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STS-38 SPACE SHUTTLE MISSION REPORT

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ABS: The STS-38 Space Shuttle Program Mission Report contains a summary of the vehicle subsystem activities on this thirty-seventh flight of the Space Shuttle and the seventh flight of the Orbiter vehicle Atlantis (OV-104). In addition to the Atlantis vehicle, the flight vehicle consisted of an External Tank (ET) (designated as ET-40/LWT-33), three Space Shuttle main engines (SSME's) (serial numbers 2019, 2022, 2027), and two Solid Rocket Boosters (SRB's), designated as BI-039. The STS-38 mission was a classified Department of Defense mission, and as much, the classified portions of the mission are not presented in this report. The sequence of

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events for this mission is shown. The significant problems that occurred in the Space Shuttle Orbiter subsystem during the mission are summarized and the official problem tracking list is presented. In addition, each Space Shuttle Orbiter problem is cited in the subsystem discussion.

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STS-38

SPACE SHUTTLE

MISSION REPORT

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INTRODUCTION

The STS-38 Space Shuttle Program Mission Report contains a summary of the vehicle subsystem activities on this thirty-seventh flight of the Space Shuttle and the seventh flight of the Orbiter vehicle Atlantis (OV-104). In addition to the Atlantis vehicle, the flight vehicle consisted of an External Tank (ET) (designated as ET-40/LWT-33), three Space Shuttle main engines (SSME's) (serial numbers 2019, 2022, 2027), and two Solid Rocket Boosters (SRB's), designated as BI-039.

The STS-38 mission was a classified Department of Defense mission, and as such, the classified portions of the mission are not presented in this report.

The sequence of events for this mission is shown in table I. The report also summarizes the significant problems that occurred in the Orbiter subsystems during the mission, and the official problem tracking list is presented in table II. In addition, each Orbiter problem is cited in the subsystem discussion within the body of the report.

The crew for this thirty-seventh flight of the Space Shuttle was Richard O. Covey, Col., USAF, Commander; Frank L. Culbertson, Capt., USN, Pilot; Charles D. Gemar, Capt., U.S. Army, Mission Specialist 1; Robert C. Springer, Col., USMC, Mission Specialist 2; and Carl J. Meade, Major, USAF, Mission Specialist 3. This was the third flight for the Commander, the first flight for the Pilot and Mission Specialists 1 and 3, and the second flight for Mission Specialist 2.

MISSION SUMMARY

The STS-38 mission was launched at 319:23:48:15.006 G.m.t. (6:48:15 p.m. e.s.t. on November 15, 1990) from launch pad 39A on a Department of Defense mission. The launch phase was satisfactory in all respects and all Orbiter subsystems operated in a nominal manner. All SSME and redesigned solid rocket motor (RSRM) start sequences occurred as expected. First stage ascent performance was normal with SRB separation, entry, deceleration, and water impact occurring as planned. Performance of the SSME's, ET, and main propulsion system (MPS) was also normal. The orbital maneuvering subsystem (OMS) -1 and OMS-2 maneuvers were performed with nominal results.

While operating on A controller, water spray boiler (WSB) 2 failed to cool the auxiliary power unit (APU) lubrication oil during ascent. WSB 2 was switched to the B controller and APU 2 was left on after APU's 1 and 3 were shut down to allow evaluation of lubrication oil cooling on the B controller. Effective lubrication oil cooling was achieved 1 minute 6 seconds after the switch to the B controller; APU 2 was then shut down. The A controller was used for entry and data showed nominal operation.

The OMS-3 maneuver and two reaction control subsystem (RCS) maneuvers were satisfactorily completed and all parameters remained within acceptable ranges.

The power reactant storage and distribution (PRSD) hydrogen tank 3 quantity sensor failed off-scale high. The crew reported that the onboard meter on panel O2 also indicated off-scale high. This failure did not impact the mission.

Circuit breaker 29 on panel L4 opened while the vacuum cleaner was being used. The vacuum cleaner was subsequently stowed. No further use was made of the vacuum cleaner or of the electrical socket into which it had been plugged.

The two-engine OMS-4 maneuver was completed with nominal performance.

On flight day 3, the RCS hot-fire test was successfully completed. The flight control system (FCS) checkout was completed using APU 3, and performance of all subsystems during the FCS checkout was nominal.

During preparations for the initial entry opportunity on flight day 4, the switch talkback indication for general purpose computer (GPC) 3 indicated that the GPC failed to go to run. The crew reinitialized the GPC and returned it to the redundant set in which it operated properly.

Three landing opportunities were canceled on flight day 4 because of unacceptable weather conditions for landing at Edwards Air Force Base. On the first opportunity, the headwinds exceeded the flight rule limit of 25 kts on runways 22 and 23. Excessive crosswinds as well as winds varying from the forecast caused the cancellation of landing on the second and third opportunities, and the mission was extended one day.

Weather forecasts for landing at Edwards Air Force Base on flight day 5 showed unfavorable winds on all runways. As a result, the decision was made to change the primary landing site to Kennedy Space Center because of the very favorable weather conditions existing at that landing site.

