NSTS-08295



# STS-66 SPACE SHUTTLE MISSION REPORT



February 1995



National Aeronautics and
Space Administration

Lyndon B. Johnson Space Center
Houston, Texas

## NOTE

The STS-66 Space Shuttle Mission Report was prepared from inputs received from the Orbiter Project as well as other organizations The following personnel may be contacted should questions arise concerning the technical content of this document

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NSTS 08295

# STS-66

# SPACE SHUTTLE

# MISSION REPORT

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
LYNDON B JOHNSON SPACE CENTER
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# INTRODUCTION

The STS-66 Space Shuttle Program Mission Report summarizes the Payload activities as well as the Orbiter, External Tank (ET), Solid Rocket Booster (SRB), Redesigned Solid Rocket Motor (RSRM), and the Space Shuttle main engine (SSME) systems performance during this sixty-sixth flight of the Space Shuttle Program and the thirteenth flight of the Orbiter vehicle Atlantis (OV-104) In addition to the Orbiter, the Space Shuttle Vehicle consisted of an ET that was designated ET-67, three SSMEs that were designated as serial numbers 2030, 2034, and 2017 in positions 1, 2, and 3, respectively, and two SRBs that were designated BI-069 The RSRMs that were installed in each SRB were designated as 360L038A (lightweight) for the left SRB, and 360W038B (welterweight) for the right SRB

The STS-66 Space Shuttle Program Mission Report fulfills the Space Shuttle Program requirement as documented in NSTS 07700, Volume VII, Appendix E The requirement is that each major organizational element of the Space Shuttle Program will report the results of their hardware and software evaluation and mission performance In addition, each element must identify all related in-flight anomalies

The primary objective of this flight was to accomplish complementary science objectives by operating the Atmospheric Laboratory for Applications and Science -3 (ATLAS-3) and the Cryogenic Infrared Spectrometers and Telescopes for the Atmosphere-Shuttle Pallet Satellite (CRISTA-SPAS) The secondary objectives of this flight were to perform the operations of the Shuttle Solar Backscatter Ultraviolet/A (SSBUV/A) payload, the Experiment of the Sun Complementing the Atlas Payload and Education-II (ESCAPE-II) payload, the Physiological and Anatomical Rodent Experiment/National Institutes of Health-Rodents (PARE/NIH-R) payload, the Protein Crystal Growth-Thermal Enclosure System (PCG-TES) payload, the Protein Crystal Growth-Single Locker Thermal Enclosure System (PCG-STES), the Space Tissue/National Institutes of Health-Cells (STL/NIH-C) -A payload, the Space Acceleration Measurement Systems (SAMS) Experiment, and Heat Pipe Performance Experiment (HPPE) payload

The 11-day plus 2 contingency day STS-66 mission was flown as planned, with no contingency days used for weather avoidance or Orbiter contingency operations The sequence of events for the STS-66 mission is shown in Table I, and the Orbiter Problem Tracking List is shown in Table II Table III shows the Government Furnished Equipment/Flight Crew Equipment (GFE/FCE) Problem Tracking List, and Table IV shows the Marshall Space Flight Center (MSFC) Problem Tracking List In addition, all Integration in-flight anomalies are referenced in applicable sections of the report Appendix A lists the sources of data from which this report was prepared, and Appendix B defines all acronyms and abbreviations used in the report All times in the report are given in Greenwich mean time (G m t ) as well as mission elapsed time (MET)

The six-person crew for STS-66 consisted of Donald R McMonagle, Lt Col , USAF, Commander, Curtis L Brown, Jr , Lt Col , USAF, Pilot, Ellen Ochoa, Ph D , Payload Commander (Mission Specialist 1), Joseph R Tanner, Mission Specialist 2, Jean-Francois Clervoy, European Space Agency, Mission Specialist 3, and Scott E Parazynski, M D , Mission Specialist 4 STS-66 was the third space flight for the Commander, the second space flight for the Pilot and Payload Commander (Mission Specialist 1), and the first space flight for Mission Specialist 2, Mission Specialist 3, and Mission Specialist 4 The crew was divided into two teams, red and blue, to enable continuous around-the-clock operations of the experiments

## MISSION SUMMARY

The STS-66 Space Shuttle vehicle was successfully launched at 307 16 59 43 004 G m t (10 59 43 a m c s t ) on November 3, 1994, from Kennedy Space Center (KSC) Launch Complex 39 B The countdown was held for 3 minutes 43 seconds at T-5 minutes to discuss the weather conditions, specifically winds, at the Transatlantic Abort Landing (TAL) site The powered ascent phase of the flight was nominal All SSME and RSRM start sequences occurred as expected and the launch phase performance was satisfactory in all respects First stage ascent performance was as expected SRB separation, entry, deceleration and water impact occurred nominally Both SRBs were recovered and returned to KSC for refurbishment Performance of the SSMEs, ET, and main propulsion system (MPS) was nominal

During the maneuver to photograph the ET after separation, the Orbiter reaction control subsystem (RCS) aft-firing thruster L1A failed off because of low chamber pressure The redundancy management (RM) software deselected the thruster 320 msec into the firing The peak chamber pressure was 11.3 psia over 160 msec (four data samples) Injector temperatures verified at least partial opening of both the fuel and oxidizer valves Thruster L1A remained deselected for the remainder of the mission.

A nominal direct-insertion trajectory was flown, consequently, no orbital maneuvering subsystem (OMS) 1 maneuver was required The OMS 2 maneuver was initiated at 307 17.35 56 1 G m.t (00.00 36 13.1 MET) The maneuver was 160 seconds in duration and the ΔV was 262 3 ft/sec A 165 1 by 164 0 nmi. orbit was achieved as a result of the OMS 2 maneuver

Payload bay door opening was completed at 307 18.29.56 G m.t (00·01 30·13 MET) During the door opening sequence, all operations were performed on dual motors within the specified time When the starboard door was opened, the ready-to-latch (RTL) switch 3 and close switch 2 did not transfer off as required Approximately 38 and 44 minutes later, respectively, the ready-to-latch and close switches transferred to their correct state This anomaly did not recur during payload bay door closing operations

The Spacelab was activated successfully at 307 19 27 G.m.t (00 02 27 MET), and the ATLAS-3 activation was completed 57 minutes later The SSBUV/A was activated at 307 23 00 G.m t (00 06.00 MET)

The remote manipulator system (RMS) checkout was successfully completed at 307.21 43 G m t (00.04 43 MET). The CRISTA-SPAS was powered on, and checked out All systems of the SPAS performed nominally and the spacecraft health was satisfactory The RMS was used to grapple the CRISTA-SPAS in the payload bay following the checkout The CRISTA-SPAS was unberthed at 308 11 45 54 G m t (00 18 46 11 MET), and released at 308 12 49 49 G m t (00 19 50 06 MET)

After release and separation from the CRISTA-SPAS, a series of RCS maneuvers were satisfactorily completed to maintain the planned separation distance between the Orbiter and CRISTA-SPAS Six of the 17 planned maneuvers (NC-3, NC-4, NC-5, NC-8, NC-12, and NC-15) were not performed because they were not required However, one small RCS maneuver (NC10A) was added to make a total of 12 maneuvers performed RCS operation during all of these maneuvers was nominal. In addition to the 12 RCS maneuvers, one OMS maneuver (OMS 3/NC-18) was also performed satisfactorily

During the rendezvous with CRISTA-SPAS, one OMS maneuver (OMS-4) was performed satisfactorily to initiate the rendezvous sequence Also, four primary RCS maneuvers were performed during the rendezvous with nominal results

Flight control system (FCS) checkout was performed using auxiliary power unit (APU) 1 and all FCS parameters were nominal The APU was started at 315:10.33 11 G.m.t. (07:17.33.28 MET) and ran for 4 minutes 2 seconds A total of 12 lb of fuel was used Hydraulics system operations were also nominal

During a systems management (SM) checkpoint from general purpose computer (GPC) 4 to mass memory unit (MMU) 1 at 315:13 26 G.m t (07.20.26 MET), two error messages (I/O ERROR MMU 1 and S60 CHECKPT FAIL) were annunciated The checkpoint was unsuccessful During troubleshooting, all further transactions between GPC 4 and MMU 1 failed Successful transactions were performed between GPC 1 and MMU 1. This interface problem between GPC 4 and MMU 1 was believed to be due to a failure of the GPC 4 bus control element (BCE) 18 transmitter and/or receiver. A software dump of GPC 4 was performed, and analysis of the dumped data supported the BCE 18 failure and indicated no other problem with GPC 4. A verification of GPC 4 as a redundant guidance, navigation and control GPC was performed at 316 18.30 G m.t (09.01:30 MET)

The SM function was moved from GPC 4 to GPC 3. GPC 4 was then placed in the redundant set with GPC 1 at 316·19 13 G m t (09 02 13 MET) to determine whether the problem that the GPC 4 interface had with MMU 1 also affected GPC 4 communications on the flight critical (FC) 8 data bus The test confirmed that GPC 4 communications on FC8 were nominal, isolating the problem to the GPC 4 BCE 18 interface with MMU 1 The condition did not impact entry procedures

A simultaneous supply/waste water dump was completed at 315 16 06 G m t (07.23.06 MET) and was followed by a successful purge of the supply water dump line Approximately 96 lb of waste water and 117 lb of supply water were dumped with no water system anomalies noted The dump was observed by the RMS end-effector camera, which showed an icicle growing toward the supply dump nozzle The dump was terminated just before the icicle reached the supply nozzle The base of the icicle was attached to the port payload bay door (PLBD) (Note A portion of the icicle remained attached to the port PLBD throughout entry and landing ) Because of the ice formation, no further waste water dumps were performed Sufficient ullage existed to support a nominal end-of-mission Supply water was dumped through the FES

The CRISTA instrument collected 180 hours of data and the Middle Atmosphere High Resolution Spectrograph Investigation (MAHRSI) instrument collected about 200 hours of data CRISTA is the first instrument to provide detailed information on the conditions in the upper atmosphere -- the dynamics of winds, temperature changes and atmospheric movements which distribute the gases that influence ozone chemistry

During the rendezvous phase with the CRISTA-SPAS satellite, a Shuttle maneuver called the "MAHRSI football" was performed This maneuver allowed the MAHRSI instrument to make observations of the Shuttle and the area immediately around it Both the CRISTA and MAHRSI teams were elated with the achievements of the payload mission The CRISTA-SPAS was grappled at 316 12 06 G m t (08 19 06 MET) After completion of the high priority objectives of the notch filter detailed test objective (DTO), the CRISTA-SPAS was berthed at 316 14 30 G m t (08 21 30 MET)

The RCS hot-fire was performed at 317·10 02 18 G m t (09 17.02 35 MET) Primary thruster L4L was not fired, L3L was fired only once, and L1A was not fired as it had failed earlier in the mission

The ATLAS-3 payload deactivation occurred at 318.02 30 G m t (10 09 30 MET), and initial Spacelab deactivation followed at 318 05 07 G m t (10 12 07 MET) The SSBUV/A instrument was deactivated at 318 06 23 G m t (10 13 23 MET) Final deactivation of the Spacelab was completed at 318 12 05 G m t (10 19 05 MET) The overall performance of the Spacelab subsystems was nominal

At 318 10 05 G m t (10 17 05 MET), the flash evaporator system (FES) B controller experienced an under-temperature shutdown The primary B controller power was cycled and the FES operated normally until radiator bypass was selected Following radiator bypass/FES checkout, several large transients occurred on the primary B controller The evaporator outlet temperature oscillated between 34 °F and 47 °F (limits are 39 °F ± 2 °F) and the primary A controller was selected at 318 12 04 G m t (10 19 04 MET) The FES operated nominally during entry

All entry stowage and deorbit preparations were completed in preparation for entry The payload bay doors were successfully closed and latched at 318 11 54 45 G m t (10 18 55 02 MET) The weather at KSC was becoming worse because of a tropical storm that was near the Florida east coast Consequently, both KSC landing opportunities were waived, and the first landing opportunity at Edwards Air Force Base was targeted The deorbit maneuver was initiated at 318:14 31:05 G m t (10:21:31:22 MET), and the maneuver was 213 8 seconds in duration with a ΔV of 380 0 ft/sec

During entry, the APU 1 supply line temperature was erratic All other APU 1 parameters were nominal As a precaution, APU 1 was shut down immediately after wheels stop

Entry was completed satisfactorily, and main landing gear touchdown occurred at the Edwards Air Force Base concrete runway 22 at 318:15 33 45 G m t (10.22 34 02 MET) on November 14, 1994 The Orbiter drag chute was deployed satisfactorily at 318:15 33:49 G m t , and nose landing gear touchdown occurred 7 seconds later The drag chute was jettisoned at 318 15 34 16 G m t with wheels stop occurring at 318 15:34:35 G.m t The rollout was normal in all respects The flight duration was 10 days 22 hours 34 minutes 02 seconds

# PAYLOADS

The STS-66 flight, Mission to Planet Earth, was launched on November 3, 1994 The Spacelab was activated successfully at 307 19 27 G m t (00 02 27 MET), and the ATLAS-3 activation was completed 57 minutes later At 307 21 00 G m t (00 04 00 MET), the CRISTA-SPAS was grappled, powered on, and checked out All systems of the SPAS performed nominally and the spacecraft health was satisfactory The SSBUV/A was activated at 307 23 00 G m t (00 06·00 MET) The CRISTA-SPAS was successfully deployed at 308 11 50 G m t (00 18 50 MET)

The science teams for the ATLAS-3, CRISTA-SPAS, and the SSBUV-A payloads are elated with the wealth of science data obtained in this extremely successful mission According to the Joint Mission Scientist, "The mission not only met our expectations, but also all our hopes and dreams as well " Preliminary analysis of the data collected indicates that the Antarctic ozone hole is a self-contained region, and that there has been a large increase in the amount of Freon-22 in the stratosphere This chemical, used as a replacement for chlorofluorocarbons (CFCs) is not as great a threat to the ozone layer as CFCs It is, however, still a growing source of stratospheric chlorine Also of note is the lack of a direct link between the Antarctic ozone hole and ozone depletion in the mid-latitudes, indicating that there are atmospheric processes that are still not well understood

The CRISTA instrument collected 180 hours of data and the Middle Atmosphere High Resolution Spectrograph Investigation (MAHRSI) instrument collected about 200 hours of data Current generation orbital satellites would require almost 6 months to collect a data set as large as CRISTA collected on this flight CRISTA is the first instrument to provide detailed information on the conditions in the upper atmosphere -- the dynamics of winds, temperature changes and atmospheric movements which distribute the gases that influence ozone chemistry During the rendezvous phase with the CRISTA-SPAS satellite, a Shuttle maneuver called the "MAHRSI football" was performed. This maneuver allowed the MAHRSI instrument to make observations of the Shuttle and the area immediately around it The measurements of the Shuttle and the attendant "Shuttle glow" will help scientists understand the phenomenon. Both the CRISTA and MAHRSI teams are elated with the achievements of their mission The CRISTA-SPAS was grappled at 316 13 05 G m t (08.20 05 MET) After completion of the high priority objectives of the notch filter detailed test objective (DTO), the CRISTA-SPAS was berthed at 316 16 50 G m t (08.23.50 MET)

The ATLAS-3 payload deactivation occurred at 318 02 30 G m t (10 09 30 MET), and initial Spacelab deactivation followed at 318 05 07 G m t (10 12 07 MET) Final deactivation of the Spacelab was completed at 318 12 05 G m t (10 19 05 MET) The SSBUV/A instrument was deactivated at

318 06 23 G m t (10 13 23 MET) The overall performance of the Spacelab subsystems was nominal

