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STS-36 SPACE SHUTTLE MISSION REPORT

April 1990

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ABS: The STS-36 Space Shuttle Program Mission Report contains a summary of the vehicle subsystem activities on this thirty-fourth flight of the Space Shuttle and the sixth flight of the OV-104 Orbiter vehicle, Atlantis. In addition to the Atlantis vehicle, the flight vehicle consisted of an External Tank (ET) (designated as ET-33/LWT-26), three Space Shuttle main engines (SSME's) (serial numbers 2019, 2030, and 2029), and two Solid Rocket Boosters (SRB's) (designated as BI-036). The STS-36 mission was a classified Department of Defense mission, and as such, the classified portions of the mission are not discussed. The unclassified sequence of events for this mission is shown in tabular form. Summarized are the

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significant problems that occurred in the Orbiter subsystems during the mission. The official problem tracking list is presented. In addition, each of the Orbiter problems is cited in the subsystem discussion.

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STS-36

SPACE SHUTTLE

MISSION REPORT

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INTRODUCTION

The STS-36 Space Shuttle Program Mission Report contains a summary of the vehicle subsystem activities on this thirty-fourth flight of the Space Shuttle and the sixth flight of the OV-104 Orbiter vehicle (Atlantis). In addition to the Atlantis vehicle, the flight vehicle consisted of an External Tank (ET) (designated as ET-33/LWT-26), three Space Shuttle main engines (SSME's) (serial numbers 2019, 2030, and 2029), and two Solid Rocket Boosters (SRB's) (designated as BI-036).

The STS-36 mission was a classified Department of Defense mission, and as such, the classified portions of the mission are not discussed in this report. The unclassified 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 of the Orbiter problems is cited in the subsystem discussion portion of the report.

The crew for this thirty-fourth flight of the Space Shuttle was John O. Creighton, Capt., U. S. Navy, Commander; John H. Casper, Col. U. S. Air Force, Pilot; David C. Hilmers, Lt. Col., U. S. Marine Corps, Mission Specialist 1; Richard M. Mullane, Col., U. S. Air Force, Mission Specialist 2; and Pierre J. Thuot, Lt. Cdr., U. S. Navy, Mission Specialist 3. This was the second flight for the Commander, the third flight for Mission Specialists 1 and 3, and the first flight for the remaining two crew members.

MISSION SUMMARY

The STS-36 launch encountered four 24-hour launch delays and one 48-hour delay. The launch was scheduled for February 22, 1990, but the Commander's physical condition was not acceptable for flight, and the launch was delayed until February 23, 1990. The second 24-hour delay was required because the crew member was still not well, and also the weather was predicted to be unacceptable for launch. A third 24-hour delay was required because of predicted unacceptable weather for launch.

The fourth 24-hour delay (until February 26, 1990) resulted from a range safety backup computer failure that was announced at T-1 minute 55 seconds during the terminal countdown. The countdown was held at T-31 seconds and during the hold, the prolonged liquid oxygen drainback resulted in the lower liquid oxygen inlet temperature limits on the three main engines being exceeded (Launch Commit Criteria limit). At that time, the launch was delayed for 24 hours. Also, during the period while the auxiliary power units (APU'S) were operating, three instrumentation anomalies occurred, none of which affected the mission. The anomalies were the failure of exhaust gas temperature sensor 1 on APU 1; erratic operation of APU 1 injector temperature sensor; and a bias on the gas generator valve module temperature on APU 1. In addition, general purpose computer (GPC)

4 experienced a "failure to synchronize". The cause of the GPC problem was a non-universal input/output error when both pulse code modulation master units (PCMMU's) were inadvertently powered on during the transition from onboard control of the PCMMU back to launch processing system (LPS) control. The GPC's were reinitialized and operated properly throughout the mission. Based on this condition, the "failure to synchronize" is an expected occurrence and is not an indication of a GPC problem.

A fifth delay resulted from the launch attempt on February 26, 1990, which was scrubbed because of unacceptable weather conditions at the Return to Launch Site (RTLS) landing site. The delay was lengthened to 48 hours to provide the launch crew with the required rest. The countdown proceeded nominally until the T-9 minute hold, which was extended because of the cloud conditions at the Shuttle Landing Facility that did not improve.