After completion of all entry preparations including stowage and payload bay door closure, the OMS deorbit maneuver was performed at 324:20:46:15 G.m.t., with a firing duration of 114.9 seconds and a differential velocity of 228.5 ft/sec. Entry interface occurred at 324:21:11:52 G.m.t., and because of the presence of the Tracking and Data Relay Satellite (TDRS), communications were maintained throughout entry.

Main landing gear touchdown occurred at 324:21:42:42 G.m.t., on the Shuttle Landing Facility at Kennedy Space Center. Nose landing gear touchdown occurred 10 seconds later with wheels stop at 324:21:43:41 G.m.t. The rollout was normal in all respects. The three APU's were shut down by 324:21:57:05.43 G.m.t., and the crew completed the required postflight reconfigurations and exited the vehicle at 324:22:32:25 G.m.t.

Postlanding data showed that the right hand vent doors 1 and 2 closed instead of going to the purge position. Investigation into the cause of this anomaly is continuing.

VEHICLE PERFORMANCE

SOLID ROCKET BOOSTERS/REDESIGNED SOLID ROCKET MOTORS

All solid rocket booster (SRB) systems performed as expected. Power-up of all igniter, joint and case heaters was accomplished routinely. All redesigned solid rocket motor (RSRM) temperatures were maintained within acceptable limits throughout the countdown. Ground purges maintained the nozzle bearing and flexible boot temperatures within the required launch commit criteria (LCC) ranges. The SRB prelaunch countdown was normal, and two RSRM in-flight anomalies have been identified. RSRM propulsion performance was well within the required specification limits, and the propellant burn rate for each RSRM was normal. RSRM thrust differentials during the buildup, steady state and tailoff phases were well within specifications. All SRB thrust vector control prelaunch conditions and flight performance requirements were met with ample margins. All electrical functions were performed properly. No SRB or SRM LCC or Operations and Maintenance Requirements and Specifications Document (OMRSD) violations occurred.

The SRB flight structural temperature response was as expected. Postflight inspection of the recovered hardware indicated that the SRB thermal protection system (TPS) performed properly during ascent with very little TPS acreage ablation. Separation subsystem performance was normal with all booster separation motors expended and all separation bolts severed. Nose cap jettison, frustum separation and nozzle jettison occurred normally on each SRB.

The entry and deceleration sequence was properly performed on both SRB's, with subsequent parachute deployment on each SRB being performed satisfactorily. The SRB's were successfully recovered and returned to KSC for disassembly.

The two in-flight anomalies that were identified were as follows:

a. Photographic analysis identified debris exiting from the thermal curtain region on both SRB's during ascent.

b. The forward face of the right SRB ET attachment ring had two areas where Instafoam was missing.

EXTERNAL TANK

All objectives and requirements associated with ET propellant loading and flight operations were successfully met. Propellant loading was completed as scheduled, and all prelaunch thermal requirements were met. As expected, only the normal ice/frost formations for the November environment were observed during the countdown. There was no frost or ice on the acreage areas of the ET. Normal quantities of ice or frost were present on the liquid oxygen and liquid hydrogen (LH_2) feedlines and on the pressurization line brackets. Frost was also present along the liquid hydrogen protuberance air load ramps. All of these observations were acceptable and in accordance with established Space Shuttle documentation.

TPS performance was as expected for the existing ambient conditions. There were no LCC or OMRSD violations during the countdown. No significant ET problems have been identified.

ET flight performance was excellent. All ET electrical equipment and instrumentation performed satisfactorily. The operation of the ET heaters and purges was monitored and all performed properly.

The ET pressurization system functioned properly throughout the engine start and flight phases. The minimum liquid oxygen ullage pressure experienced during the period of the ullage pressure slump was 13.5 psid.

The ET tumble system was inactive on this flight. Radar data from Bermuda and Antigua confirmed that the ET did not tumble. The ET entry and rupture/breakup data are not available, but ET entry and breakup was within the expected footprint.

SPACE SHUTTLE MAIN ENGINE

All prelaunch operations associated with the SSME's were executed successfully. Launch ground support equipment provided adequate control for the SSME's during launch preparation. All SSME parameters appeared to be normal throughout the prelaunch countdown, comparing very well with prelaunch parameters observed on previous flights. All engine-related conditions for engine start were achieved at the proper time, all LCC were met, and engine start and thrust buildup were normal.

Flight data indicate that SSME performance during mainstage, throttling, shutdown and propellant dump operations was well within specification. All three engines started and operated normally. High pressure oxidizer turbopump and high pressure fuel turbopump temperatures were normal throughout the period of engine operation.

After SSME shutdown (approximately 4 minutes after main engine cutoff), an anomaly was recorded on main engine 1. The indicated failure was the main engine 1 POGO charge transducer, and its failure did not impact the mission. Engine dynamic data generally compared well with previous flight and test data. All on-orbit activities associated with the SSME's were accomplished successfully. No other significant flight problems were identified.

