
STS-56-V-09	ATVC 4 Power Loss Indication	104:07:07 G.m.t. IM 56RF06 IPR 51V-0004	During FCS checkout mode/channel switch checkout, ATVC 4 showed anomalous power signature on all SSME actuators. The signature is indicative of an internal power supply anomaly in ATVC 4. KSC: Trouble shooting did not reproduce problem; ATVC 4 was replaced with F/N 29.
STS-56-V-10	Commander's HIU Failed LEVEL III CLOSURE	104:07:56 G.m.t. IM 56RF03	Commander reported that his Headset Interface Unit (HIU) had failed. Switched to a spare unit.
STS-56-V-11	TAGS Jam	104:17:17 G.m.t.	At 104:17:17 G.m.t., the crew reported that the TAGS paper had jammed around the cutter bar. The crew performed the required malfunction procedure (2.8). The crew opened the paper transport door and removed paper which had accordioned at the cutter bar. The crew then threaded paper into the lower path with the power on, and the lower booster rollers fed the paper into the developer, causing it to jam in the developer.
STS-56-V-12	Fuel Cell 1 Substack 3 Δ Voltage Increases During Purge	IM 56RF05 PR-FCP-3-17-0298	The fuel cell 1 substack 3 differential voltage (Δ Volts) increased during reactant purging and gradually decreased between purges. The increase during purges was a few millivolts larger with each succeeding purge. This condition is indicative of reactant port plugging in one or more cells in Substack 3. KSC: Removed and replaced fuel cell 1.
STS-56-V-13	RCS Thruster L5D Heater Failed On	IM 56RF07 IPR 51V-0011	RCS thruster L5D oxidizer and fuel injector temperatures stayed above 220°F during the flight. Normally, these temperatures decrease below 175°F. Temperatures decreased steadily when heaters were turned off prior to entry operations. Possible failed-on 10W thruster heater. KSC: Remove and replace thruster L5D.
STS-56-V-14	MADS Didn't Record When Commanded Prior to Entry LEVEL III CLOSURE	107:09:03 G.m.t.	The Modular Auxiliary Data Systems (MADS) recorder failed to move when "Record" was initiated by INCO sending the "PCM ON" command and the "WS ON" command at 107:09:03 G.m.t. The Recorder-Recording BITE (V78X9604) didn't go positive, indicating "Good" until 107:09:09:37.5 G.m.t.; followed by the Recorder Tape Motion BITE (V78X9605E) indicating "Good" at 107:09:09:38.5 G.m.t. This is a delay of over 6 minutes. KSC: MADS recorder replaced.

TABLE III.- MSFC ELEMENTS PROBLEM TRACKING LIST

Problem	Element	Description	Comments/Status
1. STS-56-T-1	External Tank	A postflight review of the astronauts' hand-held camera film revealed approximately 10 rather large and unique divots of the ET-54 intertank acreage (-Z axis).	The ET's intertank TPS application, effective ET-51 and subsequent, employs the use of two CPR foam spray guns which fill the valleys between the structural stringers and covers them in a single foam spray. Task I. Failure Investigation (Pending) Task II. Corrective Action (Pending Investigation) Task III Clearance of Effectivities (ET-56, STS-55). Based on the previous flights of the same intertank configuration. The following applies: - Divots are within experience base - Evaluation of divots indicates shallow surface foam loss - Photographs do not indicate bondline concerns - No heating concern for intertank - Orbiter tile damage for STS-56 and other two-gun spray ET's is within flight experience base - STS-42 IFA resulted in a detailed review of spray process qualification, build and nonconformance paper for ET's 51, 52, and 53. No definitive cause identified Task IV Cause and Corrective Action Summary (Pending Investigation) Based on the effectivities discussion within Task III, the problem was deferred on April 22, 1993 for the next six months in the Level III MSFC PRACA tracking system. This deferral presently covers flights STS-55, STS-57, STS-51, and STS-58. **Deferred**
2. STS-56-M-1	Redesigned Solid Rocket Motor	During the postflight inspection of the left RSRM nozzle-to-case joint, a small, axial scratch was observed on the aft dome boss primary sealing surface at 55.8°.	The scratched primary sealing surface was 0.58 inch from the forward edge of the aft dome boss ID at 55.8° and measured 0.040 inch long. Raised metal was detected, however, no damage was found on any of the nozzle-to-case joint O-rings. Also, the damaged metal sealing surface did not affect the sealing function of the joint O-rings, which performed flawlessly during the flight. A mold impression of the scratch was taken and later measured at the laboratory. The measured impression reflected the scratch was 0.0003 inch deep with 0.0002 inch of raised metal This condition causes concern that the damaged metal sealing surface could adversely affect seal function. Similar conditions have been observed on other recent flights. As a result, a "Scratch and Contamination Elimination" team was formed in September 1992, consisting of principal MSFC and RSRM contractor personnel. Since this trend has not been completely explained and continues to recur, the PRCB assigned this item as an in-flight anomaly with emphasis on a scratch team action to return with results and recommendations of their investigation. The culmination of the teams' efforts determined appropriate recurrence control which has been implemented in three areas: a. Operator awaremess and sensitivity; b. Communications; and c. Process reviews. Operator awarenes was heightened by the implementation of centralized training, eliminating contaminants and scratches through improvement and standardization of operator understanding and skills. Communications improvement was realized by increasing the involvement of the work centers toward timely and effective PFAR closures. Finally, the process reviews