At 315 20 53 G m t (08 03 53 MET), the Spacelab subsystem inverter shut down Data review shows the inverter voltage decreased to the 22-24 volt range per phase, and the subsystem inverter output currents increased approximately 6 amperes per phase before the subsystem inverter shut down A 20-ampere increase was reflected in the fuel-cell currents for about 20 msec The crew performed the required malfunction procedure and switched to the experiment inverter The Spacelab subsystems operated nominally for the remainder of the mission on the experiment inverter

The Joint Science Mission scientists will require many months to refine the volumes of data that were accumulated during the 11-day flight, but the success of the experiments is already apparent As the postflight data analysis is completed, the data will be deposited in the Earth Observing System Data Information System archives at NASA's Goddard Space Flight Center (GSFC) and will be available to atmospheric scientists around the world

## ATMOSPHERIC LABORATORY FOR APPLICATIONS AND SCIENCES-3

The ATLAS-3 payload was placed in orbit during a time of the year when the Antarctic ozone hole had already passed its deepest level and had begun to recover, and the Northern Hemisphere atmosphere was beginning to adjust to the approaching winter This provided the ATLAS-3 atmospheric instruments unique insights into how these changes take place

### Chemical Constituents of the Middle Atmosphere

Atmospheric Trace Molecule Spectroscopy: The Jet Propulsion Laboratory's (JPL's) Atmospheric Trace Molecule Spectroscopy (ATMOS) experiment collected more data on trace gases in the atmosphere than on all three of its previous flights combined The instrument took readings over the Northern Hemisphere from just above the U.S -Canadian border down to the equator Southern Hemisphere observations, both inside and outside the Antarctic ozone hole, revealed new insights into atmospheric chemistry there

Water vapor and nitrogen oxides are almost absent inside the ozone hole, but a similar absence was not seen on the outside The ATMOS Principal Investigator stated that this indicates that the ozone hole is a self-contained region

A comparison of the data from this flight and the first ATLAS/ATMOS flight 3 years ago shows significant increases in the halogen-containing HCFC-22 Though not as great a threat to the atmosphere as the chlorofluorocarbons it replaces, this gas is a growing source of stratospheric chlorine

Another key new finding is that reactive chlorine is converted directly to HCl during the recovery phase HCl is the primary reservoir species in the lower stratosphere within the ozone hole, while both HCl and $ClONO_2$ are reservoir species at higher altitudes

Millimeter Wave Atmospheric Sounder The Millimeter Wave Atmospheric Sounder (MAS), provided by Germany, made 10 hours of observation on the first day of the mission A malfunction in the instrument's onboard computer system after the first atmospheric observation period made it impossible to communicate with the MAS for the remainder of the flight However, the data MAS did collect were revealing

Variations in the ozone and water vapor with altitude and latitude, as seen in the preliminary data, were especially interesting The structure suggests that a considerable flow already exists from the south pole to the north pole in the mesosphere, a region of the atmosphere above the ozone layer.

The MAS instrument also obtained useful measurements of chlorine monoxide despite the relatively short observation period The results were primarily the result of improvements made to the chlorine monoxide detector that made the sensor twice as sensitive as it was on previous ATLAS flights Chlorine monoxide, formed mainly by the breakdown of chlorofluorocarbons in the atmosphere, plays an important part in the ozone loss

Shuttle Solar Backscatter Ultraviolet/A. The SSBUV/A experiment took ozone measurements to calibrate the ozone monitor on the NOAA-9 satellite, which has been in orbit since 1984. The SSBUV/A also matched observations with the Total Ozone Mapping Spectrometer on a Russian meteorological satellite In addition, the instrument took simultaneous measurements with every other ATLAS-3 instrument Comparisons of preliminary solar ultraviolet radiation data from SSBUV/A, Solar Ultraviolet Spectral Irradiance Monitor (SUSIM), and Solar Spectrum Experiment (SOLSPEC) showed the instruments to agree within approximately 5 percent of each other, a remarkable achievement for three instruments with different designs and calibration methods

The SSBUV/A initially exhibited a problem in that four unsuccessful attempts were made to open the door by ground command to activate the experiment However, the crew was able to open the door from onboard using the Small Payloads Accommodations switch Following this problem, the door operated satisfactorily by ground command for the remainder of the mission The experiment operated satisfactorily

The SSBUV/A Principal Investigator called the ATLAS-3 mission "one of the most productive in data acquisition and the most productive in science," thanks to the close collaboration among the science teams, powerful computer tools, and the "enormously flexible Shuttle systems "

## Solar Radiation and the Middle Atmosphere

Solar Spectrum Experiment  The SOLSPEC experiment, provided by France, fulfilled its primary assignment - taking absolute measurements of the Sun's radiation as a function of wavelength, from far ultraviolet to far infrared  It also made direct Earth measurements in ultraviolet ranges to assist in determining the chemical composition of the atmosphere  The SOLSPEC Principal Investigator cited the quality of ATLAS-3 measurements and the absence of technical problems in declaring the mission "a great success "

Throughout ATLAS-3 operations, the Solar Constant (SOLCON) and SOLSPEC were commanded from the Belgian Science Remote Operations center, and the instruments' home laboratories in Brussels and France processed the incoming data  The operation was highly effective, freeing the principal investigators in Huntsville to dedicate more time to science planning  The short turnaround time in data processing allowed them to exchange data with other ATLAS-3 scientists while the mission was in progress

Solar Ultraviolet Spectral Irradiance Monitor: The SUSIM collected the highest precision solar ultraviolet radiation measurements in its 15-year lifetime Improvements made since the instrument's creation have decreased uncertainties from 30 percent in 1979 to 3 percent at the present time, according to the Co-Investigator at the U S Naval Research Laboratory  The ATLAS-3 SUSIM made simultaneous measurements with the SUSIM instrument on NASA's Upper Atmosphere Research Satellite (UARS) during each solar period, and preliminary comparisons to correct the UARS instrument's measurements are being made.

## TOTAL SOLAR IRRADIANCE MEASUREMENTS

## Active Cavity Radiometer Irradiance Monitor

The Active Cavity Radiometer Irradiance Monitor (ACRIM), from NASA's Jet Propulsion Laboratory, took precise measurements of the sun's total radiation ACRIM's primary purpose was to check the accuracy of a sister instrument, which has been making solar measurements aboard NASA's UARS since its launch in 1991  Long exposure to solar radiation degrades the accuracy of satellite instruments, so comparisons with the highly calibrated ATLAS-3 instruments will help verify their reliability

## Solar Constant

Belgium's SOLCON instrument "worked perfectly throughout the mission," according to the Principal Investigator  Like ACRIM, SOLCON records very precise values of solar radiation, providing a reference point to track subtle changes over tens and even hundreds of years  A special test exposed SOLCON's sensors to atmospheric particles in the Orbiter direction of travel Results confirmed that the particles were the source of data glitches that were sometimes seen at the beginning of observations  Adjusting SOLCON data to allow for the particle interference will make the data even more reliable

# PAYLOAD MISSION-PECULIAR/MISSION-DEPENDENT EQUIPMENT

## Global Pointing System

Initially the ATLAS global positioning system (GPS) was able to track only two GPS satellites in the -Z local vertical (LV) attitude, but later was able to track up to four and five and compute solutions during the -Z solar inertial (SI) attitude periods  The pointing mode of the ATLAS GPS was changed to enable it to sequentially search for any of the 24 GPS satellites  The signal-to-noise ratio was also changed  The combination of these changes allowed the GPS receiver to compute some solutions while in the -ZLV attitude

# CRYOGENIC INFRARED SPECTROMETERS AND TELESCOPES FOR THE ATMOSPHERE-SHUTTLE PALLET SATELLITE

## Cryogenic Infrared Spectrometers and Telescopes for the Atmosphere

The Cryogenic Infrared Spectrometers and Telescopes for the Atmosphere (CRISTA) instrument, from the University of Wuppertal in Germany, made the first three-dimensional global maps of atmospheric gases  Its purpose was to determine how the conditions in the upper atmosphere transport gases from one place to another  "For instance, we were looking for cloud-like structures in ozone distribution, predicted by computer models, which could help explain why there is no lasting hole in Northern Hemisphere winter and spring," said the Principal Investigator  "So far, that is unexplained "

CRISTA made infrared measurements both inside and outside the Southern polar vortex, and also viewed the edge of the Antarctic ozone hole  A total of 51,000 vertical scans of the Earth's atmosphere, ranging from the upper atmosphere to near the ground, will furnish three-dimensional profiles of the distribution and movement of ten trace gases involved in ozone chemistry CRISTA also produced the first global map of atomic oxygen, which scientists believe helps cool the Earth

## Middle Atmosphere High Resolution Spectrograph Investigation

The MAHRSI instrument gave scientists an unprecedented look at an ozone-destroying molecule called hydroxyl The Principal Investigator, located at the Naval Research Laboratory, said "We now have in our hand four complete global maps of hydroxyl in the middle atmosphere That's something we never had before, and we're thrilled " The Principal Investigator also said that hydroxyl variations by latitude, that showed up in the preliminary data, may reflect similar variations of water vapor and ozone detected by the MAS

The MAHRSI also observed nitric oxide, another gas involved in ozone destruction, in coordination with nitric oxide measurements made by the SSBUV/A experiment

Other cooperative observations with SSBUV/A included MAHRSI ozone measurements to test a potential system for the next generation of ozone sounders; and studies of cloud tops made simultaneously by SSBUV/A, MAHRSI, and CRISTA Their combined ultraviolet and infrared measurements will help define the influence of clouds on the measurement of stratospheric ozone

"The decisions we make to protect the health of our environment need to be based on accurate scientific knowledge, and that's what the ATLAS missions were all about," said an ATLAS representative "Results will be shared by scientists all over the world in their studies of the Sun and Earth's changing atmosphere "

## EXPERIMENT OF THE SUN COMPLEMENTING THE ATLAS PAYLOAD AND EDUCATION-II

The student-designed, developed and manufactured Experiment of the Sun Complementing the ATLAS Payload and Education-II (ESCAPE-II) was successfully operated during the two data-take periods and satisfactory data were collected. Instruments on ESCAPE-II included a spectrometer and a digital imaging telescope, which gathered data in the extreme ultraviolet wavelengths where little research has been done in the last 20 years The data collected have been given to the sponsoring scientist for use in the analysis

## NATIONAL INSTITUTE OF HEALTH- RODENTS-1 PAYLOAD

The National Institute of Health-Rodents-1 (NIH-R-1) payload is a collaborative developmental biology experiment that consists of 11 studies of the effect of space flight on developing rats The data from these studies will provide important insights into the fields of gravitational and space biology and gravity's effect on living organisms All aspects of the payload performed nominally and the experimenters will evaluate the results during postflight operations

Two animal enclosure modules (AEMs) were flown, each containing five pregnant rats There were nine Principal Investigators from the U S , as well as one Principal Investigator from Russia and one from France The studies being conducted were as follows

a Effects of Space Flight on Muscles and Nerves,
b Experiment to Study the Role of Gravity in the Development of the Optic Nerve,
c Effects of Weightlessness on Vestibular Development,
d Effect of Spaceflight on Development of Immune Responses,
e Choroid Plexus, Brain and Heart Neural Physiological (NP) Development in Space,
f Fluid-Electrolyte Metabolism,
g Microgravity and Placental Development,
h Spaceflight Effects on Mammalian Development,
I Effect of Gravity on the Attachment of Tendon to Bone,
j Effect of Microgravity on Epidermal Development in the Rat, and
k Development of Sensory Receptors in Skeletal Muscle

## PROTEIN CRYSTAL GROWTH EXPERIMENTS

Two related Protein Crystal Growth Experiments (PCGE) were flown on the STS-66 mission and these were

a Crystal Observation System/Thermal Enclosure System (COS/TES), and
b Vapor Diffusion Apparatus/Single Locker Thermal Enclosure System (VDA/STES)

One of the six chambers of the COS/TES did not form a droplet during activation. The remaining five chambers had crystal growth that will be reviewed and analyzed by the Principal Investigator during postflight analysis activities The three trays, each containing 20 protein crystal growth chambers, performed nominally throughout the flight According to the Principal Investigator, STS-66 produced the highest yields and largest crystals of any protein crystal growth experiment flown on the Space Shuttle Postflight analysis will be performed by the Principal Investigator

## NATIONAL INSTITUTE OF HEALTH-CELLS-2 PAYLOAD

The National Institute of Health-Cells-2 (NIH-C-2) was comprised of two biomedical experiments, which used a computerized tissue culture incubator The Payload experiments were as follows

a Investigations of the Effects of Microgravity on *in vitro* Cartilage Calcification, and
b Effect of Space Travel on Skeletal Myofibers

The overall payload performance was nominal The results will be reviewed and analyzed during postflight operations

## SPACE ACCELERATION MEASUREMENT SYSTEM

The Space Acceleration Measurement System (SAMS) collected data which characterized the middeck environment, and was being flown for the eleventh time on the Space Shuttle Data from the SAMS are used by the Protein Crystal Growth experiments in their operation All SAMS operations were nominal, and the recorded data are being evaluated during the postflight analysis period

## HEAT PIPE PERFORMANCE EXPERIMENT

The Heat Pipe Performance Experiment-2 (HPPE-2) provided data for investigation of the thermal performance of 10 different axially grooved aluminum/Freon heat pipes in 38 individual tests, three more than planned The pipes operated with asymmetric and multiple heating zones under microgravity conditions The performance of the HPPE-2 experiment was excellent Additionally, preliminary results show that the under-filled pipes showed significantly better performance than was seen in ground tests The recorded data will be analyzed during postflight operations

## VEHICLE PERFORMANCE

The performance of the vehicle was nominal throughout the launch and the mission A total of eighteen vehicle anomalies (Tables II and IV) were defined from all elements, however, none of these anomalies had any significant impact on the mission

The Marshall Space Flight Center (MSFC) STS-66 Flight Evaluation Reports contain an in-depth discussion of the performance of each of the elements provided by MSFC The MSFC Flight Evaluation Report is divided into six volumes as follows

a Volume I - Executive Summary
b Volume II - Solid Rocket Booster Project
c Volume III - Redesigned Solid Rocket Motor Project
d Volume IV - External Tank Project
e Volume V - Space Shuttle Main Engine Project
f Volume VI - Main Propulsion System

Copies of these reports may be obtained from the George C Marshall Space Flight Center, Marshall Space Flight Center, Alabama 35812

## SOLID ROCKET BOOSTERS

Data analysis shows that all Solid Rocket Booster (SRB) systems performed nominally The SRB prelaunch countdown was normal, and no SRB Launch Commit Criteria (LCC) violations occurred One SRB Operations and Maintenance Requirements and Specifications Document (OMRSD) waiver was written Following the Launch-minus-9-hour SRB APU frequency built-in test equipment (BITE) test, it was noted that none of the APU gas generator bed temperatures exhibited the characteristic increase Normally, the APU bearing soak test at Launch minus 24 hours traps fuel in the lines and it then flows into the gas generator when the secondary speed control valve is opened during the BITE test, thereby causing the temperature increase Subsequent data retrievals showed that the SRB APU fuel pump bearing soak prior to Launch minus 24 hours had not been performed, even though the procedural step had been signed off The console operator had mistakenly opened the secondary speed control valve rather than the fuel isolation valve As a result, an additional SRB APU resistance BITE test was performed on all four APUs at approximately Launch minus 20 minutes and verified that all APUs were ready for launch

Both SRBs were satisfactorily separated from the ET 124 72 seconds after liftoff, and reports from the recovery area, based on visual sightings, indicate that the deceleration subsystems performed as designed  Both SRBs were retrieved and returned to KSC for inspection, disassembly, and refurbishment

During the inspection and disassembly phase, 53 instances of Marshall Sprayable Ablator (MSA-2) not adhering to the painted surface adjacent to the PR-1422 sealant were found in the right frustum  However, no ablator was lost  This high number of debondings is outside the experience base, and as a result, Flight Problem STS-66-B-01 was declared

## REDESIGNED SOLID ROCKET MOTORS

Data indicate that the flight performance of both RSRMs was well within the allowable performance envelope and was typical of the performance observed on previous flights  No LCC or OMRSD violations were noted, and no in-flight anomalies were identified from the data

Power-up and operation of all 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 temperatures within the LCC ranges  At T-15 minutes, the purge was changed to high pressure to inert the SRB aft skirt

The motor performance was within the contract end item (CEI) specification limits  The propellant mean bulk temperature (PMBT) was calculated to be 77 °F and the propulsion system performance based on this temperature is shown in the table on the following page.