SHUTTLE RANGE SAFETY SYSTEM

Shuttle range safety system (SRSS) closed-loop testing was completed as scheduled during the launch countdown. The SRSS safe and arm (S&A) devices were armed and all system inhibits were turned off at the appropriate times. All SRSS measurements indicated that the system performed as expected throughout the flight, with system signal strength remaining above the specified minimum of -97 dBm for the duration of the flight.

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

ORBITER SUBSYSTEM PERFORMANCE

Main Propulsion System

On June 29, 1990, the first STS-38 tanking test was conducted as a precautionary measure because of the hydrogen leak that was discovered on STS-35 (OV-102). During the test, unacceptable hydrogen concentration readings were recorded on the external liquid hydrogen umbilical drag-on sensors. Two more tanking tests were conducted (July 13 and July 25) in an attempt to isolate the source of the external leakage. The Orbiter was demated from the ET/SRB stack and the ET 17-inch disconnect and ET feedline were removed and sent to Marshall Space Flight Center for testing that revealed that the follower arm seal and shaft seal were leaking. The new ET disconnect were installed, and a successful tanking test (fourth) was performed on October 24, 1990.

The overall performance of the main propulsion system (MPS) was excellent. All pretanking purges were properly performed and liquid oxygen and liquid hydrogen loading was performed with no stop flows or reverts. There were no OMRSD or LCC violations identified.

A comparison of the calculated propellant loads at the end of replenish versus the inventory loads showed in a loading accuracy of +0.047 percent for liquid hydrogen and -0.004 percent for liquid oxygen. Throughout the preflight operations, no significant hazardous gas concentrations were detected, and the maximum hydrogen level in the Orbiter aft compartment was 237 ppm, which compares very well with previous data for this vehicle.

The gaseous oxygen flow control valves remained open during the engine-start sequence and the early portion of ascent, and performed normally throughout the remainder of the flight. The minimum liquid oxygen ullage pressure experienced during the period of ullage pressure slump was 13.5 psid, which is within the specification band.

Ascent MPS performance appeared to be completely normal. The step 2 gaseous oxygen fixed-orifice flow control valve was flown for the first time on STS-38. Postflight analysis of the valve performance data reveals good agreement with predicted performance. Data indicate that the liquid oxygen and liquid hydrogen pressurization systems performed properly, and that all net positive suction pressure requirements were met throughout the flight.

The speed indicator on the engine 1 liquid hydrogen recirculation pump had failed during a previous STS-38 tanking test and was not operative for this launch. Alternate critical measurements were used to ensure that the pump was operating properly.

Out-of-specification response times were noted for the liquid oxygen and liquid hydrogen outboard fill and drain valves (P10 and P11) at vacuum inert initiation. The specification requires a minimum response time of no less than 2.9 seconds, and the response times were 2.771 and 2.510 seconds for P10 and P11, respectively. These short response times did not impact the mission or operation of the valves as the valves are certified under anti-slam conditions.

Reaction Control Subsystem

The performance of the RCS was satisfactory with one anomaly noted. A total of 5124 lb of propellant was consumed with no forward RCS dump firing being performed. Primary thruster R1U chamber pressure was below the nominal 150 psia by approximately 20 psi (Flight Problem STS-38-07). This occurred consistently for several pulses on entry day. Earlier data were nominal. Thruster R1U was placed in last priority for entry usage and the anomaly did not impact the mission. In addition, thrusters R3D, R4U, and F3L all showed transient periods of low chamber pressure, and the discussion of the anomalous operation of these three thrusters is also a part of flight problem STS-38-07.

Orbital Maneuvering Subsystem

The OMS operated satisfactorily throughout the mission. No anomalies were recorded; however, both forward fuel probes failed. These units, which are not considered to be critical, have failed for several missions and will be replaced on an opportunity basis. During prelaunch operations, the left-hand gaseous nitrogen fill/vent valve leakage was about 83 scch and should not have been more than 15 scch. This condition was waived to fly as-is, and no significant decrease in nitrogen pressure was noted during the mission.

Five dual-engine OMS maneuvers were performed during the mission with nominal performance. A total of 13,458 lb of propellants were consumed during the mission.

Power Reactant Storage and Distribution Subsystem

The power reactant storage and distribution (PRSD) subsystem met all oxygen and hydrogen demands placed on the subsystem and operated satisfactorily during the mission. One subsystem anomaly was noted. At 320:07:05 G.m.t., the hydrogen tank 3 quantity sensor failed off-scale high (Flight Problem STS-38-03a). During postlanding inerting of the system, the quantity reading returned to normal. This anomaly did not impact the mission.

A total of 1135 lb of oxygen and 135 lb of hydrogen was consumed during the mission (56 lb of oxygen used by the crew). A 79-hour mission extension at the average power level was possible with the reactants remaining in the PRSD subsystem at touchdown.

Fuel Cell Powerplant Subsystem

The fuel cell powerplant subsystem satisfactorily supported the 118-hour mission. Two incidents occurred within the fuel cell subsystem during the mission. The oxygen flowmeter for fuel cell 3 indicated incorrect flow rate readings, and fuel cell 1 hydrogen pump motor voltage indication prior to launch was within one data bit of exceeding the LCC. Neither of these conditions impacted the mission.