TABLE III.- MSFC ELEMENTS PROBLEM TRACKING LIST

Problem	Element	Description	Comments/Status
STS-56-M-1 (Continued)			have resulted in improved general cleanliness practices (i.e., cleaning of workbenches, enhancements to handling and protection of hardware, better use of contamination clothing and tooling, and the use of lifting arrangements without weight test dates). The actions taken by this tema are adequate to minimize the occurrence of similar damage to future hardware. Since the enhancements are not effective until STS-60 (RSRM-35), it is possible that similar findings of contamination and scratches may be noted during the interim period. Several factors provide rationale for safe future flights during the interim period and beyond. (1) A preflight leak check provides positive verification of the joint's sealing capability. The nozzle-to-case joint's primary O-ring, secondary O-ring, and packings with retainers are tested at high pressure (920 ± 10 psig) and at low pressure (30 ± 3 psig) at low bolt torque and again at high pressure with high bolt torque. (2) The postflight assessment of the joint O-rings revealed no damage to to the seals because of the minimum surface flaw (0.0003 in. deep with 0.0002 inch of raised metal. (3) The minimum O-ring footprint for the nozzle-to-case joint O-ring is 0.116 inch at 14.49 percent squeeze (TWR-50063). The minimu footprint for the subject primary O-ring (as built) was 0.143 inch at 19.5 percent squeeze (TWR-63650-31). The discussed scratch length of 0.040 inch violates only 35 percent of the minimum O-ring footprint. The in-flight anomaly was closed at the Level II PRCB (PRCBD No. S044895B) on May 20, 1993. The problem report was closed in the Level III MSFC PRACA tracking system for STS-57 and subsequent on May 20, 1993. <u>Closed.</u>
3. STS-56-B-1	Solid Rocket Booster	The left SRB aft skirt HDP 5 plunger and spring escaped from the debris containment device (DCD) at lift-off.	The plunger and spring from holddown post (HDP) 5 were found in the MLP support post after the launch. The plunger is designed to seal the exit bore within the debris containment device (DCD) to prevent potential debris from escaping into the SRB plume. This was the first occurrence of this type anomaly with the DCD design, which dates back to STS-26R (28 flights). The concern associated with this circumstance is that the plunger and spring become additional debris (not previously considered) during lift-off. A MSFC/KSC/USBI anomaly team was formed to better understand this failure and perform an investigation in the following areas: (1) Design and Analysis; (2) Loads and Environments; (3) Flight Hardware; and (4) Assembly and Installation. All affected components were tested and correct material properties were verified. Examination of the plunger shoulder fracture surfaces directed the investigation to conclude that the plunger failed in a multiple-event sequence. First, the plunger struck the top of the frangible nut halves, breaking off four sections at the edges (shoulder) of the flange cutouts. It has been demonstrated by test that a zero or near zero skewed firing contributes to frangible nut recontact with the plunger. The physical evidence indicates zero skew existed during the firing of the NASA standard detonators (NSD). Second, the plunger impacted the spherical washer at the seating surface, causing the remaining edges of the plunger to fail.