During the sixth launch attempt on February 28, 1990, the countdown proceeded nominally until the T-9 minute hold, which was lengthened because of the predicted rain storms in the launch and RTLS landing areas. After a 1-hour 57-minute hold, the countdown was resumed to the T-5 minute point. After a 2-minute hold at T-5 minutes, the weather was declared acceptable for launch and the vehicle was launched from launch pad 39A at 059:07:50:22.000 G.m.t. The launch phase was satisfactory in all respects with main engine cutoff occurring at 8 minutes 30 seconds after lift-off. A quick-look determination of vehicle performance using propulsion prediction and acceleration data showed a nominal average flight-derived main engine specific impulse (Isp) of 453.2 seconds.

Prior to Solid Rocket Booster (SRB) ignition, the right reaction control subsystem (RCS) manifold 1 isolation valve open position indication changed to closed which caused the deselection of the manifold 1 thrusters. The crew later reselected these thrusters and they operated properly. In addition, the left RCS 3/4/5 B tank isolation valves momentarily lost the open indication and the left RCS 1/2 oxidizer crossfeed valves also momentarily lost the closed indication. These problems did not affect mission operations.

The RCS thruster R3D failed off at ET separation. The chamber pressure did not reach the required level within the required time period. The redundancy management (RM) deselected the thruster. The thruster remained powered off for the remainder of the mission.

During ascent, the hydraulic system 1 reservoir quantity remained constant when it should have increased because of the thermal effects. In addition, the reservoir pressure fluctuated and was not tracking the other two systems.

At 59:11:15 G.m.t., the water spray boiler 2 vent system A heater failed off, and the system B heater was used during the flight control system (FCS) checkout.

The crew reported that the volume H door and door latch were binding and the door could not be easily opened. The crew used a screwdriver from the in-flight maintenance (IFM) kit to "jimmy" the latch and pry open the door.

At 61:07:07:22 G.m.t., cathode ray tube (CRT) 4 went blank. The crew performed power cycles and recovered the CRT. However, after about 2 hours, the CRT again went blank and power cycles were only able to temporarily recover the CRT. Consequently, the CRT was powered off for the remainder of the mission. Three CRT's were still available for crew use.

Upon acquisition of signal (AOS) at 61:17:45 G.m.t., the crew reported free water below the middeck floor as a result of water carry-over from humidity separator A. The crew had switched to humidity separator A about 7 hours earlier. The crew used the redesigned vacuum cleaner wand and cleaned up the water. The crew switched back to humidity separator B, and further inspections revealed no water coming from the air outlet on humidity separator B, which was used for the remainder of the mission.

After a normal supply water dump, tank A started emptying into tank B before tank A was full, and the tank A inlet valve was closed to stop the flow. Flight data indicate that the valve resealed and there was no apparent leakage for the remainder of the mission. The check valve between supply tanks A and B had a leak above specification that was waived before flight.

The flight control system (FCS) checkout was successfully completed at 62:12:29:03 G.m.t., using APU 2. The APU accumulated 6 minutes and 38.33 seconds of run-time and used 16 lb of fuel.

During the RCS hot-fire test, thruster R4R did not fire. Loss of this thruster had no impact on the mission.

After completion of all final entry preparations including stowage and payload bay door closure, the orbital maneuvering subsystem (OMS) deorbit maneuver was performed at 63:17:11:17.24 G.m.t., with a firing duration of 125.48 seconds and a differential velocity of 256.4 ft/sec. Entry interface occurred at 63:17:37:39.56 G.m.t. The Tracking and Data Relay Satellite (TDRS) West provided data throughout the normal entry blackout period.