The fuel cells produced 1570 kWh of electrical energy and 1214 lb of potable water from 1079 lb of oxygen and 135 lb of hydrogen. The average total Orbiter electrical power was 13.3 kW and 416 A. The fuel cells remained powered up for approximately 34 hours after landing.

Auxiliary Power Unit Subsystem

The APU subsystem performance was satisfactory during the mission. Three anomalies were noted during the mission, none of which impacted the mission. The following table shows the run time and fuel consumption for each APU during the flight.

Flight phase	APU 1		APU 2		APU 3	
	Time, min:sec	Fuel consumption, lb	Time, min:sec	Fuel consumption, lb	Time, min:sec	Fuel consumption, lb
Ascent	00:19:27	46	00:21:12	59	00:19:26	51
FCS checkout					00:05:09	17
Entry scrub	00:00:38	1				
Entry	01:15:50	131	00:58:09	137	00:58:09	121
Total[a]	01:35:55	178	01:19:21	196	01:22:44	189

[a] A total of 14 minutes 19 seconds of run time occurred after landing.

During ascent, the APU 2 lubrication oil outlet and bearing temperatures reached 305 °F and 330 °F, respectively, during ascent while water spray boiler (WSB) controller A was selected (Flight Problem STS-38-01). APU 2 was started at entry interface minus 13 minutes with WSB controller A selected, and lubrication oil outlet and bearing temperatures remained in the nominal temperature range.

The APU 3 X-axis accelerometer operated erratically during descent (Flight Problem STS-38-3b). Since APU 3 will be removed because of completion of its life cycle, only limited troubleshooting will be performed on the vehicle.

A number of APU instrumentation anomalies occurred during this mission. The APU 2 exhaust gas temperature (EGT) 1 and 2 sensors operated erratically during ascent and descent. Also, the APU 2 and 3 injector temperature sensors operated erratically during both ascent and descent (Flight Problem STS-38-05). Evaluation showed an anomalous interaction between these two groups of sensors. The APU 1 EGT 1 was also lost during descent (Flight Problem STS-38-05).

Hydraulics/Water Spray Boiler Subsystem

The hydraulics/water spray boiler subsystem performed nominally with the exception of the system 2 WSB core freeze-up that occurred during ascent while operating on controller A. Also, the APU lubrication oil was not cooled adequately following main engine cutoff (Flight Problem STS-38-01). When WSB controller B was selected, cooling the lubrication oil outlet and bearing temperatures began 1 minute 6 seconds after the switchover. Controller A was used on all three WSB's during entry and all WSB operations were nominal.

Pyrotechnics Subsystem

The pyrotechnics subsystem operated nominally.

Environmental Control and Life Support Subsystem

Analysis of the flight data shows that the performance of the atmospheric revitalization system, pressure control systems, and active thermal control systems was satisfactory. One heater anomaly was identified on the flash evaporator system B water supply accumulator in which heater strings 1 and 2 showed a shift in the control band (Flight Problem STS-38-02).

Early in the mission, the flash evaporator system (FES) secondary feedline water supply accumulator temperature measurement dropped below 50 °F. When the heater system was switched from heater string 1 to 2, the temperature slowly recovered.

In addition, the supply and waste water systems were managed successfully through the use of the overboard dump system and flash evaporator system. Four supply water dumps and one waste water dump were made.

The potable water quantity transducer in tank C indicated an instantaneous change to a high value. A mechanical problem is suspected in the transducer mechanism. This condition did not impact the mission.

Smoke Detection and Fire Suppression Subsystem

The smoke detection and fire suppression subsystem operated nominally. Sporadic smoke detection alarm event indications were seen; however, none tripped the alarm (Flight Problem STS-38-09). These indications have been seen on previous flights of other vehicles and have not been a problem.

Airlock Support System

The airlock support system was not used this mission as the airlock was used only as a stowage area.

Avionics and Software Subsystems

The avionics and software subsystems performed nominally; however, several minor anomalous conditions were noted during the mission.

The integrated guidance, navigation and control subsystem performance was satisfactory for all phases of the mission. The flight control subsystem (FCS) performance was satisfactory during all phases of the mission including operations during the FCS checkout two days prior to entry.

The performance of the inertial measurement units and the star trackers was also satisfactory in all respects. Two minor problems were noted during preparations for entry when operating the data processing subsystem/flight software. When activating general purpose computer (GPC) 3 during deorbit preparations, the GPC 3 talkback did not indicate run when the GPC was taken from halt to standby. A GPC initial program load was performed and the GPC operated properly. Analysis of the dump from GPC 3 indicated that the GPC was not allowed to complete standby processing during freeze-dry procedures. The problem did not impact the mission. Also, during the IPL of GPC 3, a temporary loss of communications occurred. This condition was caused by the stored program command not completing execution prior to the backup flight system GPC being given the payload data busses. Crew action reenabled communications.

The electrical power distribution and control subsystem operated normally; however, two anomalies were noted. The short circuit in the vacuum cleaner (flight problem STS-38-04a), which caused circuit breaker 29 on panel L4 to open, is discussed in the Flight Crew Equipment section of this report.