TABLE III.- MSFC ELEMENTS PROBLEM TRACKING LIST

Problem	Element	Description	Comments/Status
3. STS-56-B-1 (Continued)			USBI and Rockwell International performed statistical analyses to determine the debris risk to the vehicle. The reliability of the plunger assembly operation on any given flight was determined to be 0.9646. Rockwell reevaluated the probability of vehicle impact due to the additional debris (spring and plunger) and concluded the probability to be less than 0.054 percent. The analyses concluded that the reliability of the plunger systems in combination with the low probability of no HDP debris impact to the vehicle of 0.99998. Consequently, this problem is not considered a safety of flight issue. Since this incident was a random occurrence which presents very low probability of debris impact to the vehicle, no corrective action is required. It should also be noted that the affected harware involves non-reusable parts. The Level II IFA closure was accepted at the noon PRCB (PRCBD no. S044895A) on April 21, 1993. The problem report was subsequently closed in the Level III MSFC PRACA tracking system for STS-57, and subsequent on May 24, 1993. **Closed.**
4. STS-56-E-1	Space Shuttle Main Engine	During the propellant loading on STS-56, on April 6 and April 8, 1993 both of the ME-1 anti-flood valve skin temperature measurements read 60°F to 70°F warmer than normal.	The aft compartment environment was believed to be different for this flow, and the reason has not yet been identified. All aft compartment parameters, both Orbiter and SSME, have been reviewed, and no condition was observed that indicated any associated anomaly existed. It has been demonstrated (STS-26R FRF) that the AFV skin temperature are influenced by the aft compartment environment. After much discussion, an LCC deviation (PRCBD 72379DA) was written to implement a workaround for ME-1. The AFV skin temperatures 1 and 2 and GO_2 interface temperature were monitored from T-2 minute 55 seconds to T-31 seconds via RPS stripcharts for a 5°F temperature drop maximum to verify no leakage past the ME-1 anti-flood valve. The AFV LCC limit ensures protection against oxidizer leakage. The LCC limit is set for 100° below the obserrved aft compartment temperature. The limit assures that no liquid oxidizer formation reaches the heat exchanger coil. Postflight inspection of the associated SSME hardware (skin temperature sensors and/or purge ducts) revealed nominal conditions and configuration. Efforts have been presently directed toward the Orbiter to determine if any purges of the aft compartment or vents from the drag chute compartment were different on STS-56. The investigation is continuing. The AFV sensors from engine 2024 will be x-ray-inspected for possible bonding problems. It is not believed anything anomalous will be found, since the sensors provided nominal data during the flight. After inspection, the sensors will be removed and replaced as an added precautionary measure. The in-flight anomaly will not be addressed until the next two missions have flown (waiting for the Discovery flight, STS-51). This will help determine if this condition resulted from a problem with the sensors or Discovery's aft compartment/environment, since engine 2024 is assigned to a different Orbiter (Columbia instead of Discovery). If the countdown and flight data from these missions establish the sensor or engines are not responsible, the SSME Project will recommend that the in-flight anomaly either be transferred to Shuttle Integration, if appropriate, or be closed out as an unexplained anomaly. **Open.**

DOCUMENT SOURCES

In an attempt to define the official as well as the unofficial sources of data for this STS-56 Mission Report, the following list is provided.