## EXTERNAL TANK

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

Normal quantities of ice and/or frost were observed during the countdown, and all observations were acceptable based on Space Shuttle documentation  No anomalous thermal protection subsystem (TPS) conditions were found in the countdown inspection  However, a single recurring and acceptable crack was noted where the foam bridges between the vertical strut cable tray and fitting fairing

## RSRM PROPULSION PERFORMANCE

| Parameter | Left motor, 77 °F | | Right motor, 77 °F | |
|---|---|---|---|---|
| | Predicted | Actual | Predicted | Actual |
| Impulse gates | | | | |
| I-20, $10^6$ lbf-sec | 66.31 | 65.44 | 66.02 | 65.43 |
| I-60, $10^6$ lbf-sec | 176.49 | 175.27 | 175.82 | 175.12 |
| I-AT, $10^6$ lbf-sec | 297.09 | 297.05 | 296.06 | 297.15 |
| Vacuum Isp, lbf-sec/lbm | 268.6 | 268.6 | 268.6 | 268.7 |
| Burn rate, in/sec @ 60 °F at 625 psia | 0.3690 | 0.3669 | 0.3680 | 0.3665 |
| Burn rate, in/sec @ 81 °F at 625 psia | 0.3735 | 0.3714 | 0.3725 | 0.3710 |
| Event times, seconds[a] | | | | |
| Ignition interval | 0.232 | N/A | 0.232 | N/A |
| Web time[b] | 108.7 | 110.0 | 109.2 | 109.9 |
| Separation cue, 50 psia | 118.4 | 120.0 | 118.9 | 119.5 |
| Action time[b] | 120.4 | 122.2 | 121.0 | 121.4 |
| Separation command | 123.8 | 124.8 | 123.8 | 124.8 |
| PMBT, °F | 77 | 77 | 77 | 77 |
| Maximum ignition rise rate, psia/10 ms | 90.4 | N/A | 90.4 | N/A |
| Decay time, seconds (59.4 psia to 85 K) | 2.8 | 3.0 | 2.8 | 2.6 |
| Tailoff Imbalance Impulse | Predicted | | Actual | |
| differential, Klbf-sec | N/A | | 258.4 | |

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

The ET pressurization system functioned properly throughout the countdown and flight The minimum ullage pressure experienced during the ullage pressure slump was 13 6 psid

The ET was separated as planned, and the predicted intact impact point was 45 nmi uprange of the preflight prediction, and within the preflight predicted footprint

The postflight evaluation of ascent and post-separation photography showed several divots and areas of missing insulation None of these conditions were anomalous

## SPACE SHUTTLE MAIN ENGINES

All SSME parameters were normal throughout the countdown and were typical of the conditions observed on previous flights Engine-ready was achieved on time, all LCC were met, and engine-start and thrust buildup were nominal

Flight data indicate that the SSME performance during all phases of ascent was nominal The high pressure oxidizer turbopump (HPOTP) and high pressure fuel turbopump (HPFTP) temperatures were well within specification throughout engine operation Engine cutoff times for SSME 1, 2, and 3 were 520 12, 520 24, and 520 37 seconds after the engine start command, respectively Specific impulse (Isp) was rated as a nominal 451 77 seconds based on trajectory data Controller and software performance was also satisfactory A number of minor problems were noted in the flight data, however, none were significant and no in-flight anomalies were identified

## SHUTTLE RANGE SAFETY SYSTEM

The Shuttle Range Safety System (SRSS) performed normally throughout the ascent phase of the flight The closed-loop testing was completed as scheduled during the countdown All SRSS safe and arm (S&A) devices were armed and system inhibits were turned off at the appropriate times

## ORBITER SUBSYSTEMS

### Main Propulsion System

The overall performance of the MPS was as expected with no in-flight anomalies noted Liquid oxygen ($LO_2$) and liquid hydrogen ($LH_2$) loading was performed as planned with two exceptions Propellant loading was delayed approximately 1.5 hours because of a Helium supply system air intrusion indication (7 percent air), which was later determined to be a false indication from the hydrogen umbilical mass spectrometer (HUMS) The postflight inspection revealed numerous loose fittings Also, an $LO_2$ revert occurred because the loading console was failing to electronically update adequately, and the console was replaced during the 24-minute delay caused by the revert No LCC or OMRSD violations were identified during the countdown

Throughout the preflight operations, no significant hazardous gas concentrations were detected with the exception of a high Helium concentration (up to 36,000 ppm) detected in the aft compartment during Helium bottle pressurization Evaluation showed that the Helium was being detected in the area around the T-zero disconnect and not the aft compartment A Helium bottle pressure decay check was performed and it showed that the system was acceptable for flight The maximum hydrogen concentration level in the Orbiter aft compartment, that occurred shortly after the start of fast-fill, was approximately 150 ppm This level compares favorably with previous data for this vehicle

Data from prelaunch as well as flight operations showed no anomalous valve movement All timings were within the required specification limits as well as the historical data base

Data analysis of the MPS performance during ascent has revealed nominal performance except that the SSME 1 $LH_2$ inlet pressure dropped from approximately 24 5 psia to 22 psia 2 5 minutes after liftoff and then gradually recovered to 27 psia by 4 minutes after liftoff (Flight Problem STS-66-V-08) A similar pressure signature on SSME 1 has been present on every OV-104 flight since installation of the current pressure transducer (nine flights) Troubleshooting showed that the pressure transducer was operating nominally, however, based on the indicated pressure response of this transducer that was seen during the last nine flights, the transducer was replaced

The pressurization and feed systems performed satisfactorily and satisfied all tank ullage pressure and SSME inlet net positive suction pressure (NPSP) requirements The gaseous hydrogen ($GH_2$) flow control valve performance was nominal Performance analysis of the propulsion systems during start, mainstage, and shutdown showed nominal operations, and all requirements were satisfied During the vacuum inerting process, the $LH_2$ manifold pressure rose to 29 psia after the MPS dump, and the vacuum inerting was completed As a result, the vacuum inerting process was repeated This condition has been seen since the MPS dump and vacuum inerting procedure was modified in the OI-23 software The OI-23 software procedures have been modified for future flights

## Reaction Control Subsystem

The RCS fulfilled all requirements that were levied upon it, however, three in-flight anomalies were identified from the subsystem data Propellant consumption during the mission from the RCS tanks was 4,726 9 lbm plus an additional 3830 5 lbm from the OMS tanks during interconnect operations

During the maneuver to photograph the ET after separation, RCS aft-firing primary thruster L1A failed off because of low chamber pressure (Flight Problem STS-66-V-01) The redundancy management (RM) software deselected the thruster 320 msec into the firing The peak chamber pressure was 11 3 psia over 160 msec (four data samples) Injector temperatures verified at least partial opening of both the fuel and oxidizer valves Thruster L1A remained deselected for the remainder of the mission During the postflight turnaround activities, the thruster was replaced

The RCS orbit adjust (station keeping) and rendezvous maneuvers performed in support of the CRISTA-SPAS retrieval operations are shown in the following table The RCS performed nominally during these maneuvers Note that the

NC 3, NC 4, NC 5, NC 8, NC 12 and NC 14 maneuvers were not performed because they were not required

**RCS MANEUVERS FOR CRISTA-SPAS RETRIEVAL**

| Maneuver | Thrusters fired and maneuver duration, seconds | Start time, G.m.t. and MET | ΔV, ft/sec |
|---|---|---|---|
| NC 1 | F3U, L1U, R1U<br>0.72 second | 308:16:04:52 G.m.t.<br>00:23:05:09 MET | — |
| NC 2 | L3A, R3A<br>7.0 seconds | 309:10:16:13 G.m.t.<br>01:17:16:30 MET | 1.8 |
| NC 6 | L3A, R3A<br>6.0 seconds | 310:23:12:42 G.m.t.<br>03:06:11:59 MET | 1.98 |
| NC 7 | L3A, R3A<br>6.0 seconds | 311:18:07:29 G.m.t.<br>04:01:07:46 MET | 1.5 |
| NC 9 | L3A, R3A<br>2.0 seconds | 312:11:19:43 G.m.t.<br>04:18:20:00 MET | 0.5 |
| NC 10 | L3A, R3A<br>— | 312:22:45:00 G.m.t.<br>05:05:46:17 MET | 2.5 |
| NC 10A | L3A, R3A<br>— | 313:02:23:44 G.m.t.<br>05:09:24:01 MET | — |
| NC 11 | L3A, R3A, F3D, F4D, L1U, L2D, L3D, R1U, R2D, and R3D<br>— | 313:12:54:42 G.m.t.<br>05:19:54:59 MET | 0.8 |
| NC 13 | L3A, R3A<br>10 seconds | 314:11:43:43 G.m.t.<br>06:18:44:00 MET | 2.5 |
| NC 15 | L3A, R3A<br>8 seconds | 315:19:24:33 G.m.t.<br>08:02:24:50 MET | 0.6 |
| NC 16 | L3A, R3A<br>12 seconds | 316:00:41:43 G.m.t.<br>08:07:42:00 MET | 1.81 |
| NC 17 | R3R, L3A, R3A, R1U, and L3D<br>93 seconds | 316:05:59 G.m.t.<br>08:12:59 MET | 22.6 |
| NCC 1 | F1F, F2F, F3D, F3L, F4D, F4R, L1L, L1U, R1U, and R3D<br>24 seconds | 316:08:02 G.m.t.<br>08:15:02 MET | 5.9 |
| MC 1 | F3U, L1U, R1U, L3A, and R3A<br>— | 316:10:49:17 G.m.t.<br>08:17:49:34 MET | 0.3 |
| MC 2 | F3U, L1U, R1U, L3A, and R3A<br>— | 316:11:21:46 G.m.t.<br>08:18:22:03 MET | 1.79 |
| MC 3 | F3U, L1U, R1U, L3A, and R3A<br>— | 316:11:31:40 G.m.t.<br>08:18:31:57 MET | 1.3 |
| MC4 | F3D, F3L, F4D, L2D, L3A, L3D, R2D, R3A, and R3D<br>— | 316:11:53:10 G.m.t.<br>08:18:53: 27 MET | — |

Data review indicated that the forward RCS oxidizer tank helium regulator B was regulating low This regulator has a history of low regulation pressure and a waiver was written against this regulator during flow 10 in preparation for STS-44 The regulation pressure was waived for all subsequent flights to

240 psia (should be no less than 242 psia) The performance of the regulator was not significantly worse on STS-66 KSC performed the normal regulator response and functional checkout as well as a low pressure/flow response test and functional checkout The regulator performance was acceptable during the tests

The RCS was reconfigured from interconnect to straight feed at 317 05 42 G m t (09 12 42 MET) Telemetry indicated ac motor-valve current on the ac bus 1, and a toggling closed-valve position indication on the left RCS 3/4/5 fuel crossfeed valve (Flight Problem STS-66-V-11) after the left RCS 3/4/5 crossfeed switch controlling both the oxidizer and fuel valves was moved to close the valves The valve continued to drive until the switch was cycled and then taken to GPC to remove the close commands At the time of the switch cycle, data indicate that two of the three ac 1 phases had dropped off because of a thermal cutoff in the motor The valve's ac motor was allowed to cool, and the crew repeated the valve cycle attempt at 317 08 16 G.m t (09 15 16 MET) All on-board and ground telemetry data indicated nominal movement occurred on the fuel and oxidizer valves

During entry, at approximately 318 14 58 G m t (10 21 58 MET), the left RCS 3/4/5 fuel crossfeed valve close indication showed open, however, line differential pressures indicated that the valve was still closed The redundant circuit verification, performed postlanding, was nominal as commanded, and the left RCS 3/4/5 fuel crossfeed valve regained the closed indication The crew reported that the talkback was indicating correctly KSC troubleshooting did not indicate a problem with the valve or actuator The anomaly is suspected to have been caused by a faulty limit switch within the actuator The actuator was replaced and shipped to the vendor for further analysis and testing

The RCS hot-fire was performed at 317:10.02.18 G.m.t (09 17.02.35 MET) Primary thruster L4L was not fired and L3L was fired only once as a result of an early termination of the hot-fire The hot-fire was terminated early when it was discovered that the RMS had been hit by the forward RCS thruster plumes Additional firings of those two thrusters were not required

During entry at 318 15:25 49 85 (10.22.26 06 85 MET), the primary thruster R3R fuel injector temperature went off-scale high (Flight Problem STS-66-V-14) The initial indication was followed by two dips in temperature, after which the transducer remained off-scale high The loss of this sensor did not affect entry operations KSC troubleshooting revealed a failed-open circuit in the thruster, and the thruster was replaced

## Orbital Maneuvering Subsystem

The OMS performed very satisfactorily during the four planned firings with the left engine operating for 416 3 seconds (four starts) and the right engine for 373 6 seconds (two starts) OMS propellant usage was 18,952 9 lbm, of which 3830 5 lbm were used by the RCS The following table shows the pertinent parameters

**OMS FIRINGS**

| OMS firing | Engine | Time, G.m.t./MET | Firing duration, seconds | ΔV, ft/sec |
|---|---|---|---|---|
| OMS-2 | Both | 307:17:35:56:1 G.m.t.<br>00:00:36:13.1 MET | 159.8 | 262.3 |
| OMS-3 (NC-18) | Left | 316:07:18:00.0 G.m.t.<br>08:14:18:17.0 MET | 31.6 | 26.0 |
| OMS-4 (TI) | Left | 316:10:29:00.2 G.m.t.<br>08:17:29:17.2 MET | 11.1 | 9.8 |
| Deorbit | Both | 318:14:31:04.9 G.m.t.<br>10:21:31:21.9 MET | 213.8 | 380.0 |

During prelaunch operations, the right-hand oxidizer inlet pressure transducer bias shifted unexpectedly The pressure indication changed from 280 psia to 285 psia with no corresponding change in oxidizer ullage pressure As a result, the measurement was questionable and the decision was made during the preflight period to not use the indication as a confirming cue in the event of a right OME failure during an ascent abort The measurement tracked the oxidizer ullage pressure and did not exhibit any additional shifts during the mission KSC has replaced the transducer

The left OMS fuel tank total quantity gauging system suddenly dropped to 31 percent 2 minutes into the OMS 2 maneuver Data indicate that the forward probe quantity reading of zero volts was an indication that the measurement had failed A similar failure occurred during the previous flight of this pod (STS-61)

## Power Reactant Storage and Distribution Subsystem

The power reactant storage and distribution (PRSD) subsystem performed nominally throughout the mission A total of 2969 lbm of oxygen and 360 lbm of hydrogen was used during the mission Crew cabin requirements for breathing consumed 112 lbm of the total usage of oxygen The 955 lbm of oxygen and 96 lbm of hydrogen consumables remaining in the PRSD would have supported a 61-hour extension at the mission average power level of 15 9 kW

The hydrogen tank 4 quantity measurement exhibited almost instantaneous changes from 40 3 percent to 46 5 percent at 311 08 45 G m t (03 15 45 MET) One day after the tank was depleted to 2 percent, the quantity measurement increased to 10 percent and was erratic between 2 and 10 percent for the remainder of the mission Prior to launch, a 6-percent bias was noted in this measurement, and an OMRSD waiver was written to fly as is The erratic operation did not affect the mission operations The telemetry signal conditioner was replaced during turnaround operations following the mission