Approximately 1 minute prior to landing, the main bus A mid power controller 1 current dropped to zero (Flight Problem STS-38-03c). No change in fuel cell 1 current was noted when this event occurred, indicating a sensor failure.

At approximately T-20 minutes in the final countdown, the fuel cell 1 hydrogen pump motor condition indication voltage rose to as high as 0.74 V (LCC limit is 0.75 V) during fuel cell conditioning load application. Data from three previous Shuttle flights and from STS-38 were evaluated, and this evaluation resulted in a postulation that the higher-than-anticipated readings were the direct result of panel lighting dimmer operation causing uneven loading between the three phases of the ac busses. The condition sensor is sensitive to uneven loads between ac bus phases. An in-flight test was performed that supported this theory; consequently, a LCC change will be processed to raise the upper limit to 1.0 V.

The displays and controls components performed nominally except for the payload bay mid-port floodlight, which was operating intermittently during the payload bay door closing. This same problem was seen on STS-36 and is currently being shown as an unexplained anomaly by Kennedy Space Center.

The operational instrumentation subsystem performed nominally during the mission, except for APU instrumentation problems (Flight Problem STS-38-05) that are discussed in the Auxiliary Power Unit Subsystem section of this report.

A tire pressure fault detection annunciator (FDA) message was annunciated continuously after landing (Flight Problem STS-38-08). Inspection of the tire pressure connectors showed no anomalous condition existed in that part of the subsystem.

Communications and Tracking Subsystem

The communications and tracking subsystem performance was satisfactory with two minor problems and one anomaly noted during the mission.

A Ku-band power amplifier problem was noted, and the problem was isolated to a circuit breaker which had not been closed. The crew closed the circuit breaker and subsequent subsystem performance was nominal.

Closed-circuit television (CCTV) cameras C and D were reported by the crew to be malfunctioning (Flight Problem STS-38-4c and -4d, respectively). Camera C could not be focused by the crew, and camera D had no indication of power. The crew cycled the TV system power and these problems were corrected. The two cameras operated properly for the remainder of the flight.

An over-current condition in the low-voltage power supply of TV monitor 2 was noted (Flight Problem STS-38-04b). The crew performed malfunction procedures, but satisfactory monitor operation was not recovered. Monitor 1 was used for the remainder of the mission.

Mechanical Subsystems

The performance of the mechanical subsystems was nominal throughout the mission except for one anomaly that occurred at OPS 9 transition after landing. Right-hand vent doors 1 and 2 failed to stop at the purge position when commanded to move from open to purge during the postlanding vent door repositioning (Flight Problem STS-38-06). The failure caused no concerns for the postflight purge of the forward compartment.

Video and telemetry data of the landing and deceleration activities showed main gear touchdown occurred at a ground speed of 194.3 knots approximately 1414 feet from the runway threshold. Nose gear touchdown occurred 10 seconds later at a ground speed of 161.9 knots approximately 4213 feet from the runway threshold. Braking was initiated at a ground speed of 124 knots approximately 7400 feet from the runway threshold. Wheels stop occurred approximately 10484 feet from the runway threshold with brake energies in the nominal range from 18.94 million ft-lb to 26.00 million ft-lb.

Aerodynamics

Ascent and entry aerodynamics were nominal in all respects with the vehicle responding as expected.

Thermal Control Subsystem

All Orbiter structural and component temperatures were maintained within acceptable limits throughout the mission; however, one anomaly was noted during data evaluation. The flash evaporator system (FES) secondary feedline water supply accumulator heater indicated on-orbit cycling in a lower and narrower band (48 ° to 54 °F) than the nominal band of 55 ° to 75 °F (Flight Problem STS-38-02). Since other measures of this heater's performance appeared nominal and the off-nominal temperature response was observed on both heater systems, it was postulated that this response may have been the result of a faulty sensor. This postulation was confirmed during postflight turnaround activities.

Aerodynamic Heating and Thermal Interface Temperatures

Analysis of heating data indicated nominal aerodynamic and plume heating, but analysis of these data are continuing. Aerodynamic heating on the SSME nozzles was within the TPS limits based on data analysis and the postflight inspection.

All thermal interface temperatures (ET/Orbiter) were maintained within acceptable limits during prelaunch operations and ascent. No LCC were violated and all OMRSD requirements were met. In addition, all Orbiter/SSME hydraulic interface temperatures were maintained within the nominal limits established in interface control documentation.

Aerothermodynamics and Thermal Protection Subsystem

Acreage heating was nominal during entry with nominal structural temperature rises observed in the data. Postflight inspection and analysis revealed that localized heating was also nominal with typical atmospheric density gradients determined between 250,000- and 240,000-ft altitude.

The TPS performance was nominal based on structural temperature response data and some tile surface temperature measurement data. The overall boundary transition from laminar to turbulent flow was nominal and occurred at 1200 seconds after entry interface. Transition was symmetrical.