Entry data showed the hydraulic fluid quantity in reservoir 1 was decreasing. Some decrease had also been noted during ascent while the APU was running, but the quantity remained stable throughout the on-orbit phase of the mission. As a result of the decreasing quantity, the hydraulic main pump was switched to low-pressure operation to minimize that loss. The pump outlet pressure should have dropped to 800 psia, but instead went from 3000 to 2100 psia and then ramped up to 2500 psia for almost 6 minutes before dropping to 600 psia where it remained. At terminal area energy management (TAEM), the pump was taken back to normal pressure operation for approach and landing. As a result of the loss of hydraulic fluid during entry, APU 1 was shut down at 63:18:10:06 G.m.t., shortly after wheels stop.

Main landing gear touchdown occurred at 63:18:08:44 G.m.t., on lakebed runway 23 at Edwards Air Force Base, CA. Nose landing gear touchdown followed 10 seconds later with wheels stop at 63:18:09:37.32 G.m.t. The rollout was normal in all respects and because of the high head winds and the light weight of the Orbiter, the rollout was much shorter than expected. APU's 2 and 3 were shut down at 63:18:23:57.56 and 63:18:23:58.37 G.m.t., respectively, and the crew completed their required postflight reconfigurations and egressed at 63:18:59 G.m.t.

Four development test objectives (DTO's) and six detailed supplementary objectives (DSO's) were assigned to the STS-36 mission. Data were collected for the two ascent-phase DTO's, but neither of the landing-phase DTO's were performed. Data were collected on all six DSO's.

SOLID ROCKET BOOSTERS

All Solid Rocket Booster (SRB) systems performed as expected. The SRB prelaunch countdown was normal, and nine SRB and solid rocket motor (SRM) in-flight anomalies were identified. No SRB or SRM Launch Commit Criteria (LCC) or Operations and Maintenance Requirements and Specification Document (OMRSD) violations occurred. Power up of all igniter, joint and case heaters was accomplished routinely. All SRM temperatures were maintained within acceptable limits throughout the countdown. Ground purges maintained the nozzle bearing and flexible boot temperatures within the required LCC ranges; however, the purge temperature/pressure was again regulated, as on the two launch attempts, to preclude exceeding the fuel supply module (FSM) pressure LCC limit.

The flight performance of both SRM's was well within the allowable performance envelopes. SRM propulsion performance was well within the required specification limits, and the propellant burn rate for each SRM was normal. SRM thrust differentials during the buildup, steady state, and tailoff phases were well within specifications. All SRB thrust vector control (TVC) prelaunch conditions and flight performance requirements were met with ample margins. All electrical functions were performed properly. There were no LCC or OMRSD violations during the launch countdown.

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 entirely 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. SRM nozzle jettison occurred after frustum separation, and the subsequent parachute deployments were successfully performed. Two parachute problems occurred during deployment, and these are discussed in the following paragraph. All drogue and main parachutes were successfully recovered.

Nine in-flight anomalies were documented as a result of the observed damage to the SRB's and SRM's. The anomalies were:

a. The right SRM igniter/forward dome boss interface had a small area of surface metal that was pitted and the cadmium plating on the gask-o-seal was also damaged.

b. A material separation was observed on the inner diameter of the igniter adapter plug secondary O-ring on the left SRM.

c. A frustum separation pin from the ordnance ring was found embedded in the forward face of the ET attachment (ETA) ring foam.

d. A nut was missing from the left SRB frustum main parachute support structure.

e. A safety wire was missing from the "B" nut on the gaseous nitrogen purge tube assembly in the right SRB aft skirt.

f. The left SRB drogue parachute redundant first stage (7-second) reefing line cutter did not fire.

g. Several cable tie-wraps were disengaged from the electrical cable assemblies on the left and right SRB ETA rings.

h. An area of missing cork was noted on the aft side of the right SRB ETA ring.

i. Sixteen small debonded areas were noted on the MSFC trowellable ablator (MTA-2) on the right SRB frustum ramps.

EXTERNAL TANK

All objectives and requirements associated with ET propellant loading and flight operations were met. The 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. No LCC and OMRSD violations were identified.

The Ice/Frost Team reported that there was no frost or ice on the acreage areas of the ET, and that there were no anomalous thermal protection system conditions. Normal quantities of ice or frost were present on the liquid oxygen and liquid hydrogen feedlines and on the pressurization line brackets. Frost was also present along the edges of the liquid hydrogen protuberance air load ramps. All of these observations were acceptable in accordance with official documentation.