## Fuel Cell Powerplant Subsystem

The fuel cell powerplant (FCP) subsystem performed nominally with 4164 kWh of power generated at an average power level of 15 9 kW The fuel cells consumed 360 lbm of hydrogen and 2857 lbm of oxygen with a total of 3217 lbm of water produced as a result

The fuel cell 2 alternate water line temperature rose from 84 °F at 307 18:00 G.m t (00 01 00 MET) to 138 °F at 307 19 00 G m t. (00 02 00 MET) (Flight Problem STS-66-V-03) The temperature remained in the 130 °F to 140 °F range for the remainder of the mission The temperature normally cycles as the line heater cycles between 70 °F and 90 °F The data indicate that warm fuel cell water was flowing through the FC 2 alternate water line because of a check valve leak in that line Water in the FC alternate water lines flows into supply water tank B This flow maintained the FC 2 alternate water line nearly as warm as the FC 2 product water line throughout the mission. Leakage of this check valve has been seen on previous missions, although not to the extent observed on this flight As a result, the check valve was replaced following the mission

The fuel cell 2 hydrogen pump motor current sensor measurement exhibited step changes between 0 36 and 0.48 Vdc throughout the mission Six individual step changes were noted during the mission with the final reading being 0 40 Vdc The ac bus 2 phases (A, B, and C) voltage and currents remained steady throughout all of the step changes The observed values of 0 36 and 0 48 volts are well within the limits (0.28 and 0 75 volt) allowed by the Shuttle Operational Data Book (SODB) The fuel cell vendor indicates that the condition was not a concern for fuel cell failure

## Auxiliary Power Unit Subsystem

The APU subsystem performed nominally Some minor problems were noted, however, none compromised the successful completion of the mission The requirements of DTO 414 were fulfilled following ascent with the APUs shutdown in the prescribed order (3, 1, 2) APU run-times and fuel consumption are shown in the table on the following page

## APU RUN TIMES AND FUEL CONSUMPTION

| Flight phase | APU 1 (S/N 207) | | APU 2 (S/N 402) | | APU 3 (S/N 303) | |
|---|---|---|---|---|---|---|
| | Time, min:sec | Fuel consumption, lb | Time, min:sec | Fuel consumption, lb | Time, min:sec | Fuel consumption, lb |
| Ascent | 19:08 | 48 | 19:22 | 51 | 18:42 | 47 |
| FCS checkout | 04:03 | 12 | | | | |
| Entry[a] | 46:13 | 76 | 83:01 | 163 | 59:32 | 121 |
| Total | 69:24 | 136 | 102:23 | 214 | 78:14 | 168 |

**[a] APU 1 was shut down about 2 minutes after landing, and APUs 2 and 3 were shut down approximately 16 minutes after main gear touchdown.**

During ascent, the APU 3 lubrication (lube) oil return and outlet temperatures ran warmer than the same temperatures on APUs 1 and 2 As a result, water spray boiler (WSB) 3 spray cooling began right at main engine cutoff (MECO), it normally occurs about two minutes after MECO. Data show that this APU required spray cooling up to one minute earlier than the APUs with which it was flown on STS-49, -47, -54, and -57 in the OV-105 vehicle During entry, the more rapid warm-up was again noted. The condition had no impact on APU performance The APU will be removed and sent to the vendor for planned refurbishment.

During entry, the APU 1 supply line temperature became erratic with the temperature decreasing to 50 °F and then increasing (Flight Problem STS-66-V-12). The temperature should have tracked the bypass line temperature and fuel pump outlet temperature, for which the indicators were about 4 inches away on either side and performed nominally All other APU 1 parameters were nominal As a precaution, APU 1 was shut down two minutes after landing A sniff-check and a visual inspection were performed after landing, and no evidence of a fuel leak was found

## Hydraulics/Water Spray Boiler Subsystem

The hydraulics/WSB subsystem performed nominally throughout the prelaunch countdown and the flight with one exception The system 3 WSB $GN_2$ regulator outlet pressure began decaying when the WSB was deactivated after ascent (Flight Problem STS-66-V-04) At WSB 3 deactivation, the regulator outlet pressure was 27.3 psia, and the leak rate was 0 125 psi/hr during the first 24 hours of the mission The leak rate decayed throughout the mission and the regulator outlet pressure was 15 3 psia when the WSB was activated for entry This leak had no mission impact KSC has performed a crack and reseat test and decay test, and the results are being evaluated for possible replacement of the regulator

## Electrical Power Distribution and Control Subsystem

The electrical power distribution and control (EPDC) subsystem performed nominally throughout all phases of the mission

## Environmental Control and Life Support System

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

The active thermal control subsystem (ATCS) experienced several FES problems The response of the Freon coolant loop (FCL) 1 evaporator outlet temperature sensor lagged the FCL 2 evaporator outlet temperature sensor during transient heat loads (Flight Problem STS-66-V-05) The maximum temperature difference observed was 11 °F when the crew switched the FES controller from GPC to Primary A ON Since this sensor is used for monitoring only and is not used for control by the FES, the condition did not impact ATCS performance KSC will troubleshoot the problem

The FES exhibited several periods of anomalous behavior At the beginning of the mission when the FES was operating on the primary A controller in the topping mode, the Freon outlet temperature oscillated within a 3 to 4 °F range (normal is ± 1 °F) when the heat load was low (radiator outlet temperatures of 42 °F to 47 °F) (Flight Problem STS-66-V-06), yet it operated in a very stable manner at higher heat loads At 311:12 30 G m t (03:19.30 MET), the FES was turned off because of payload requirements When it was turned back on at 311 13.25 G.m.t (03.20:25 MET), the FES primary B controller was selected The primary B controller experienced an over-temperature shutdown during start-up. The shutdown was attributed to a small pocket of air trapped in the water feedline system during reservicing that passed through the water spray valve and caused a momentary lapse in cooling. The FES was restarted with the primary B controller and no oscillations were seen in the outlet temperature

Near the end of the mission at 316:15 55 G m t (08 22 55 MET), a change was made to operate again on the primary A controller to obtain additional data Although the vehicle attitudes did not provide many periods of low heat-loads, the outlet temperature still oscillated at those times Postflight troubleshooting has shown that the supply A topping spray valve was leaking, and the valve was replaced

In performing the normal deorbit preparation timeline, the primary B controller was selected for the radiator cold-soak The radiator outlet temperature was set to 57 °F, which is a high heat-load for the topping FES About 15 minutes after the radiator cold-soak period had begun [318.10 06 G m t (10 17.06 MET)], the

FES experienced an under-temperature shutdown when the outlet temperature dropped below 37 °F for more than 20 seconds (Flight Problem STS-66-V-13) The FES was restarted on the primary B controller and the radiator cold-soak was completed without any further problems A checkout of the secondary controller was then performed satisfactorily Just prior to PLB door closure, the radiators were bypassed and the primary B controller was reselected with the FES in the full-up evaporator (both topper and high-load cores) mode The FES began exhibiting large oscillations that did not dampen or become stable The maximum oscillation observed was from 34 °F to 44 °F (normal is 39 ± 1 °F) As a result, the crew switched back to the primary A controller and no further oscillations were noted during the mission Postflight troubleshooting revealed that one mid-point sensor was not operating properly The sensor was replaced

The on-orbit radiator cold-soak provided a cooling reserve adequate for entry through landing plus 6 minutes, at which time ammonia system B using the primary/GPC controller was activated Ammonia system B provided cooling for 32 minutes, after which time the ground cooling was activated

STS-66 was the second flight of the supply water dump line purge assembly (SWDLPA) The third supply water dump was viewed with the RMS video camera to observe the performance of the purge assembly During the dump, which was performed simultaneously with the fourth waste water dump, an icicle formed on the PLBD and extended back toward the dump nozzle (Flight Problem STS-66-V-10) The dump was terminated prior to the icicle reaching the nozzle Since this occurred on the final dump of the mission, the icicle had no water management impact. Data and hardware evaluations are continuing in an attempt to determine the cause of the anomaly These evaluations have revealed that the supply nozzle is canted up approximately 4 degrees from horizontal This is currently believed to be the most probable cause of the icicle formation

With the exception of the icicle formation, the supply and waste water systems performed normally throughout the mission All supply water in-flight checkout requirements were satisfactorily completed before landing

The supply water was managed through the use of the FES and the overboard dump system. Three supply water dumps were performed from tanks B and D at an average dump rate of 1 76 percent/minute (1 9 lb/min) Using supply line heaters, the supply water dump line temperature was maintained between 69 °F and 95 °F throughout the mission

Waste water was gathered at about the predicted rate Four waste water dumps were performed at an average dump rate of 1 8 percent/minute (3 18 lb/min) The waste water dump line temperature was maintained in a satisfactory range between 55 °F and 77 °F The vacuum vent line temperature was maintained between 58 °F and 76 °F, with the vacuum vent nozzle temperature in a satisfactory range between 120 °F and 193 °F

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

The atmospheric revitalization system (ARS) performed satisfactorily throughout the mission DTO 664 - Cabin Temperature Survey was performed in support of this system Also, the atmospheric revitalization pressure control system performed nominally throughout the mission During the redundant systems check, the alternate system functioned normally

## Smoke Detection and Fire Suppression Subsystem

The smoke detection system showed no indications of smoke generation during the entire mission However, the avionics bay 2A smoke detector concentration indicated a drop to -500 $\mu g/m^3$ at 314.02 17 G m t (06 09.17 MET), and then gradually recovered to a nominal reading over a period of approximately 36 hours (Flight Problem STS-66-V-16) Redundant detector concentrations were in the nominal ±200 $\mu g/m^3$ range. A circuit self-test at 314:22:50 G m.t (07·05 50 MET) produced nominal results The same detector experienced excursions down to -700 $\mu g/m^3$ on the last flight of this vehicle (STS-46) The detector's ability to detect a fire was not considered to be compromised and was therefore acceptable for continued use during the mission Troubleshooting on the vehicle did not reproduce the anomaly However, the detector was removed and replaced

## Airlock Support System

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

## Avionics and Software Systems

The guidance, navigation and control systems performed nominally Problems encountered in the data processing system (DPS) are discussed in the following paragraphs

Two error messages, "I/O ERROR MMU1" and "CHECKPT FAIL", were annunciated at 314 22 01.20 G.m.t (07.05 01 37 MET) while the crew was attempting to perform a systems management (SM) checkpoint, which failed The SM checkpoint was reattempted and successfully accomplished

During a subsequent SM checkpoint from GPC 4 to MMU 1 at 315 13 18 40 G m t (07 20 18 57 MET), the same two error messages (I/O ERROR MMU 1 and S60 CHECKPT FAIL) were annunciated (Flight Problem STS-66-V-09) The checkpoint was unsuccessful During troubleshooting, all further transactions between GPC 4 and MMU 1 failed This interface problem between GPC 4 and MMU 1 was believed to be due to a failure of the GPC 4 bus control element (BCE) 18 transmitter and/or receiver A software dump of GPC 4 was performed, and analysis of the dumped data supported the BCE 18 failure and indicated no other problem with GPC 4

The SM function was moved from GPC 4 to GPC 3 GPC 4 was then placed in the redundant set with GPC 1 at 316 19:13 G m t (09 02 13 MET) to determine whether the problem that the GPC 4 interface had with MMU 1 also affected GPC 4 communications on the flight critical (FC) 8 data bus This communication is done with BCE 17, which is in the same multiplexer interface adapter (MIA) as BCE 18 The test confirmed that GPC 4 communications on FC8 were nominal, isolating the problem to the GPC 4 BCE 18 interface with MMU 1 The condition did not significantly impact entry procedures

A GPC 2 fail-to-sync occurred at 316:01 58.58 G m t (08 08 59 15 MET) while the crew was establishing a redundant set in preparation for rendezvous When the crew moded GPC 2 from halt to standby, they reported observing a mode talkback indicating run and an output talkback indicating gray, while the mode switch was in standby. The downlist data indicate that GPC 2 was moded from halt to run to standby This sequence would result in the observed talkback response and subsequent GPC failure messages GPC 2 was then moded to run, and it successfully joined the common set It was used in a redundant set with GPC 1 and GPC 3 during the SPAS rendezvous GPC 2 performed nominally for the remainder of the mission

GPC hardware user note 006 describes what can happen if a GPC is in the sleep mode and the mode switch is moved out of halt into the deadband between halt and standby The GPC will exit the sleep mode because of the loss of halt at the receiver, and if the HALT/STBY/RUN latches come up in the run state (one of four possible states), the GPC will initialize in the run mode (driving the talkbacks to run and gray) and then join the common set If the mode switch is moved into standby from the run state, the GPC will transition from run to standby, and this results in a fail-to-sync The observed symptoms are consistent with this condition documented by the user note A hardware-initiated stand-alone memory (HISAM) dump of GPC 2 was performed at 316 04 48 G m t (08 11 48 MET), and an analysis of the HISAM dump did not indicate a problem

GPC 1 annunciated fail-off messages for primary RCS thrusters F3D, F4D, F4R, L2D, L3D, R2D, R3D, and R3R at 313 20 23 43 G m t (06 03 24 00 MET) The primary reaction jet drivers (RJDs) were powered off at the time, and no thruster firings had occurred Prior to the failures, the vernier thrusters were selected Data at one sample-per-second for this period show high outputs from the forward translational hand controller (FWD THC) C contacts for the +Y, +X, +Z, and -Z simultaneous to the flight controller power switch on panel F7 being taken to ON in preparation for manual maneuvering There were no FWD THC A or B contact indications for the same sample period Normally, when power is applied to the THC, all of the THC switch contacts will go high momentarily (for approximately 40 ms), and the software responds to the simultaneous positive and negative direction inputs for each axis by nulling the associated selected outputs to the digital autopilot (DAP) Data show the selected FWD THC -Y and -Z outputs to the DAP were ON during the sample period, and the THC hot-stick logic apparently correctly responded by automatically changing to the primary thruster DAP mode to support the translation request (there is no translation capability with vernier thrusters) and subsequently returning to vernier mode The commanded primary thrusters did not fire because the RJDs were not powered, and this resulted in deselection of the thrusters by the GPC The crew reported that they believed it was possible that the THC was deflected in the -Y and -Z directions when the flight controller power switch was moved, and this is consistent with the data and the responses of the DAP and GPC 1 A procedure to test the THC was uplinked to the crew and accomplished successfully All deselected thrusters were reselected and remained operational for the remainder of the mission

At 318 15 58 G.m t , about 20 minutes after the ET umbilical doors were opened following landing, the ET umbilical door aft centerline latch 2 "locked" indication 2 transferred for 8 seconds and then off again (Flight Problem STS-66-V-17) The two "stow" indications remained on and the locked indication stayed off throughout the entire time, indicating that the centerline latch could not have moved This discrete goes through multiplexer/demultiplexer (MDM) flight critical aft (FA) card 3 channel 1 bit 14 After the vehicle was powered up in the Orbiter Processing Facility (OPF), BITE testing of MDM FA3 confirmed that the failure was in the MDM Troubleshooting was performed, and MDM FA3 was removed and replaced.

## Displays and Controls Subsystem

The displays and controls subsystem performance was nominal with the exception of an unexplained occurrence with the Ku-band digital display unit and several failures in the payload bay floodlight subsystem.