Flight damage to the TPS was minimal with three scrap tiles identified during the runway inspection. Debris impact damage to the lower surface was also minimal with a total of 46 damage sites (hits), six of which were significant impacts in that the major dimension was 1 inch or greater. The hits were approximately equally divided about the vehicle centerline. Five hits were noted on the body flap lower surface with each damage site exhibiting thermal erosion to a depth of 1/2 inch with melting of the adjacent tile-coating material. The base heat shield peppering (approximately 150 sites) was lighter than normal.

Overall, all reusable carbon carbon (RCC) parts appeared normal. A gap was evident around the chin panel 441 gap filler. The nose landing gear door TPS was in good condition with only one loose Nicalon sacrificial thermal barrier patch. The right main landing gear door thermal barrier outboard section had two breached areas. The ET door thermal barriers were in good condition with evidence of a minor flow path on the right-hand barrier. No evidence of damage was apparent from the ice seen in the debris films. The elevon cove TPS and elevon-elevon gap tiles were all in good condition. Six left-hand rudder speed brake (trailing edge) tiles had a broken coating. The engine-mounted heat shield thermal curtains were damaged on all three engines with the worst damage on engine two. The upper surface and OMS pod TPS was in good condition.

Orbiter windows 2 and 5 were lightly hazed, and moderate haze was found on windows 3 and 4.

FLIGHT CREW EQUIPMENT

The flight crew equipment performed nominally except for the vacuum cleaner and a minor water leak in the galley.

When the crew compartment vacuum cleaner was turned on at 321:02:29 G.m.t., circuit breaker 29 on panel L4 opened (Flight Problem STS-38-04a). Data review indicated that a short existed in the vacuum cleaner motor; however, as a precautionary measure, the outlet to which the vacuum cleaner was connected was not used for the remainder of the mission. Alternate procedures were used to clean screens, etc., after loss of the vacuum cleaner. Postflight testing revealed a short circuit in the vacuum cleaner motor.

A small water leak was noted at the MV3 valve in the galley. This leak is similar to that noted on STS-41. The leak was wiped up with a towel and the leak did not impact the use of the galley in any manner.

The crew also reported that the galley rehydration station initially dispensed two cups of water and then stopped dispensing. The crew performed the malfunction procedure and regained the dispensing capability.

PHOTOGRAPHIC AND VIDEO ANALYSIS

On launch day, 25 video films of ascent were screened. A potential anomaly was observed when a piece of ice fell from the liquid hydrogen umbilical plate and hit the edge of the umbilical cavity. A review by the subsystem manager indicated that no damage had been done, and that no anomaly had occurred. Subsequent postflight investigation also showed no damage. The results of the entire launch film review revealed no unexpected events or occurrences.

Six video films plus NASA Select video of the landing at KSC were reviewed and no anomalies were noted. Also, seven films of landing were reviewed, and no anomalies were noted. Sink rates could not be determined as the KSC camera configuration was not compatible for providing these data.

DEVELOPMENT TEST OBJECTIVES AND DETAILED SUPPLEMENTARY OBJECTIVES

DEVELOPMENT TEST OBJECTIVES

Three of the five planned development test objectives (DTO's) were completed.

DTO 301 - Ascent Structural Capability Evaluation - The objective of DTO 301 is to verify the adequacy of the Shuttle structural capability at (or near) design conditions. Data were recorded during flight, and the evaluation is underway.

DTO 309 - Ascent Flutter Boundary Evaluation (Test 4) - The objective of DTO 309 is to verify Shuttle performance near the ascent flutter boundary. Data were recorded for the period of interest, and the evaluation is underway.

DTO 517 - Hot Nosewheel Steering Runway Evaluation - DTO 517 was not performed because of the KSC landing.

DTO 785 - HUD Backup to COAS - The objective of DTO 785 is to verify the suitability of the head up display (HUD) as a substitute star-sighting device to replace the crewman optical alignment sight (COAS) when performing inertial measurement unit alignments. The DTO was successfully completed and the data evaluation is underway.

DTO 805 - Crosswind Landing Performance - DTO 805 was not performed.

DETAILED SUPPLEMENTARY OBJECTIVES

The two planned detailed supplementary objectives (DSO's) were completed.

DSO 462 - Non Invasive Estimation of Central Venous Pressure During Spaceflight The objective of DSO 462 was to evaluate central venous pressure of crew members during spaceflight. This DSO was deleted prior to flight because of weight considerations.

DSO 473 - Delay Type Hypersensitivity - The objective of DSO 473 is to evaluate the extent of the delayed-type hypersensitivity mechanism during space flight. The DSO was successfully completed, and data are being evaluated.

DSO 477 - Muscle Performance - DSO 477 is designed to test concentric and eccentric muscle contractions of crew members during spaceflight. The DSO was successfully completed.