The ET pressurization system functioned properly throughout engine start and flight. The minimum liquid oxygen ullage pressure experienced during the period of ullage pressure slump was 15.1 psid, which is the lowest pressure observed on any flight.

The ET tumble system was activated for this flight. ET separation was confirmed, and the ET entry and breakup were in the predicted footprint.

SPACE SHUTTLE MAIN ENGINES

All Space Shuttle main engine (SSME) parameters appeared normal throughout the prelaunch countdown, comparing very well with prelaunch parameters observed on previous flights. Engine "ready" was achieved at the proper time, all LCC were met, and engine start and thrust buildup were normal.

Preliminary flight data indicate that SSME performance during engine start, mainstage, throttling, shutdown and propellant dumping operations was normal. High pressure oxidizer turbopump and high pressure fuel turbopump temperatures were well within specification limits throughout engine operation. The SSME controllers provided the proper control of the engines throughout powered flight. 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 failures were identified, and no significant SSME problems have been 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 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.

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

Postflight analysis of the SRSS data indicates that the performance of the onboard system for both SRB's and the ET was normal. The system signal strength remained above the specified minimum (-97 dBm) for the duration of the flight, except for the right SRB B system which dropped to -100 dBm approximately 100 seconds into the flight. However, the system remained functional.

ORBITER PERFORMANCE

MAIN PROPULSION SYSTEM

The overall performance of the main propulsion system (MPS) was excellent. During prelaunch operations at 55:18:45 G.m.t., the ET liquid oxygen ullage pressure sensor displayed erratic behavior and stabilized 15 minutes later. No further problem was noted during subsequent operations. Postflight data analysis explained this condition as acceptable operation.

During liquid hydrogen loading for the first launch attempt, the MPS 17-inch disconnect "B" open indication dropped out for 11 seconds during fast fill (Flight Problem STS-36-02). The dropout caused the ground software to initiate a liquid hydrogen stop flow. Investigation did not reveal any cause for the anomaly and the fast fill operation was resumed. The indication was normal for all subsequent loading operations.

The launch delay that occurred at T-31 seconds because a range safety computer could not be brought on line resulted in a launch scrub when the minimum liquid oxygen engine inlet temperature of -289.2 °F was exceeded and caused an LCC violation. The minimum temperature has been established to produce engine start-up conditions that are within specified limits (start-box). Prior to liquid oxygen drainback, unconditioned (warmer) liquid oxygen from the ground supply flows through the SSME's and yields slightly higher engine inlet temperatures. After liquid oxygen drainback is initiated at T-4:45, the engine inlet temperatures decreases as a result of the colder, conditioned liquid oxygen from the ET flowing through the SSME/Orbiter bleed system and overboard. The available bleed time at T-31 seconds is vehicle dependent, and the violation of the LCC was caused by the extended liquid oxygen drainback during the hold at T-31 seconds. System behavior was nominal in this extended-hold condition.

All pretanking purges were properly performed, and loading of liquid oxygen and liquid hydrogen was completed during the launch countdown with no stop flows or reverts. During liquid oxygen loading, the A127 liquid oxygen pump tachometer reading was erratic. There was no problem with the pump itself, and loading continued with A127 using the pump discharge pressure to monitor pump performance.

The MPS helium system also performed satisfactorily. No LCC or OMRSD violations were identified during launch operations on February 28, 1990. Throughout the preflight operations, no significant hazardous gas concentrations were detected. The maximum hydrogen level in the aft compartment was 131 ppm, which compares well with previous vehicle data.

A comparison of the calculated propellant loads at the end of replenish versus the inventory load results in a loading accuracy of -0.095 percent and -0.023 percent for liquid hydrogen and oxygen, respectively.

Ascent MPS performance appeared to be normal. Preliminary data indicate that the liquid oxygen and hydrogen pressurizations systems performed as planned, and that all net positive suction pressure requirements were met throughout the flight. The data show that the gaseous oxygen flow control valves were fully open during the period of the maximum ET pressure slump, which reached a level of 15.1 psia, the lowest observed on any flight.