The crew reported zeros instead of eights or threes on their Ku-band digital display at the end of the Ku-band self-test at 307 19 48 G.m t (00 02 48 MET) Ground telemetry, however, showed eights, indicating a successful self-test. The crew verified that the switch configuration was correct, and also performed a lamp test with nominal results Two additional self-tests of the Ku-band were completed at 308 12 10 G m t (00 19 10 MET), and again the indication was not as expected onboard However, the ground telemetry again indicated successful tests There was not a problem with the Ku-band system and the digital display performance was nominal during Ku-band operations During a subsequent self-test that was performed prior to the CRISTA-SPAS retrieval, the indication on the digital display was nominal (all eights)

The payload bay floodlights were activated at 316 12 44 G m t (08 19 44 MET) for RMS operations and CRISTA/SPAS grapple and berthing Current spikes were noted on mid main B bus and the crew reported a flickering forward starboard floodlight The forward starboard floodlight was switched off Current on mid main A rose six amperes for two seconds then dropped 15 amperes at 316 12 48 G m t (08 19 48 MET) indicating a 10-ampere remote power controller (RPC) overcurrent trip. The crew confirmed failure of the aft starboard floodlight at this time A second RPC overcurrent trip indication was seen on mid power control assembly (MPCA) 2 RPC 9 at 316 13 04 G m t (08 20 04 MET) and the crew confirmed failure of the forward bulkhead floodlight Postflight, KSC confirmed that the forward starboard floodlight and the forward bulkhead floodlight failed. Both of the floodlights have been replaced Failure of the aft starboard floodlight was isolated to a problem with a floodlight electronics assembly and it has been replaced.

## Communications and Tracking Subsystems

The communications and tracking subsystems performed nominally except for the anomaly that occurred when using the Ku-band with NSP 2, as discussed in the following paragraph The Ku-band digital display did not indicate properly during Ku-band self-tests, and this is discussed in the Displays and Controls Subsystem section of this report.

White Sands and the Second TDRS Ground Terminal (STGT) both reported no detectable modulation on Ku-band channel 1 on orbit 61W at 311 12 30 G.m.t (03 19 30 MET) and for a number of following passes with NSP 2 configured for two-way Ku-band operation (Flight Problem STS-66-V-07) Nominal data were observed on Ku-band channels 2 and 3 The link was configured for use with NSP 1 five orbits later, and nominal Ku-band channel 1 modulation was detected The link remained configured for NSP 1 use on-orbit to provide operational instrumentation data downlink through the Ku-band

NSP 2 was reselected at 317.22.27 G m t (010 05 27 MET) and nominal modulation of Ku-band channel 1 was observed at White Sands Ground Terminal (WSGT) and STGT Coding of Ku-band channel 1 was turned off during a Goldstone hand-down on S-band at 318 00.39 G.m t (010 07 39 MET), and nominal uncoded modulation was received by STGT through Tracking and

Data Relay Satellite (TDRS) -West on Ku-band channel 1 No recurrence of the previously reported NSP-2 anomaly was observed NSP 2 was used as planned for entry since the NSP 2-to-Ku-band channel 1 interface was not used at that time Troubleshooting at KSC failed to repeat the anomaly

## Operational Instrumentation/Modular Auxiliary Data System

During the STS-66 mission, the instrumentation subsystems operated nominally, although four instrumentation-related anomalies were recorded None of these anomalies impacted the mission, however, the erratic APU 1 supply line temperature (Flight Problem SS-66-V-12) did result in shutting down APU 1 two minutes after wheels stop This anomaly is discussed in greater detail in the Auxiliary Power Unit Subsystem section of this report

The remaining three instrumentation-related anomalies are

a FES outlet temperature sensor response lag (Flight Problem STS-66-V-05) This anomaly is discussed in the Environmental Control and Life Support System section of this report
b SSME 1 $LH_2$ inlet pressure response (Flight Problem STS-66-V-08) This anomaly is discussed in the Main Propulsion System section of this report
c Thruster R3R fuel injector temperature failed off-scale high (Flight Problem STS-66-V-14). This anomaly is discussed in the Reaction Control Subsystem section of this report.

During the postlanding OPS 2 recorder dump, the recorder head temperature was increasing above normal The recorder was shut off earlier than planned (at 118 °F) to prevent the temperature from exceeding 120 °F, at which point damage to the tape may occur. High head temperatures are typically seen for entry with wave-offs on the first and second landing opportunities These higher head temperatures are the result of reduced cooling to the recorders due to the payload bay doors being closed during the deorbit wave-off

## Structures and Mechanical Systems

The structures and mechanical systems operated nominally The landing and braking data are shown in the table on the following page

Payload bay door opening was completed at 307 18 29 56 G m t (00 01 30.13 MET) During the door opening sequence, all operations were performed on dual motors within the specified time When the starboard door was opened, the ready-to-latch (RTL) switch 3 and close switch 2 did not transfer off as required (Flight Problem STS-66-V-02) Approximately 38 and 44 minutes later, respectively, the ready-to-latch and close switches transferred to their correct state The most likely cause of this occurrence is the starboard aft bulkhead RTL switch module internal rigging KSC has replaced the switch module

## LANDING AND BRAKING PARAMETERS

| Parameter | From threshold, ft | Speed, keas | Sink rate, ft/sec | Pitch rate, deg/sec |
|---|---|---|---|---|
| Main gear touchdown | 3322 | 193.7 | -1.0 | N/A |
| Nose gear touchdown | 6376 | 143.9 | N/A | ~3.8 |

| | |
|---|---|
| Brake initiation speed | 31.9 seconds |
| Brake-on time | 7667 feet |
| Rollout distance | 104.9 knots (keas) |
| Rollout time | 51.5 seconds |
| Runway | 22 (concrete) EAFB |
| Orbiter weight at landing | 211,327 lb |

| Brake sensor location | Peak pressure, psia | Brake assembly | Energy, million ft-lb |
|---|---|---|---|
| Left-hand inboard 1 | 1044 | Left-hand inboard | 20.53 |
| Left-hand inboard 3 | 1020 | | |
| Left-hand outboard 2 | 996 | Left-hand outboard | 17.68 |
| Left-hand outboard 4 | 924 | | |
| Right-hand inboard 1 | 804 | Right-hand inboard | 16.18 |
| Right-hand inboard 3 | 840 | | |
| Right-hand outboard 2 | 846 | Right-hand outboard | 15.19 |
| Right-hand outboard 4 | 768 | | |

## Integrated Aerodynamics, Heating and Thermal Interfaces

The review of the prelaunch thermal interface purges showed no temperatures in excess of the established limits. Based on trajectory parameters and films, the ascent aerodynamic and plume heating was nominal. Likewise, based on trajectory data, the aerodynamic heating to the SSME nozzles during descent was nominal.

The ascent and entry aerodynamics were nominal with no problems, anomalies, or unexpected conditions identified in the data DTO 254 - Subsonic Aerodynamics Verification - was performed during the final approach to the runway

## Thermal Control Subsystem

The thermal control subsystem (TCS) performed nominally during all phases of the mission, and all subsystem temperatures were maintained within acceptable limits There were no heater system anomalies or failures during the mission

## Aerothermodynamics

The acreage heating was nominal during entry, and there was no unusual local heating Boundary layer transition was nominal based on the structural temperature rise data There was heating damage in the left-hand inboard elevon cove at the center hinge The elevon deflections were within limits, and were not the cause of the heating damage

## Thermal Protection Subsystem and Windows

The TPS performed satisfactorily Based on structural temperature response data (temperature rise), the entry heating was slightly above average, but not beyond previous flight experience Boundary-layer transition from laminar to turbulent flow occurred 1210 seconds after entry interface (EI) on the forward centerline and left-hand side of the vehicle At the forward right-hand side of the vehicle, boundary-layer transition occurred between 10 and 30 seconds later than the centerline and left-hand side of the vehicle Thermocouple data are not available on this vehicle to determine transition times at the aft locations of the vehicle

Based on data from the debris team inspection, overall debris damage was above average The postlanding inspection showed that the TPS had sustained 148 hits, of which 28 had a major dimension of one inch or greater A comparison of the hits with the statistics from 50 previous missions of similar TPS configuration indicated that the total number of hits, as well as the number of hits one inch or larger, was slightly greater than average

Of the total hits on the Orbiter, 111 were on the lower surface and 22 of these had a major dimension that was one inch or greater This number is above the average value of 15 The two most significant damage sites on the lower surface were located forward of the $LO_2$ umbilical and measured 7 375 inches by 3 75 inches by 0 5 inch and 5 25 inches by 1 25 inches by 0 25 inch Slumping was observed on two tiles on the lower surface of the left-hand inboard elevon leading edge near the center-hinge location

A total of 29 hits were found on the upper surface and two of these had a major dimension of one inch or greater The largest damage sites on the vehicle were on top of the right-hand OMS pod forward-facing surface, measuring 5 inches by 5 inches by 2 inches, and on the leading edge of the right-hand rudder/speedbrake panel, measuring 12 inches by 4 inches by 2 inches

On flight day 2, the crew noticed damage to a tile adjacent to overhead window 8 (Flight Problem STS-66-V-15) The damaged tile was in the same location as the tile that fractured during the previous flight (STS-68) The tile damage was not as severe on STS-66 as it was on the previous flight The damage area was limited to a 3 5-inch length of the tile overhang that protects the edge of the carrier panel There is also ceramic sleeving between the tile and the carrier panel edge, and it was still intact A review of the tile's repair history does not indicate that a failed repair might be the cause of the damage No thermal damage occurred as a result of this tile damage

A portion of the icicle (formed during the waste water dump) that was attached to the forward section of the left-hand PLBD was still attached after landing The remaining ice measured approximately 4 inches by 2 inches Two large impacts of the aft upper surface may have been caused by the break-up of the icicle The first damage site involved two tiles on the right-hand OMS pod and measured eight inches by five inches by two inches deep The second damage site also involved two tiles on the leading edge of the right-hand speedbrake and measured 12 inches by 4 inches in area Neither damage site showed signs of heating, and no damage to the underlying structure was noted

The only other significant TPS item was the slumping of two tiles on the lower left-hand inboard elevon The two tiles, located on the elevon leading edge at the elevon center hinge, had a 0 375-inch wide by 1 5-inch long gap between them as a result of the over-heating. The gap filler was melted, but still present No internal thermal damage occurred except some discoloration of the koropon on the tile carrier panel, and minor thermal cracking of the inboard polyimide seal The apparent cause of the slumping was low compression on the gap filler, and this was apparent on the undamaged portion An additional contributor may have been a large aft-facing step on the wing immediately forward of this location.

Orbiter windows 3 and 4 exhibited light hazing and streaks A total of 17 hits were observed on the perimeter tiles of windows 2, 3, 4, and 5 The largest damage area measured 1.5 inches by 1 inch by 1 inch at window 2 Tile hits in this area have been attributed in the past to impacts from the forward RCS paper covers and/or paper-cover room temperature vulcanizing (RTV) adhesive

A carrier plate was debonded on the leading edge perimeter of the side access fuselage door 45, causing the advanced flexible reusable surface insulation (AFRSI) to protrude Also, all four flexible reusable surface insulation (FRSI) plugs were missing from the fastener holes of the emergency ejection access tile

## REMOTE MANIPULATOR SYSTEM

The RMS performed nominally on the STS-66 flight, which was the thirty-eighth flight of an RMS arm and the first flight of this newest arm (S/N 202)

Following RMS initialization activities, which were completed approximately 2 5 hours after launch, the standard checkout procedure was completed satisfactorily Prior to uncradling the arm, the crew and ground controllers noted that the wrist roll joint angle was +1 1 degrees (Flight Problem STS-66-F-11) The crew procedure requires that all joint angles be zero ± 0 5 degree The crew was advised that this condition was not a concern for arm operations

A data review indicated that the wrist roll was in tolerance (0 ± 0 2 degree) when the manipulator retention latches were latched in the Orbiter Processing Facility (OPF) However, the wrist roll was 0 9 degree on the pad

CRISTA-SPAS deployment commenced at 307 21 45 G m t (00 04 45 MET) The CRISTA-SPAS was grappled by the RMS, and the arm was left parked with the payload grappled but still latched in the payload bay The next morning (flight day 2), payload deployment activities were begun The CRISTA-SPAS was deployed on-time at 308 12.50 G m t (00 19 50 MET) The RMS was then moved to an extended-park position, out of the view of the ATLAS payload

The arm remained in the extended-park position until flight day 9 when a water dump survey was conducted. A large icicle became attached to the payload bay door and was extending back toward the dump nozzle when the dump was stopped. A more detailed discussion of the results of the water dump survey is contained in the Environmental Control and Life Support System section of this report

On flight day 10, prior to the CRISTA-SPAS rendezvous, the arm was moved to the poised-for-capture position The CRISTA-SPAS was captured as planned after 8 days of free-flight The CRISTA-SPAS was then maneuvered to the extended-park position to allow performance of DTO 834 - Notch Filter, a portion of which was completed

The CRISTA/SPAS payload was retrieved and berthed at 316 16 50 02 G m t (08 23 50 19 MET) During berthing, the port payload retention latch assembly (PRLA) ready-for-latch (RFL) indications were received, but the starboard PRLA RFL indications could not be obtained by driving the payload with the RMS With only the port PRLA RFL indications on, the keel latch was closed with nominal indications, but the starboard PRLA RFL indications still did not transfer The port and starboard PRLAs were commanded to latch simultaneously and the 2-of-2 starboard RFL indications transferred just prior to receiving all PRLA latch indications at 316 16 50 G m t (08 23 50 MET), confirming successful berthing

Following the successful berthing, the RMS was returned to the water-dump survey position

Prior to the decision to use the RMS to remove the ice from the payload door, a series of primary RCS firings were performed in an unsuccessful attempt to remove the ice from the door During the firings, the RMS wrist/end effector was inadvertently subjected to the exhaust plume from these firings Approximately an hour later, the RMS wrist camera failed As a result, using the RMS to remove the ice was no longer a consideration

## FLIGHT CREW EQUIPMENT/GOVERNMENT FURNISHED EQUIPMENT

The flight crew equipment/Government furnished equipment (FCE/GFE) performed nominally A number of anomalies occurred, however, none significantly impacted the mission A discussion of each of the anomalies is provided in the following paragraphs

The crew reported that there was excessive resistance on the cycle ergometer when it was configured in the no-workload setting of the power mode (Flight Problem STS-66-F-01) The problem was believed to be with a portion of the adjustable band that produced friction on the internal flywheel The band was thought to be in continual contact with the flywheel so that when the ergometer was configured to the no-workload setting, flywheel resistance was maintained An in-flight maintenance (IFM) procedure to recover controlled resistance on the flywheel was successfully performed

The crew reported that the Arriflex camera (S/N 1003) dragged and the "not-up-to-speed" light illuminated when the camera was operated (Flight Problem STS-66-F-02). The crew changed magazines twice and with the second changeout, the dragging ceased. Two batteries were depleted, and the crew used the camera with dc power connected

The crew reported finding the ON/OFF knob on hand-held LIDAR (HHL) S/N 2 sheared off and the same knob on HHL S/N 3 bent over about 20° when the locker containing the two units (MF28E) was opened (Flight Problem STS-66-F-03) The crew reported that the S/N 3 unit with the bent knob performed nominally during SPAS deployment

The crew successfully moved the sheared-off HHL S/N 2 power switch to the ON position and controlled HHL power by mating and demating the dc battery power cable After HHL power was restored, the unit's night scope was found to be out of alignment, and adjustment of the display intensity knob was not causing the display intensity to change. The display intensity was set to dim, and crewmembers felt the display was acceptable for night viewing but were not certain the HHL display would be usable during sunlit operations

Later in the mission, the crew performed an HHL nightscope changeout, moving the nightscope from the S/N 2 HHL to the S/N 3 HHL An alignment of the nightscope was subsequently performed The S/N 3 unit was used during the SPAS retrieval and performed satisfactorily

At 315 13 01 G m t (07 20 01 MET), the crew reported that video cassette recorder (VCR) 2 had malfunctioned (Flight Problem STS-66-F-04) The report indicated that a spring in the recorder had popped off A camcorder was used in place of VCR 2 for the remainder of the mission

The crew reported that the 100 mm lens was jammed on one of the three Hasselblad cameras, and the lens could not be removed (Flight Problem STS-66-F-05) The crew was advised to stow the camera to prevent additional damage from occurring Since two other Hasselblad cameras and other lenses were available, the loss of this camera did not affect operations

The Linhof camera dc power cable connector at the camera had a failed circuit segment going to pin 3 in the connector (Flight Problem STS-66-F-06) The crew successfully performed an IFM with the pin kit

Early in the mission, the closed-circuit television (CCTV) camera A pan/tilt unit (PTU) failed to pan when commanded (Flight Problem STS-66-F-07) Rather than move when commanded, the unit would jerk, possibly indicating that the PTU was jammed This condition did not repeat during camera operations later in the mission

On CCTV camera A, a burned-in image of the Orbiter payload bay and the limb of the Earth was visible in low-light-level conditions (Flight Problem STS-66-F-08). Camera A is one of the older CCTV cameras that uses Vidicon imaging tubes rather than charge coupled device (CCD) images The images can be burned out after the flight.