TABLE I.- STS-38 SEQUENCE OF EVENTS

Event	Description	Actual time, G.m.t.
APU activation	APU-1 GG chamber pressure	319:23:43:24.25
	APU-2 GG chamber pressure	319:23:43:25.91
	APU-3 GG chamber pressure	319:23:43:27.14
SRB HPU activation	LH HPU system A start command	319:23:47:47.24
	LH HPU system B start command	318:23:47:47.30
	RH HPU system A start command	319:23:47:47.52
	RH HPU system B start command	319:23:47:47.55
Main propulsion System start	Engine 3 start command to EIU	319:23:48:08.436
	Engine 2 start command to EIU	319:23:48:08.578
	Engine 1 start command to EIU	319:23:48:08.692
SRB ignition command (lift-off)	SRB ignition command to SRB	319:23:48.15.006
Throttle up to 104 percent thrust	Engine 3 command accepted	319:23:48:18:916
	Engine 2 command accepted	319:23:48:18.939
	Engine 1 command accepted	319:23:48:18.933
Throttle down to 72 percent thrust	Engine 3 command accepted	319:23:48:41.157
	Engine 2 command accepted	319:23:48:41.179
	Engine 1 command accepted	319:23:48:41.173
Maximum dynamic pressure (q)	Derived ascent dynamic pressure	319:23:49:04
Throttle up to 104 percent thrust	Engine 3 command accepted	319:23:49:17.158
	Engine 2 command accepted	319:23:49:17.180
	Engine 1 command accepted	319:23:49:17.174
Both SRM's chamber pressure at 50 psi	LH SRM chamber pressure mid-range select	319:23:50:13.61
	RH SRM chamber pressure mid-range select	319:23:50:13.33
End SRM action	LH SRM chamber pressure mid-range select	319:23:50:16.376
	RH SRM chamber pressure mid-range select	319:23:50:16.129
SRB separation command	SRB separation command flag	319:23:50:16 - 21
SRB physical separation	SRB physical separation	
	LH APU A turbine speed LOS*	319:23:50:18.85
	LH APU B turbine speed LOS*	319:23:50:18.85
	RH APU A turbine speed LOS*	319:23:50:18.85
	RH APU B turbine speed LOS*	319:23:50:18.85
Throttle down for 3g acceleration	Engine 3 command accepted	319:23:55:49.328
	Engine 2 command accepted	319:23:55:49.350
	Engine 1 command accepted	319:23:55:49.306
3g acceleration	Total load factor	319:23:55:50
MECO	MECO command flag	319:23:56:44
	MECO confirm flag	319:23:56:45
ET separation	ET separation command flag	319:23:57:02
OMS-1 ignition	Left engine bi-prop valve position	319:23:58:45.2
	Right engine bi-prop valve position	319:23:58:45.2

* = loss of signal

TABLE I.- CONTINUED

Event	Description	Actual time, G.m.t.
OMS-1 cutoff	Left engine bi-prop valve position	320:00:00:06.8
	Right engine bi-prop valve position	320:00:00:06.6
APU deactivation	APU-1 GG chamber pressure	320:00:02:51.59
	APU-2 GG chamber pressure	320:00:04:38.12
	APU-3 GG chamber pressure	320:00:02:52.83
OMS-2 ignition	Left engine bi-prop valve position	320:00:25:48.2
	Right engine bi-prop valve position	320:00:25:48.2
OMS-2 cutoff	Left engine bi-prop valve position	320:00:27:21.0
	Right engine bi-prop valve position	320:00:27:20.8
Flight control system checkout		
APU start	APU-3 GG chamber pressure	322:20:24:48.60
APU stop	APU-3 GG chamber pressure	322:20 29:57.14
APU activation for entry	APU-1 GG chamber pressure	324:20:41:14.41
	APU-2 GG chamber pressure	324:20:58:56.02
	APU-3 GG chamber pressure	324:20:58:56.89
Deorbit maneuver ignition	Left engine bi-prop valve position	324:20:46:15
	Right engine bi-prop valve position	324:20:46:15
Deorbit maneuver cutoff	Left engine bi-prop valve position	
	Right engine bi-prop valve position	
Entry interface (400k)	Current orbital altitude above reference ellipsoid	324:21:11:52
Blackout end	Data locked at high sample rate	No blackout because of TDRS
Terminal area energy management	Major mode change (305)	324:21:36:12
Main landing gear contact	Left MLG tire pressure	324:21:42:42
	Right MLG tire pressure	324:21:42:42
Main landing gear weight on wheels	Left MLG weight on wheels	324:21:42:46
	Right MLG weight on wheels	324:21:42:46
Nose landing gear contact	NLG1 tire pressure	324:21:42:52
Nose landing gear weight on wheels	NLG weight on wheels	324:21:42:52
Wheels stop	Velocity with respect to runway	324:21:43:41
APU deactivation	APU-1 GG chamber pressure	324:21:57:04.04
	APU-2 GG chamber pressure	324:21:57:04.95
	APU-3 GG chamber pressure	324:21:57:05.43