Ullage pressures were maintained within the required limits throughout the flight. Feed system performance was normal, and the liquid oxygen and liquid hydrogen propellant conditions were within specified limits during all phases of operation. Propellant dump and vacuum inerting were accomplished satisfactorily. One MPS-related instrumentation failure occurred during the launch operations. The facility liquid oxygen bypass temperature measurement failed low during the second loading (February 25, 1990) and remained failed during the third loading (February 27, 1990).

Evaluation of prelaunch, main engine cutoff (MECO), and post-MECO valve actuations were performed. Out-of-specification valve response times (< 2.9 seconds) were noted for the liquid oxygen inboard and liquid hydrogen outboard fill and drain valves (PV10 and PV11) at the initiation of the vacuum inerting operation. The quick valve response times (2.87 and 2.51 seconds) are a result of the deletion of the manual anti-slam procedure. The valves are certified under slam-operation conditions. These quicker responses have been experienced in the past at vacuum inert initiation.

REACTION CONTROL SUBSYSTEM

The reaction control subsystem (RCS) supported the mission satisfactorily, but five anomalies were noted. A total of 3929.9 lb of propellant was used during the mission with no forward dump of the RCS being performed as planned.

The instrumentation indicated a number of RCS problems between 3 seconds prior to SRB ignition and 45 seconds after lift-off. At 3 seconds prior to SRB ignition, the right RCS manifold 1 isolation valve lost the open indication and the redundancy management (RM) deselected all manifold 1 thrusters (Flight Problem STS-36-6a). The valve switch was cycled after SRB separation and the proper valve indications were obtained and the thrusters were reselected. At 8 seconds after lift-off, the left RCS 3/4/5B oxidizer tank isolation valve lost its open indication (Flight Problem STS-36-6b). Two seconds later, the open indication was regained with no crew action. At 45 seconds after lift-off, the left RCS 1/2 oxidizer crossfeed isolation valve lost its closed indication (Flight Problem STS-36-6c). The proper indication was regained after the crew cycled the valve switch from GPC to open.

At ET separation, thruster R3D failed off (Flight Problem STS-36-04). The indicated chamber pressure reached only 12 psia. During the RCS hot fire test following the FCS checkout, thruster R4R failed (Flight Problem STS-36-12). The failure was similar to the R3D failure in that chamber pressure reached only 9 psia. The loss of these two thrusters did not impact mission operations.

ORBITAL MANEUVERING SUBSYSTEM

The orbital maneuvering subsystem (OMS) performance was within specification limits throughout the mission with five maneuvers being performed. Three of the maneuvers (OMS-2, OMS-3 and deorbit) were dual engine firings, and the remaining two maneuvers (OMS-4 and OMS-5) were single engine firings. A total of 7054 lb of oxidizer and 4195 lb of fuel were used during the maneuvers.

During prelaunch operations, the right-hand helium isolation valve leak rate was extremely high (9000 scch versus 360 scch maximum), and the condition were waived prior to flight. The leak was not detectable on-orbit as the regulators prevented any noticeable increase in propellant tank ullage pressure. Also, the liquid hydrogen gaseous nitrogen isolation valve leakage was high (24 scch versus 15 scch maximum), but this leak was not noticeable on-orbit either as the regulator prevented gaseous nitrogen depletion.

Two gauge problems that had been detected on previous flights and waived for this flight were also apparent. The left-hand fuel total quantity gauge indicated slightly high during all maneuvers and was off-scale high at the beginning of the deorbit maneuver, but read 81.4 percent (should have been 27 percent) by the end of the maneuver. A high bias on this gauge was also noted during propellant loading. The right-hand total quantity gauge also read erroneously (about 18 percent high) at the beginning of the mission, but at the beginning of the OMS-2 maneuver, the gauge began reading properly and continued to do so for the remainder of the mission.