The RMS wrist camera failed with a blurred image at approximately 317.12:00 G.m.t. (09:19:00 MET) (Flight Problem STS-66-F-09) Zoom, focus, and iris adjustments, as well as camera power cycles, were performed with no success in recovering the image. The camera was powered down and was not operational for the remainder of the mission

CCTV camera D exhibited intermittent asynchronous behavior (Flight Problem STS-66-F-10) A static G.m.t line appeared in the active video portion of the camera output on at least two different occasions The camera automatic light control (ALC) and gamma values were also erratic during these periods

## CARGO INTEGRATION

Integration hardware performance was nominal throughout the mission with no anomalies identified

## DEVELOPMENT TEST OBJECTIVES/DETAILED SUPPLEMENTARY OBJECTIVES

A total of 19 Development Test Objectives (DTOs) and 16 Detailed Supplementary Objectives (DSOs) were assigned to the STS-66 mission Data were collected on 18 of the 19 DTOs and on all 16 DSOs The following paragraphs document the preliminary results, if available, for each DTO and DSO

### DEVELOPMENT TEST OBJECTIVES

#### DTO 254 - Subsonic Aerodynamic Verification (Part 2)

The maneuver required for this DTO was performed during the final approach to runway 22 at Edwards Air Force Base (EAFB), CA Postflight data evaluation is required because the data are recorded on the MADS recorder, which is dumped postflight Data were given to the sponsor for evaluation, and the results will be published in separate documentation

#### DTO 301D - Ascent Structural Capability Evaluation

This DTO was performed during the ascent phase of the mission Postflight data evaluation is required because the data were recorded on the MADS recorder, which is dumped postflight The data were given to the sponsor for evaluation, and the results will be published in separate documentation

#### DTO 307D - Entry Structural Capability

This DTO was performed during the entry phase of the mission Postflight data evaluation is required because the data were recorded on the MADS recorder, which is dumped postflight The data were given to the sponsor for evaluation, and the results will be published in separate documentation

#### DTO 312 - ET TPS Performance (Methods 1 and 3)

Twenty-two exposures of the ET after separation were taken using the Nikon camera, 300 mm lens, and the 2X extender (Method 3) The focus was good at all times, however, the lighting conditions during the photography acquisition period were not good, with the ET being back-lit by the Sun Also after the twelfth frame, the ET crossed the Earth's terminator and the images became very dark The first picture was taken approximately 15 9 minutes after liftoff and the final picture was taken approximately 5 minutes later

The -Y/+Z axis, +Y/-Z axis, and the nose of the ET were imaged The visible portions of the ET appeared to be in good condition Two white marks (possible divots) was visible on the ET TPS, and they were located as follows

a The -Y side of the $LH_2$ TPS, and
b The +Y/-Z axis on the $LH_2$ TPS

A review of the hand-held video of the ET after separation showed multiple pieces of white debris (probably frozen hydrogen) and vapors spewing from the aft end of the ET The debris and vapors appear to originate from the ET/Orbiter umbilicals In one segment of the video, the debris and vapors can be seen coming from the $LH_2$ umbilical area Venting from the umbilical area after separation has been observed previously on STS-45, STS-53, and STS-68

## DTO 414 - APU Shutdown Test (Sequence A)

This DTO was performed to continue the investigation into an anomalous 40-second hydraulics system 3 supply pressure hang-up observed when APU 3 was shut down early during ascent on STS-54 The DTO was performed with an APU shut-down sequence of 3, 1, and 2 with at least 5 seconds between APU shut-downs No anomalous pressure hang-ups or power drive unit (PDU) back-driving were noted

## DTO 521 - Orbiter Drag Chute System (Test 5, DTO of Opportunity)

All activities required in test condition 5 were completed. The data show nominal performance in all drag chute parameters

## DTO 623 - Cabin Air Monitoring

All planned cabin air samples were collected, and the samples have been given to the sponsor for analysis The results of this DTO will be reported in separate documentation

## DTO 664 - Cabin Temperature Survey

All planned cabin temperature data were collected, and the data have been given to the sponsor for evaluation The results of this DTO will be reported separately

**DTO 668 - Advanced Lower Body Restraint Test**

All activities were completed and data were collected for this DTO The data have been given to the sponsor for analysis, and the results will be reported in separate documentation

**DTO 677 - Evaluation of Microbial Capture Device in Microgravity**

The crew attempted to perform this DTO, however, the crew reported leakage of the syringe at the 2 cc and the 10 cc levels As a result, the DTO hardware was stowed and all other DTO 677 activities were discontinued All data gathered were given to the sponsor, and the results of that evaluation will be reported in separate documentation

**DTO 680 - On Orbit Fit Check of the Recumbent Seating System for OV-104**

All activities in support of this DTO were completed The results of these fit-checks were given to the sponsor for evaluation and analysis, and the results will be reported in separate documentation

**DTO 683 - Interlimb Resistance Device Evaluation**

All activities were completed in support of DTO 683 The data were given to the sponsor for evaluation and analysis The results of the analysis will be reported in separate documentation

**DTO 700-2 - Laser Range and Range Rate Device**

The crew reported finding the ON/OFF knob on hand-held light distance and ranging (LIDAR) S/N 2 sheared off and the same knob on HHL S/N 3 bent over about 20°, when the locker containing the two units (MF28E) was opened (Flight Problem STS-66-F-03). The crew reported that the S/N 3 unit with the bent knob performed nominally during SPAS deployment

The crew successfully moved the sheared-off HHL S/N 2 power switch to the ON position and controlled HHL power by mating and demating the dc battery power cable After HHL power was restored, the unit's night scope was found to be out of alignment, and adjustment of the display intensity knob was not causing the display intensity to change The display intensity was set to dim, and crewmembers felt the display was acceptable for night viewing but were not certain the HHL display would be usable during sunlit operations

Later in the mission, the crew performed the HHL nightscope changeout, moving the nightscope from the S/N 2 HHL to the S/N 3 HHL An alignment of the nightscope was subsequently performed The S/N 3 unit was used successfully during the SPAS retrieval

The sponsor for this DTO has the data from the mission, and an analysis is being performed The results of that analysis will be reported in separate documentation

**DTO 700-7 - Orbiter Data for Real-Time Navigation Evaluation**

All activities were performed as scheduled The data from these activities have been given to the sponsor for evaluation and analysis The results of the evaluation will be reported in separate documentation

**DTO 805 - Crosswind Landing Performance**

This DTO was not performed because crosswinds were of insufficient magnitude to meet the requirements of the DTO

**DTO 834 - Notch Filter**

The primary RCS thruster portion (high priority) of the DTO objectives was completed on flight day 10 The vernier RCS portion of the DTO was not completed because of timeline constraints levied by the primary payload The data from the primary RCS thruster operation have been given to the sponsor for evaluation. The results of the evaluation will be reported in separate documentation

**DTO 835 - Mir Approach Demonstration (Objectives 1 through 4)**

Data were collected for this DTO, and these data have been given to the sponsor for evaluation The results of the evaluation will be reported in separate documentation.

**DTO 836 - Tools for Rendezvous and Docking Test (Test 1 through 4)**

Data for this DTO were collected and have been given to the sponsor for evaluation The results of the evaluation will be reported in separate documentation

**DTO 1119 - Orbiter Evaluation of Reduced MILA S-band Uplink Power During Ascent (200 W)**

Data were collected for this DTO and have been given to the sponsor for evaluation The results of the evaluation will be reported in separate documentation

## DETAILED SUPPLEMENTARY OBJECTIVES

### DSO 448B - Circadian Shifting in Astronauts by Bright Light

Data were collected for this DSO, and these data have been given to the sponsor for evaluation The results of that evaluation will be reported in separate documentation

### DSO 485 - Inter Mars Tissue Equivalent Proportional Counter

Data were collected for the Inter Mars Tissue Equivalent Proportional Counter (ITEPC) and these data have been given to the sponsor for evaluation The results of that evaluation will be reported in separate documentation

### DSO 487 - Immunological Assessment of Crewmembers

Data were collected for this DSO, and these data have been given to the sponsor for evaluation The results of that evaluation will be reported in separate documentation

### DSO 493 - Monitoring Latent Virus Reactivation and Shedding in Astronauts

Data were collected daily for this DSO, and these data have been given to the sponsor for evaluation. The results of that evaluation will be reported in separate documentation

### DSO 603 - Orthostatic Function During Entry, Landing, and Egress (603C Configuration)

Data were collected during entry, landing, and egress for this DSO, and these data have been given to the sponsor for evaluation The results of that evaluation will be reported in separate documentation

### DSO 604 - Visual-Vestibular Integration as a Function of Adaptation (O1-3B Preflight and Postflight)

Data were collected during the preflight and postflight periods for this DSO, and these data have been given to the sponsor for evaluation The results of that evaluation will be reported in separate documentation

**DSO 605 - Postflight Recovery of Postural Equilibrium Control**

Data were collected after landing for this DSO, and these data have been given to the sponsor for evaluation The results of that evaluation will be reported in separate documentation

**DSO 608 - Effects of Space Flight on Aerobic and Anaerobic Metabolism During Exercise ( Cycle Ergometer)**

The ergometer was used numerous times throughout the flight Data were collected during each exercise period for this DSO, and these data have been given to the sponsor for evaluation The results of that evaluation will be reported in separate documentation

**DSO 612 - Energy Utilization**

Data were collected for this DSO, and these data have been given to the sponsor for evaluation The results of that evaluation will be reported in separate documentation

**DSO 614B - Head and Gaze Stability During Locomotion**

Data were collected for this DSO, and these data have been given to the sponsor for evaluation. The results of that evaluation will be reported in separate documentation

**DSO 621 - In-Flight Use of Florinef to Improve Orthostatic Intolerance Postflight**

Data were collected for this DSO, and these data have been given to the sponsor for evaluation The results of that evaluation will be reported in separate documentation

**DSO 624 - Preflight and Postflight Measurement of Cardiorespiratory Responses to Submaximal Exercise**

Data were collected for this DSO, and these data have been given to the sponsor for evaluation The results of that evaluation will be reported in separate documentation

**DSO 626 - Cardiovascular and Cerebrovascular Responses to Standing Before and After Space Flight**

Data were collected for this DSO, and these data have been given to the sponsor for evaluation The results of that evaluation will be reported in separate documentation

**DSO 901 - Documentary Television**

Data were collected for this DSO, and these data have been given to the sponsor for evaluation The results of that evaluation will be reported in separate documentation

**DSO 902 - Documentary Motion Picture Photography**

Data were collected for this DSO, and these data have been given to the sponsor for evaluation The results of that evaluation will be reported in separate documentation

**DSO 903 - Documentary Still Photography**

Data were collected for this DSO, and these data have been given to the sponsor for evaluation The results of that evaluation will be reported in separate documentation.

# PHOTOGRAPHY AND TELEVISION ANALYSIS

## LAUNCH PHOTOGRAPHY AND VIDEO DATA ANALYSIS

A total of 23 videos was screened on launch day, and 53 films of the launch activities were examined following launch day, No anomalies or significant findings resulted from this analysis

In addition to the films from ground sites, three rolls of film were exposed by the umbilical well cameras, and that film was also reviewed for possible anomalies Neither the 35 mm nor the two 16 mm films revealed any significant findings or anomalies

## ON-ORBIT PHOTOGRAPHY AND VIDEO DATA ANALYSIS

No significant on-orbit video or photographically recorded events were observed that required analysis, aside from the analysis of the DTO 312 photography that is reported in the Development Test Objectives section of this report

## LANDING PHOTOGRAPHY AND VIDEO DATA ANALYSIS

Six videos, in addition to the NASA Select composite video, of the Orbiter approach and landing at Edwards Air Force Base concrete runway 22 were screened The most significant finding of this screening was that a portion of the ice that became attached to the payload bay door during an on-orbit water dump was still attached.

Fifteen landing films were also screened for significant or anomalous events, and none were found

## TABLE I.- STS-66 MISSION EVENTS

| Event | Description | Actual time, G.m.t. |
|---|---|---|
| APU Activation | APU-1 GG chamber pressure<br>APU-2 GG chamber pressure<br>APU-3 GG chamber pressure | 307:16:54:54.59<br>307:16:54:56.51<br>307:16:54:58.37 |
| SRB HPU Activation[a] | LH HPU System A start command<br>LH HPU System B start command<br>RH HPU System A start command<br>RH HPU System B start command | 307:16:59:15.134<br>307:16:59:15.294<br>307:16:59:15.454<br>307:16:59:15.614 |
| Main Propulsion System Start[a] | ME-3 Start command accepted<br>ME-2 Start command accepted<br>ME-1 Start command accepted | 307:16:59:36.429<br>307:16:59:36.580<br>307:16:59:36.674 |
| SRB Ignition Command (Liftoff) | Calculated SRB ignition command | 307:16:59:43.004 |
| Throttle up to 100 Percent Thrust[a] | ME-3 Command accepted<br>ME-1 Command accepted<br>ME-2 Command accepted | 307:16:59:46.869<br>307:16:59:46:874<br>307:16:59:46.900 |
| Throttle down to 69 Percent Thrust[a] | ME-3 Command accepted<br>ME-1 Command accepted<br>ME-2 Command accepted | 307:17:00:09.909<br>307:17:00:09.915<br>307:17:00:09.940 |
| Maximum Dynamic Pressure (q) | Derived ascent dynamic pressure | 307:17:00:34 |
| Throttle up to 104 Percent[a] | ME-3 Command accepted<br>ME-1 Command accepted<br>ME-2 Command accepted | 307:17:00:45.430<br>307:17:00:45.435<br>307:17:00:45.461 |
| Both SRM's Chamber Pressure at 50 psi[a] | RH SRM chamber pressure mid-range select<br>LH SRM chamber pressure mid-range select | 307:17:01:42.164<br>307:17:01:42.764 |
| End SRM Action[a] | RH SRM chamber pressure mid-range select<br>LH SRM chamber pressure mid-range select | 307:17:01:44.644<br>307:17:01:45.424 |
| SRB Physical Separation[a] | LH rate APU turbine speed - LOS<br>RH rate APU turbine speed - LOS | 307:17:01:47.724<br>307:17:01:47.724 |
| SRB Separation Command | SRB separation command flag | 307:17:01:48 |
| Throttle Down for 3g Acceleration[a] | ME-3 command accepted<br>ME-1 command accepted<br>ME-2 command accepted | 307:17:07:12.479<br>307:17:07:12.480<br>307:17:07:12.508 |
| 3g Acceleration | Total load factor | 307:17:07:14.3 |
| Throttle Down to 67 Percent Thrust[a] | ME-3 command accepted<br>ME-1 command accepted<br>ME-2 command accepted | 307:17:08:10.720<br>307:17:08:10.721<br>307:17:08:10.749 |
| SSME Shutdown[a] | ME-3 command accepted<br>ME-1 command accepted<br>ME-2 command accepted | 307:17:08:16.801<br>307:17:08:16.801<br>307:17:08:16.829 |
| MECO | MECO command flag<br>MECO confirm flag | 307:17:08:18<br>307:17:08:18 |
| ET Separation | ET separation command flag | 307:17:08:36 |