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

ACRONYMS AND ABBREVIATIONS

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

ACR	Active Cavity Radiometer
AEM	animal enclosure module
AFV	anti-flood valve
AMOS	Air Force Maui Optical Site
APU	auxiliary power unit
ATLAS-2	Atmospheric Laboratory for Applications and Science
ATCS	Active thermal control system
ATMOS	Atmospheric Trace Molecule Spectroscopy
ATVC	ascent thrust vector control
BPM	bioprocessing module
BSM	booster separation motor
CCTV	closed circuit television
CMIX	Commercial Materials Dispersions Apparatus Assembly
CPM	cell performance monitor
CREAM	Cosmic Ray Effects and Activation Monitor
DAP	digital autopilot
dB	decibel
DPS	data processing system
DSO	Detailed Supplementary Objective
DTO	Development Test Objective
ΔV	differential velocity
ECLSS	Environmental Control and Life Support System
EPDC	electrical power distribution and control subsystem
ESA	European Space Agency
ET	External Tank
EURECA	European Carrier Satellite
EVA	extravehicular activity
FCL	Freon coolant loop
FCS	flight control system
FDA	fault detection and annunciation subsystem
FES	flash evaporator system
FM	frequency modulation
FPV	flow proportioning valve
GAS	getaway special
GH_2	gaseous hydrogen
GLS	ground launch sequencer
G.m.t.	Greenwich mean time
GO_2	gaseous oxygen
GPS	Global Positioning System
GSFC	Goddard Space Flight Center
HAP	HERCULES attitude processor
HDP	hold down post
HDRR	high data rate recorder
HERCULES	Hand-Held, Earth-Oriented, Real-Time, Cooperative, User-Friendly, Location-Targeting and Environmental System
HIMU	HERCULES inertial measurement unit
HIU	headset interface unit

HPFTP	high pressure fuel turbopump
HPOTP	high pressure oxidizer turbopump
HPU	hydraulic power unit
HRM	high-rate multiplexer
IAPU	improved auxiliary power unit
IFM	in-flight maintenance
Isp	specific impulse
ITA	Instrumentation Technology Associates
keas	knots estimated air speed
KSC	Kennedy Space Center
KUSP	Ku-band signal processor
kWh	kilowatt hours
LCC	Launch Commit Criteria
LESC	Lockheed Engineering and Sciences Company
LH_2	liquid hydrogen
LO_2	liquid oxygen
LTI	Laser Technology Inc.
MADS	modular auxiliary data system
MAS	Millimeter Wave Atmospheric Sounder
MDA	Materials Dispersion Apparatus
MECO	main engine cutoff
MELIOS	Mini Eyesafe Laser Infrared Observation Set
MET	mission elapsed time
MLGD	main landing gear door
MLP	mobile launch platform
MPS	main propulsion system
MPESS	mission peculiar experiment support structure
MSFC	George C. Marshall Space Flight Center
NASA	National Aeronautics and Space Administration
NC1	nominal correction 1
NLG	nose landing gear
NLGD	nose landing gear door
NPC	nominal plane change
NPSP	net positive suction pressure
NSP	network signal processor
NSR	nominal slow rate
NSTS	National Space Transportation System
OI	operational instrumentation
OMRSD	Operations and Maintenance Requirements and Specifications Document
OMS	orbital maneuvering subsystem
PADM	portable audio data modem
PAL	protuberance air load
PARE	Physiological and Anatomical Rodent Experiment
PDU	playback/downlink unit
PGSC	payload general support computer
PLBD	payload bay door
PM	phase modulation
PMBT	propellant mean bulk temperature
ppm	parts per million
PRSD	power reactant storage and distribution
PTI	programmed test input
RCC	reinforced carbon carbon
RCS	reaction control subsystem

REM	release-engage mechanism
RME-III	radiation monitoring equipment-III
RMS	remote manipulator system
RSRM	Redesigned Solid Rocket Motor
S&A	safe and arm
SAREX-II	Shuttle Amateur Radio Experiment-II
SIP	strain isolation pad
SODB	Shuttle Operational Data Book
SOLCON	Solar Constant experiment
SOLSPEC	Solar Spectrum measurement
SPARTAN-201	Shuttle Pointed Autonomous Research Tool for Astronomy-201
SPF	Software Production Facility
SRB	Solid Rocket Booster
SRSS	Shuttle Range Safety System
SSBUV	Shuttle Solar Backscatter Ultraviolet experiment
SSME	Space Shuttle main engine
STI	Shuttle thermal imager
STL	Space Tissue Loss experiment
STS	Space Transportation System
SUSIM	Solar Ultraviolet Spectral Irradiance Monitor experiment
SUVE	Solar Ultraviolet Experiment
TAGS	text and graphics system
TCS	thermal control system
TEPC	Tissue Equivalent Proportion Counter
TIPS	thermal impulse printer system
TPS	thermal protection system/subsystem
UARS	Upper Atmosphere Research Satellite
USMC	U. S. Marine Corps
UVCS	Ultraviolet Coronal Spectrometer
V	volt
W	Watt
WCS	Waste Collection System
WLC	White Light Coronagraph
WSB	water spray boiler

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