TABLE II.- STS-38 PROBLEM TRACKING SUMMARY

Number	Title	Reference	Comments
STS-38-01	Water Spray Boiler (WSB) 2 not Cooling While on Controller A	Ascent IM 38RF01	WSB 2A failed to cool APU lubrication oil after end of the pool boiling period during ascent. WSB was switched to B controller and APU 2 was left on after APU 1 and 3 were shut down. Effective lubricatione oil cooling was obtained 1 minute 6 seconds after the switch to B controller. Analysis continuing. Fly as is. Worked nominally during entry. Apparent spray bar freeze-up on ascent. Remove and replace.
STS-38-02	FES Water Supply Accumulator Heater System Biased Low	320:02:00 G.m.t. IM 38RF02 PR ECL 4-08-0462	Heater 1 did not cycle within its prescribed range of 55-75 °F. When temperature reached 49 °F, string 2 was activated. String 2 cycled in 48-54 °F range with normal appearing duty cycles. Suspect temperature sensor (V63T1760A) problem. Temperature sensor found debonded.
STS-38-03	Instrumentation: a) PRSD H2 Tank 3 Quantity Transducer Fail Off-Scale	a) 320:07:05 G.m.t. IPR 37V-0005 IM 38RF03 PR FCP 4-08-0124	a) Transducer went from 97 percent to off-scale during LOS. Crew verified panel meter reading off-scale, too.
	b) APU 3 X-Axis Accelerometer Erratic	b) 324:21:10 G.m.t. IM38RF04 PR APU 4-08-0223	b) Acceleration trace erratic during entry. KSC to check connectors. APU 3 being removed and replaced due to life/time cycle.
	c) MNA MPC1 Amps Transducer Failure	c) 324:21:41 G.m.t. PR EPD 4-08-0864 IM38RF07	c) One minute prior to landing, the MNA MPC1 current dropped to zero (V76C3085A). No change in fuel cell 1 amps detected. OPS STATS did not go to zero. Remove and replace transducer.
STS-38-04	GFE: a) Vacuum Cleaner Short Circuit	a) 321:02:29 G.m.t. FIAR BFCE-213-F005 EPD-4-08-184	a) When crew turned vacuum cleaner on, CB 29 on panel L4 was opened open by a current surge. No further use of utility outlet M013Q for remainder of flight. KSC to perform OMRSD V76AWO.030-B. Outlet test complete and nominal. Vacuum removed and shipped 11/21. Troubleshooting found short of phase B to case in the vacuum cleaner.
	b) Closed Circuit TV Monitor 2 Fault Light On	b) 321:19:52 G.m.t. FIAR BFCE-029-F020 IPR 37V-0001	b) Fault light came on indicating monitor overtemperature or under-voltage. Crew performed malfunction procedure and fault light didn't clear. Monitor 2 powered off for remainder of mission. Failure reproduced at KSC. Remove and replace monitor.
	c) Camera C Failed to Focus	320:03:51 G.m.t. FIAR BFCE 029-FO21	c) During first attempt to use camera C, the crew was unable to focus the camera. Camera C focus capability was regained when CCTV system was power cycled.
	d) Camera D - No Power	320:03:51 G.m.t. FIAR BFCE 029-FO23	d) When crew powered up camera D, there was no indication of power to the camera (i.e., no lights for ALC or gamma). Crew power-cycled the CCTV system and recovered the camera for the remainder of the flight. Postflight, crew commented that a similar problem was seen during preflight testing. Test plan is in work

TABLE II.- STS-38 PROBLEM TRACKING SUMMARY

Number	Title	Reference	Comments
STS-38-05	APU Instrumentation Interaction	321:23:48 G.m.t. EGT's IPR 37V-0008 IM38RF05	APU 2 exhaust gas temperature sensors (EGT's) 1 & 2 (V46T0242A and V46T0240A) and APU 2 and 3 injector tube temperatures (V46T0274A and V46T0374A) became erratic during launch. Analysis shows momentary shorting-to-ground of EGT's drove tube temperatures erratic. No problem with injector measurement, only EGT's.
STS-38-06	Right Vent Door 1 and 2 Purge Position Failure	324:22:06 G.m.t. PR MEQ 4-08-0319 IM38RF06	During postlanding vent door purge positioning operation, the right vent door 1 and 2 drove to the closed position instead of the purge position. KSC troubleshooting reproduced problem. Failure isolated to purge position limit switch. Remove and replace actuator.
STS-38-07	Thruster R1U Low Chamber Pressure. Thrusters R3D, R4U and F3L Transient Low Chamber Pressure	324:19:57 G.m.t. IM38RF08	R1U showed a degraded chamber pressure by approximately 20 psi. R1U will be investigated and the results will drive the testing required for the other three thrusters. Visual inspection showed no anomalies. Chamber decay test of R1U showed no leak. Will borescope and perform three point calibration on the transducer. Pod RP03 now on OV-103, and testing will be done on that vehicle.
STS-38-08	Continuous "Tire Press" FDA Messages Post-landing	324:21:50 G.m.t.	Message annunciated continuously, should annunciate once. KSC inspection of tire pressure connectors show no problem.
STS-38-09	Smoke Detector Transient Event Indications	Mission Duration PR ECL 4-08-0460	Several smoke detectors had event indicators go high, but not high enough to trigger alarm. No corresponding increase in smoke concentrations noted. Remove smoke detector from cabin heat exchanger for analysis. Similar problem seen on STS-32.

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