[a] MSFC supplied data

## TABLE I.- STS-66 MISSION EVENTS (Continued)

| Event | Description | Actual time, G.m.t. |
|---|---|---|
| APU Deactivation | APU-3 GG chamber pressure<br>APU 1 GG chamber pressure<br>APU 2 GG chamber pressure | 307:17:13:40.23<br>307:17:14:02.89<br>307:17:14:19.12 |
| OMS-1 Ignition | Left engine bi-prop valve position<br>Right engine bi-prop valve position | Not performed - direct insertion trajectory flown |
| OMS-1 Cutoff | Left engine bi-prop valve position<br>Right engine bi-prop valve position | |
| OMS-2 Ignition | Left engine bi-prop valve position<br>Right engine bi-prop valve position | 307:17:35:56.1<br>307:17:35:56.1 |
| OMS-2 Cutoff | Left engine bi-prop valve position<br>Right engine bi-prop valve position | 307:17:38:36.1<br>307:17:38:36.1 |
| Payload Bay Doors (PLBDs) Open | PLBD right open 1<br>PLBD left open 1 | 307:18:28:37<br>307:18:29:56 |
| SPAS Unberthed | Payload select 1 latch 1A release | 308:11:45:54 |
| SPAS Released | Payload captured | 308:12:49:49 |
| Flight Control System Checkout<br>APU Start<br>APU Stop | <br>APU-1 GG chamber pressure<br>APU-1 GG chamber pressure | <br>315:10:33:10.32<br>315:10:37:13:39 |
| OMS-3 Ignition | Left engine bi-prop valve position<br>Right engine bi-prop valve position | 316:07:28:12.1<br>N/A |
| OMS-3 Cutoff | Left engine bi-prop valve position<br>Right engine bi-prop valve position | 316:07:28:44.2<br>N/A |
| OMS-4 Ignition | Left engine bi-prop valve position<br>Right engine bi-prop valve position | 316:10:29:00.2<br>N/A |
| OMS-4 Cutoff | Left engine bi-prop valve position<br>Right engine bi-prop valve position | 316:10:29:11.4<br>N/A |
| SPAS Grappled | Payload captured | 316:13:05:18 |
| SPAS Berthed | Payload select 1 latch 1A latched | 316:16:50:02 |
| Payload Bay Doors Close | PLBD left close 1<br>PLBD right close 1 | 318:11:50:07<br>318:11:53:46 |
| APU Activation for Entry | APU-2 GG chamber pressure<br>APU-1 GG chamber pressure<br>APU-3 GG chamber pressure | 318:14:26:10.01<br>318:14:49:38.84<br>318:14:49:42.38 |
| Deorbit Burn Ignition | Right engine bi-prop valve position<br>Left engine bi-prop valve position | 318:14:31:04.9<br>318:14:31:05.4 |
| Deorbit Burn Cutoff | Right engine bi-prop valve position<br>Left engine bi-prop valve position | 318:14:34:38.9<br>318:14:34:38.9 |
| Entry Interface (400K feet) | Current orbital altitude above | 318:15:02:26 |
| Blackout end | Data locked (high sample rate) | No blackout |
| Terminal Area Energy | Major mode change (305) | 318:15:27:28 |
| Main Landing Gear Contact | LH main landing gear tire pressure 1<br>RH main landing gear tire pressure 2 | 318:15:33:45<br>318:15:33:46 |
| Main Landing Gear Weight on Wheels | LH main landing gear weight on wheels<br>RH main landing gear weight on wheels | 318:15:33:45<br>318:15:33:45 |

TABLE I.- STS-66 MISSION EVENTS (Continued)

| Event | Description | Actual time, G.m.t. |
|---|---|---|
| Drag Chute Deployment | Drag chute deploy 1 CP Volts | 318:15:33:49.2 |
| Nose Landing Gear Contact | NLG LH tire pressure 1 | 318:15:33:56 |
| Nose Landing Gear Weight On Wheels | NLG weight on wheels 1 | 318:15:33:56 |
| Drag Chute Jettison | Drag chute jettison 1 CP Volts | 318:15:34:16.2 |
| Wheel Stop | Velocity with respect to runway | 318:15:34:35 |
| APU Deactivation | APU-1 GG chamber pressure<br>APU-2 GG chamber pressure<br>APU-3 GG chamber pressure | 318:15:35:51.81<br>318:15:49:11.18<br>318:15:49:13.54 |

## TABLE II.- ORBITER PROBLEM TRACKING LIST

| No. | Title | Reference | Comments |
|---|---|---|---|
| STS-66-V-01 | Aft RCS Thruster L1A Failed Off | 307 17 09 G m t<br>00 00 09 MET<br>CAR 66RF01<br>PR LP03-18-0478 | At 307 17 08 49 (00 00 09 06 MET), dunng the maneuver to photograph the ET after separation, reaction control subsystem (RCS) aft-finng thruster L1A A/N 218) failed off due to low chamber pressure The redundancy management (RM) deselected the thruster 320 msec into the finng The peak chamber pressure was 11 3 psia over 160 msec (four data samples) Injector temperatures venfied at least partial opening of both the fuel and oxidizer valves This is the first flight of thruster S/N 218 since vendor refurbishment<br>KSC The thruster will be removed and replaced The vendor will perform a failure analysis on the oxidizer valve |
| STS-66-V-02 | Starboard PLBD Aft RTL 3 and Close 2 Indications Failed On | 307 18 30 G m t<br>00 01 30 MET<br>CAR 66RF02<br>IPR 71V-0003 | Payload bay door opening was completed at 307 18 30 G m t (00 01 30 MET) When the starboard PLBD was opened, the ready-to-latch (RTL) switch 3 and close switch 2 did not transfer off as they should have Approximately 38 and 44 minutes later, respectively, the RTL and close switches both transferred to their correct state The most likely cause of the anomalous condition is the starboard aft bulkhead RTL switch module internal ngging The other three switch modules on OV-104 have undergone a rework that included potting of the adjustment set screws and the use of PIND tested limit switches<br>KSC The switch module will be replaced with a switch module from OV-102 which is being reworked The OV-104 switch module will be reworked and installed on OV-102 |
| STS-66-V-03 | Fuel Cell 2 Alternate Water Line Check Valve Leakage | 307 18 00 G m t<br>00 01 00 MET<br>CAR 66RF04<br>IPR 71V-0005 | At 307 18 00 G m t (00 01 00 MET), the fuel cell 2 alternate water line temperature increased from 84 °F to 138 °F in one hour The temperature remained steady in the 130 to 140 °F range throughout the flight The temperature should have cycled (as the line heater cycled) in the 70 to 90 °F range This temperature increase indicated that warm fuel cell water was flowing through the alternate water line check valve at a high enough rate to keep the alternate water line temperature almost equal to the product water line temperature, which is 140 to 145 °F This signature was different from previous occurrences of alternate water line check-valve leakage In the past, the temperatures were erratic, going from 70 to 130 °F, with varying temperature nse and fall rates that indicated that the check valve was just leaking a small amount of warm fuel cell water The temperatures from STS-66 indicated a higher flow rate through the check valve Leakage has been seen through this check valve on previous flights of OV-104 Troubleshooting at DFRC venfied that the alternate water line check valve leaks |

## TABLE II.- ORBITER PROBLEM TRACKING LIST

| No. | Title | Reference | Comments |
|---|---|---|---|
| STS-66-V-03 (Continued) | Fuel Cell 2 Alternate Water Line Check Valve Leakage (Continued) | (Continued) | KSC The check valve will be removed and replaced |
| STS-66-V-04 | WSB 3 $GN_2$ Regulator Outlet Pressure Decay | 309 17 00 G m t<br>02 00 00 MET<br>CAR 66RF05<br>IPR 71V-0023 | The WSB 3 $GN_2$ regulator outlet pressure began decreasing following WSB deactivation after ascent At deactivation, the regulator outlet pressure was 27 5 psia and by 309 14 00 G m t (01 21 00 MET), the pressure had decayed to 21 9 psia This corresponds to a leak rate of approximately 0 124 psi/hr This regulator (S/N 016) was installed on OV-102 prior to STS-5 and flew eight flights through STS-50. After STS-50, the WSB (S/N 009) was removed due to a pin hole leak through the heat exchanger core STS-66 is the first flight since STS-50 (6/92) for this WSB and regulator This is a -4 regulator The leak continued at a decreasing rate throughout the flight The pressure was 15 3 psia when the WSB was activated for entry<br>KSC Troubleshooting will be performed |
| STS-66-V-05 | FES Outlet Temperature Sensor Response Lag<br><br><br><br>Level III Closure | 307 17 15 G m t<br>00 00 15 MET<br>CAR 66RF06<br>IPR 71V-0021 | The thermal response of the Freon coolant loop (FCL) 1 flash evaporator system (FES) outlet temperature sensor lagged the FCL 2 FES outlet temperature response During FES start-up on ascent when the largest transients are experienced, the FCL 1 temperature difference of 11 °F when the crew switched the FES controller from GPC to ON During steady periods, the difference was approximately 1 5 °F These measurements are not seen by the FES controllers, but are used for ground insight only This is an instrumentation anomaly, possibly caused by a partial debonding of the sensor There was no impact to ATCS performance<br>KSC Troubleshooting will be performed |
| STS-66-V-06 | FES Primary A Oscillations at Low Heat Loads | 308 23 20 G m t<br>01 06 20 MET<br>CAR 66RF07<br>IPR 71V-0020 | During several periods of FES operation while on the Primary A controller during flight day 2, slight oscillations in the FES outlet temperatures were noted These oscillations were 2 to 3 °F in magnitude and occurred only at low heat loads (radiator outlet temperatures in the 40 to 45 °F range ) The FES Primary B controller was powered on at 311 13 25 G m t (03 20 25 MET) No low heat load oscillations in the FES outlet temperatures were observed while using the FES Primary B controller The FES Primary A controller was enabled at 316 16 55 G m t (08 23 55 MET) and similar outlet temperature oscillations recurred at low heat loads As a result of the FES Primary B controller problems (Flight Problem STS-66-V-13), the Primary A controller was used during entry, and its performance was nominal (high heat loads) |

## TABLE II.- ORBITER PROBLEM TRACKING LIST

| No. | Title | Reference | Comments |
|---|---|---|---|
| STS-66-V-06 (Continued) | FES Primary A Oscillations at Low Heat Loads (Continued) | (Continued) | KSC Troubleshooting will be performed |
| STS-66-V-07 | NSP 2/Ku-Band Interface Channel 1 Failure | 307 17 03 G m.t<br>04 03 59 MET<br>CAR 66RF08<br>IPR 71V-0024 | At approximately 311 12 30 G m t (03 19 30 MET), on orbit 61W with the network signal processor (NSP) -2 configured for two-way Ku-Band, both White Sands and the Second Tracking and Data Relay Satellite (TDRS) Ground Terminal (STGT) observed channel 2 and channel 3 data on the downlink, but no modulation was observed on channel 1 for several passes NSP-2 was configured for S-band with coding off to observe Ku-Band channel 1 and to maintain the link simultaneously Ku-Band channel 1 modulation was not observed On orbit 66W, the link was configured using the second-string NSP, NSP-1 Both White Sands and the STGT observed Ku-Band channel 1 modulation Symptoms indicate a problem in the interface or the logic driving the interface between NSP-2 and the Ku-Band signal processor (KUSP) NSP-2 was reselected at 317 22 27 G m t (10.05:27 MET) and nominal Ku-Band channel 1 modulation was observed with and without coding<br>KSC Troubleshooting will be performed |
| STS-66-V-08 | SSME 1 $LH_2$ Inlet Pressure Response | 307.17 03 G m t<br>000 03 00 MET<br>CAR 66RF09<br>IPR 71V-0007 | Approximately 2 5 minutes after liftoff, the SSME 1 $LH_2$ inlet pressure dropped from approximately 24 5 psia to 22 psia and then gradually recovered to 27 psia by four minutes after liftoff A signature similar to the SSME 1 $LH_2$ inlet pressure signature seen during STS-66 has been present on every OV-104 flight since the installation of the current pressure transducer (nine flights)<br>KSC: Troubleshooting will be performed and the pressure transducer will be replaced if defective |
| STS-66-V-09 | GPC 4/MMU 1 Interface Problem | 315 13 20 G.m t.<br>07 20 20 MET<br>IPR 71V-0010 | During an SM checkpoint at 315 13 20 G m t (07 20 20 MET), GPC 4 annunciated I/O ERROR MMU 1 and CHECKPOINT FAIL messages Recovery procedures were unsuccessful and troubleshooting steps indicated a problem with the GPC 4 to MMU 1 interface The GPC 1 to MMU 1 interface was verified as was the GPC 4 to MMU 2 interface MMU 2 was selected A software dump of GPC 4 showed no additional or contradictory symptoms Following CRISTA/SPAS retrieval, SM was moved to GPC 3 and GPC 4 was placed in a redundant set with GPC 1 for monitoring GPC 4 was used in the G3 redundant set for entry with nominal stringing<br>KSC Troubleshooting will be performed |

# TABLE II.- ORBITER PROBLEM TRACKING LIST

| No. | Title | Reference | Comments |
|---|---|---|---|
| STS-66-V-10 | Ice Formation During Supply Water Dump | 315 15 56 G m t<br>07 22 56 MET<br>CAR 66RF10<br>IPR 71V-0013 | During video downlink at 315 15 56 G m t (07 22 56 MET), a finger of ice was observed growing toward the supply water nozzle and was being fed by supply water being dumped at the time The ice initially formed on the port PLBD The dump was terminated on time and before the ice reached the nozzle The dump was a simultaneous waste and supply water dump The waste water dump had been terminated earlier<br>KSC. Troubleshooting will be performed |
| STS-66-V-11 | Left RCS 3/4/5 Crossfeed Fuel Valve Operation | 317.05:43 G m t<br>09 12.42 MET)<br>CAR 66RF14<br>IPR 71V-0008 | The RCS was configured from interconnect to straight feed at 317 05 42 G m t (09 12 42 MET) Telemetry indicated ac motor-valve current on the ac 1 bus and a toggling closed valve position indicator on the left RCS 3/4/5 fuel crossfeed valve after the valve switch controlling both the oxidizer and fuel valves was moved to the close position The valve continued to drive until the switch was cycled and then taken to GPC to remove the close commands At the time of the switch cycle, data indicate that 2 of 3 ac 1 phases had dropped of due to a thermal cutoff in the motor The valve's ac motor was allowed to cool, and the crew repeated the valve cycle attempt at 317 08 16 G m t (09 15 16 MET) Nominal movement occurred on both the fuel and oxidizer valves The valve again failed to indicate closed during entry when the switch was in GPC During the nominal postlanding valve test, the valve cycled as expected<br>KSC Troubleshooting will be performed |
| STS-66-V-12 | APU 1 Supply Line Temperature Decrease | 318 16 00 G m t<br>10 23 00 MET<br>CAR 66RF15<br>IPR 71V-0011 | About 8 minutes after APU 1 start during entry, the APU 1 supply line temperature decreased from 80 °F to 52 °F over a 35-minute period Just prior to touchdown, the temperature began to increase All other APU 1 parameters were nominal As a precaution, APU 1 was shut down immediately after wheels stop A sniff check and visual inspection of the APU were performed at Dryden Flight Research Center before ferry No evidence of a fuel leak was found<br>KSC Troubleshooting will be performed prior to returning the APU to vendor for planned work |
| STS-66-V-13 | FES Primary B Shutdowns and Oscillations | 311.13 26 G m t<br>03 20 26 MET<br>CAR 66RF16<br>IPR 71V-0020 | The FES experienced an over-temperature shutdown at 311 13 26 G m t (03 20 26 MET) during its first start-up on the primary B controller The primary B controller power was cycled and a normal start-up was seen The most probable cause of this shutdown was a small amount of air in the water system Similar shutdowns have been seen on past flights which had FES change-outs prior to flight (as was the case with STS-66) At 318 10 05 G m t (10 17 06 MET), the FES B controller experienced an under-temperature shutdown The primary B |

## TABLE II.- ORBITER PROBLEM TRACKING LIST

| No. | Title | Reference | Comments |
|---|---|---|---|
| STS-66-V-13 (Continued) | FES Primary B Shutdowns and Oscillation (Continued) | (Continued) | controller power was cycled and the FES operated normally until radiator bypass was selected. Following radiator bypass/FES checkout, several large transients occurred on the Primary B controller. The evaporator outlet temperature oscillated between 34 °F and 47 °F (limits are 39 ± 2 °F), and the primary A controller was selected at 318 12 04 G.m.t. (10 19 04 MET).<br>KSC: Troubleshooting will be performed. |
| STS-66-V-14 | Thruster R3R Fuel Injector Temperature Failed Off-Scale High | 318 15 26 G.m.t.<br>10 22 26 MET)<br>CAR 66RF17<br>IPR 71V-0009 | During entry at 318 15 25 49.85 G.m.t. (10 22 26 06.85 MET), the primary thruster R4R fuel injector temperature went off-scale high. The initial indication was followed by two dips in temperature after which it remained off-scale high. The loss of this sensor did not affect entry operations.<br>KSC: Troubleshooting will be performed, and the transducer will be replaced if it is faulty. |
| STS-66-V-15 | Damaged Tile Along Aft Edge of Window 8 | 308 22.09 G.m.t.<br>01 05 09 MET<br>CAR 66RF18 | The inboard straight tile along the aft edge of the port overhead window (W8) was damaged during flight. The tile is in the same location as the tile that failed during STS-68 (OV-105). During that mission, the tile fractured along a plane at the tile densified layer, and therefore, the majority of the tile was lost. On this mission, the damage is located along the lip of the tile facing the window, and the damaged area is approximately 3 1/2 inches long and 3/4 inch deep.<br>KSC: Tile replacement will be performed. |
| STS-66-V-16 | Avionics Bay 2 Smoke Detector A Negative Excursions | 314 03 18 G.m.t.<br>06 10 18 MET<br>CAR 66RF19 | At approximately 314 03 18 G.m.t. (06 10 18 MET), the avionics bay 2 smoke detector concentration sensor A showed a shift in concentration to about -400 to -500 $\mu g/m^3$. It remained at that level for about 14 hours and exhibited intermediate shifts until the end of the mission. The redundant detector in avionics bay 2 indicated nominal values (-100 to 100 $\mu g/m^3$ throughout the period. Smoke detector self tests were performed on orbit and the indication was that the detector was functioning nominally. This same detector exhibited negative excursions to -700 $\mu g/m^3$ on the previous flight of OV-104 (Flight Problem STS-46-V-04).<br>KSC: Troubleshooting will be performed, and the detector will be replaced if faulty. |

## TABLE II.- ORBITER PROBLEM TRACKING LIST

| No. | Title | Reference | Comments |
|---|---|---|---|
| STS-66-V-17 | Bit Failure on MDM FA3 Card 3 | 318 15 58 G m t<br>Postlanding<br>IPR 71V-0026 | At 318 15 58 G m t , about 20 minutes after the postlanding ET umbilical door opening, the ET umbilical door aft centerline latch 2 locked indication 2 transferred on for 8 seconds and then off The two stow indications remained on and the locked indication 1 stayed off throughout the entire time frame, indicating that the centerline latch could not have moved This discrete goes through MDM FA3 card 3 channel 1 bit 14 After the vehicle was powered up in the Orbiter Processing Facility, bit testing confirmed that the failure was in the MDM<br>KSC Troubleshooting was continued and MDM FA3 will be replaced if faulty |

TABLE III.- GOVERNMENT FURNISHED EQUIPMENT PROBLEM TRACKING LIST

| No. | Title | Time | Comments |
|---|---|---|---|
| STS-66-F-01 | Ergometer High Resistance at "No-Workload" Setting | 308:18:25 G.m.t.<br>01:01:25 MET | The crew reported that there was excessive resistance on the cycle ergometer when it was configured in the "no-workload" setting of the power mode. The problem is believed to be a portion of the adjustable band that produces friction on the internal flywheel The band may be in continual contact with the flywheel so that when the ergometer is configured in the "no workload" setting, flywheel resistance is maintained. An in-flight maintenance (IFM) procedure was performed and the power mode was recovered. The ergometer can also be used in the manual mode. |
| STS-66-F-02 | Arriflex Camera Dragging Battery Down | 311:13:01 G.m.t.<br>03:20:01 MET | The crew reported that the Arriflex camera (S/N1003) dragged and the "not-up-to-speed" light illuminated when the camera was operated. The crew changed magazines twice and with the second change, the dragging ceased. Two batteries were depleted, and the crew used the camera with the dc power connected. Additional troubleshooting procedures were provided to the crew, should the dragging have recurred. |
| STS-66-F-03 | Control Knobs on HHLs | 314:03:57 G.m.t.<br>07:10:57 MET | The crew reported finding the ON/OFF knob sheared off of hand-held LIDAR (HHL) S/N 2 and the same knob on HHL S/N 3 bent over 20 degrees when the locker containing the two units (MF28E) was opened. The crew reported that the S/N 3 unit |

TABLE III.- GOVERNMENT FURNISHED EQUIPMENT PROBLEM TRACKING LIST

| | | | |
|---|---|---|---|
| STS-66-F-03 (Continued) | Control Knobs on HHLs (Continued) | 314:03:57 G m.t. 07:10:57 MET (Continued) | was used for the SPAS deploy with nominal performance. The crew successfully moved the sheared-off HHL (S/N 2) power switch to the on position and is now able to control power by mating and demating the dc power cable. After the HHL was repowered, the crew reported finding that the display intensity know also looked and felt damaged The intensity know felt like it was moving without resistance between the stops and know movement had no observed effect on the intensity. |
| STS-66-F-04 | VCR-2 Failure | 315:13:01 G.m.t. 07:20:01 MET | At 315:13:01 G.m.t. (07:20:01 MET), the crew reported that VCR-2 (a TEAC recorder) had malfunctioned. The crew report indicated that a spring in the recorder had popped off The crew was able to remove the tape that was in the VCR, but they could not load another tape. A camcorder was used in place of VCR 2 for the remainder of the mission. |
| STS-66-F-05 | Hasselblad Camera with Jammed 100 mm lens | 317:16:22 G.m.t. 09:23:22 MET | The 100 mm lens was jammed on a Hasselblad camera and could not be removed. The crew was advised to stow the camera for fear of damage. There were two additional Hasselblad cameras and other lenses onboard. |
| STS-66-F-06 | Linhof Camera Failure | 317:21:07 G.m.t 10:04:07 MET | The Linhof camera dc power cable connector at the camera had a failed circuit segment going to pin no 3 in the connector. The crew successfully performed an IFM with the pin kit |

TABLE III.- GOVERNMENT FURNISHED EQUIPMENT PROBLEM TRACKING LIST

| | | | |
|---|---|---|---|
| STS-66-F-07 | CCTV Camera A Pan/Tilt Unit Intermittent Failure | 315:13:20 G.m.t.<br>07:20:20 MET | Early in the mission, the CCTV camera A pan/tilt unit (PTU) failed to pan when commanded. Rather than move when commanded, the unit would jerk, a possible indication that the PTU was jammed. The condition ceased late in the mission |
| STS-66-F-08 | CCTV Camera A Degraded Video | 316:13:20 G.m.t.<br>08:20:20 MET | CCTV camera A appears to have an Earth limb and Orbiter OMS pod and tail visible at low-light levels in the video. |
| STS-66-F-09 | RMS Wrist Camera Failure | 317:12:00 G.m.t.<br>09:19:00 MET | At 317.12:00 G.m.t. (09.19.00 MET), the RMS wrist camera downlinked image was blurred to the point of being unrecognizable. Attempts to recover the camera included power cycling and various combinations of zoom, focus, and gamma selections. None were successful. The camera was allowed to cool and further attempts to use it were also unsuccessful. The camera was unusable for the remainder of the mission. |
| STS-66-F-10 | CCTV Camera D Intermittent Problems | 316:22:52 G.m.t.<br>09:05:51 MET | CCTV camera D exhibited intermittent asynchronous behavior. A static G.m.t. line appeared in the active video portion of the camera output on at least two different occasions. The camera automatic light control (ALC) and gamma values were also erratic during these periods. |
| STS-66-F-11 | Wrist Roll Joint Angle Exceedance at Power-up | 307:20:19 G.m.t.<br>00:03:20 MET | When the RMS was selected for initial power-up, the value of the wrist roll joint angle was 1.1° prior to MRL release. This value exceeds the tolerance identified in the crew procedures (0.5°). A data review indicates that the wrist roll was in tolerance (0° ± 0.2°) when the MRLs were latched in the OPF. However, the wrist roll was 0.9° on the pad |

## TABLE IV.- MSFC PROBLEM TRACKING LIST

| No | Title | Time | Comments |
|---|---|---|---|
| STS-66-B-01 | Right-hand Frustum MSA-2 Not Adhering to Painted Surface | Postflight inspection | The right-hand frustum had Marshall Sprayable Ablator (MSA) -2 that did not adhere to the painted surface adjacent to PR-1422 sealant over fastener unbonds. No material loss was associated with the unbonded areas. Potential contributors are<br>1. Microballoons were lower in moisture content than previous lots (moisture content still within specification; and<br>2. Pump return flow rate on low side (normally spray parameters could be adjusted to compensate for dryness of microballoons |

# DOCUMENT SOURCES

In an attempt to define the official as well as the unofficial sources of data for this mission report, the following list is provided.

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

# ACRONYMS AND ABBREVIATIONS

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

| | |
|---|---|
| ac | alternating current |
| ACRIM | Active Cavity Radiometer Irradiance Monitor |
| AEM | animal enclosure module |
| AFRSI | Advanced felt reusable surface insulation |
| ALC | automatic light control |
| APU | auxiliary power unit |
| ARS | atmospheric revitalization system |
| ATCS | active thermal control system |
| ATLAS-3 | Atmospheric Laboratory for Applications and Science -3 |
| ATMOS | Atmospheric Trace Molecule Spectroscopy |
| BCE | bus control element |
| BITE | built-in test equipment |
| CCD | charge coupled device |
| CCTV | closed circuit television |
| CEI | contract end item |
| CFC | Chlorofluorocarbons |
| COS | Crystal Observation System |
| CRISTA | Cryogenic Infrared Spectrometers and Telescopes for the Atmosphere |
| DAP | digital autopilot |
| dc | direct current |
| DPS | data processing system |
| DSO | Detailed Supplementary Objective |
| DTO | Developmental Test Objective |
| $\Delta V$ | differential velocity |
| EAFB | Edwards Air Force Base |
| ECLSS | environmental control and life support system |
| EI | entry interface |
| EPDC | electrical power distribution and control subsystem |
| ESCAPE-II | Experiment of the Sun Complementing the ATLAS Payload and Education-II |
| ET | External Tank |
| FC | fuel cell/flight critical |
| FCE | flight crew equipment |
| FCL | Freon coolant loop |
| FCP | fuel cell powerplant |
| FCS | flight control system |
| FES | flash evaporator system |
| ft/sec | feet per second |
| FWD THC | forward translation hand controller |
| GFE | Government furnished equipment |
| $GH_2$ | gaseous hydrogen |
| G.m.t. | Greenwich mean time |
| $GN_2$ | gaseous nitrogen |
| GPC | general purpose computer |

| | |
|---|---|
| GPS | Global Positioning System |
| GSFC | Goddard Space Flight Center |
| HHL | hand-held LIDAR |
| HISAM | hardware-initiated stand-alone memory |
| HPFTP | high pressure fuel turbopump |
| HPOTP | high pressure oxidizer turbopump |
| HPPE-2 | Heat Pipe Performance Experiment-2 |
| HPPE | Heat Pipe Performance Experiment |
| HUMS | hydrogen umbilical mass spectrometer |
| IFM | in-flight maintenance |
| IMU | inertial measurement unit |
| Isp | specific impulse |
| ITEPC | Inter Mars Tissue Equivalent Proportional Counter |
| JPL | Jet Propulsion Laboratory |
| KSC | Kennedy Space Center |
| kW | kilowatt |
| kWh | kilowatt hour |
| lb | pound |
| LCC | Launch Commit Criteria |
| LESC | Lockheed Engineering and Science Company |
| $LH_2$ | liquid hydrogen |
| LIDAR | light distance and ranging |
| $LO_2$ | liquid oxygen |
| LV | local vertical |
| MADS | modular auxiliary data system |
| MAHRSI | Middle Atmosphere High Resolution Spectrograph Investigation |
| MAS | Millimeter Wave Atmospheric Sounder |
| M.D. | Doctor of Medicine |
| MECO | main engine cutoff |
| MET | mission elapsed time |
| MMU | mass memory unit |
| MPCA | mid power control assembly |
| MPS | main propulsion system |
| ms | millisecond |
| MSA | Marshall Sprayable Ablator |
| MSFC | Marshall Space Flight Center |
| NASA | National Aeronautics and Space Administration |
| NIH-C-2 | National Institutes of Health-Cells |
| NIH-R-1 | National Institutes of Health-Rodents |
| NPSP | net positive suction pressure |
| NSP | network signal processor |
| NSTS | National Space Transportation System (i.e., Space Shuttle Program) |
| OME | orbital maneuvering engine |
| OMRSD | Operations and Maintenance Requirements and Specifications Document |
| OMS | orbital maneuvering subsystem |
| OPF | Orbiter Processing Facility |
| OPS | operations |
| PARE | Physiological and Anatomical Rodent Experiment |
| $P_c$ | chamber pressure |

| | |
|---|---|
| PCG | Protein Crystal Growth |
| PCGE | Protein Crystal Growth Experiments |
| PDU | power drive unit |
| PLBD | payload bay door |
| PMBT | propellant mean bulk temperature |
| PRLA | payload retention latch assembly |
| PRSD | power reactant storage and distribution |
| PTU | pan/tilt unit |
| RCS | reaction control subsystem |
| RFL | ready for latch |
| RJD | reaction jet driver |
| RM | redundancy management |
| RMS | remote manipulator system |
| RPC | remote power controller |
| RSRM | Redesigned Solid Rocket Motor |
| RTL | ready to latch |
| RTV | room temperature vulcanizing |
| S&A | safe and arm |
| SAMS | Space Acceleration Measurement System |
| SI | solar inertial |
| SM | systems management |
| S/N | serial number |
| SODB | Shuttle Operational Data Book |
| SOLCON | Solar Constant |
| SOLSPEC | Solar Spectrum Experiment |
| SPAS | Shuttle Pallet Satellite |
| SRB | Solid Rocket Booster |
| SRSS | Shuttle range safety system |
| SSBUV-A | Shuttle Solar Backscatter Ultraviolet/A |
| SSME | Space Shuttle main engine\ |
| STES | single locker thermal enclosure system |
| STGT | Second TDRS Ground Terminal |
| STL | Space Tissue |
| STS | Space Transportation System |
| SUSIM | Solar Ultraviolet Spectral Irradiance Monitor |
| SWDLPA | supply water dump line purge assembly |
| TAL | TransAtlantic Abort Landing |
| TCS | thermal control system |
| TDRS | Tracking and Data Relay Satellite |
| TES | Thermal Enclosure System |
| TPS | thermal protection subsystem |
| UARS | Upper Atmosphere Research Satellite |
| USAF | United States Air Force |
| V | volt |
| VCR | video cassette recorder |
| VDA | Vapor Diffusion Apparatus |
| WCS | Waste collection system |
| WSB | water spray boiler |
| WSGT | White Sands Ground Terminal |

**End of Document**