POWER REACTANT STORAGE AND DISTRIBUTION SUBSYSTEM

The power reactant storage and distribution (PRSD) subsystem performed nominally throughout the mission with no identified anomalies. A total of 1076.9 lb of oxygen and 128.1 lb of hydrogen were used during the mission by the fuel cells and crew (60.2 lb of oxygen). A 70-hour mission extension at the average power level was possible with the reactants remaining at touchdown as the Orbiter landed with 853.7 lb of oxygen and 119.0 lb of hydrogen remaining.

FUEL CELL POWERPLANT SUBSYSTEM

Performance of the fuel cell powerplant subsystem was nominal for the 106-hour STS-36 mission during which 1467 kWh of electrical energy and 1144.8 lb of potable water were produced. A total of 1016.7 lb of oxygen and 128.1 lb of hydrogen was used, and the average Orbiter electrical power level was 13.6 kW.

Fuel cell 2 hydrogen pump motor current read high [4.28 A versus 0.75 A (Launch Commit Criteria maximum)] when the pumps were powered during the start sequence for fuel cell 2. Review of pump characteristic performance indicated that the pump was operating on two phases (no phase B), and data verified changes in phase A and C current only at fuel cell start. Visual inspection of the circuit breakers indicated that all three fuel cell 2 pump breakers appeared closed; however, the motor current returned to normal (0.62 W) when the AC2-FC2-Phase B circuit breaker was reset. No recurrence of this problem was noted during the mission.

At 54:22:44 G.m.t., during prelaunch operations, phase A of inverter 2 exhibited voltage fluctuations from 112 to 122.8 Vac (110 to 120 Vac is the Shuttle Operational Data Book limit) during a 2-minute period and was declared failed (Flight Problem STS-36-01). The decision was made to remove and replace the inverter which is located in avionics bay 2, and fuel cell 2 was stopped at 055:07:06 G.m.t., for inverter replacement. No performance loss was noted as a result of the stop/start cycle on the fuel cell.

AUXILIARY POWER UNIT SUBSYSTEM

The APU performance was nominal during all phases of the mission, although a number of minor anomalies were noted. The following table shows the run time and fuel consumption of each APU during the launch scrub and 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
Launch scrub	10:45	30	10:45	30	10:45	30
Ascent	18:42	51	18:42	48	18:42	48
FCS checkout	-	--	06:39	16	-	--
Entry	45:19	72	59:10	136	77:26	155
Total	74:46	153	95:16	230	106:53	233

APU 1 was shut down shortly after wheels stop because of a hydraulic leak (Flight Problem STS-36-08) that is discussed in the next section of the report. APU 2 and 3 were operated in the "inhibit" mode during entry to prevent any automatic shutdown of these APU's before landing.

During the launch scrub on February 26, 1990, the APU 1 exhaust gas temperature (EGT) 1 sensor failed (Flight Problem STS-36-03a). Also during the launch scrub, the APU 1 injector tube temperature reading became erratic, going off-scale high on several occasions (Flight Problem STS-36-03b). This condition continued during launch and entry. The APU 1 gas generator valve module (GGVM) temperature 1 sensor was biased high by 20 to 30 °F (Flight Problem STS-36-03c). The APU 3 EGT 2 sensor failed after landing (Flight Problem STS-36-03e). None of these failures impacted the successful completion of the mission.

HYDRAULICS/WATER SPRAY BOILER SUBSYSTEM

The hydraulics subsystem met all mission requirements; however, a significant failure occurred in system 1. Data show that reservoir quantity dropped between 5 and 10 percent while APU 1 was operating during ascent (Flight Problem STS-36-08). As a result, APU 1 was started at entry interface (EI) minus 13 minutes and reservoir quantity continued to decrease throughout entry. At entry interface, hydraulic system 1 was switched to low; however, the pump output did not immediately drop to the expected 800 psia (Flight Problem STS-36-17), but rather went from 3000 psia to 2100 psia and then ramped to 2500 psia for almost 6 minutes before dropping to 600 psia where it remained. The fluid level reached 40 percent by landing gear deployment, and APU 1 was shut down shortly after wheels stop. The postflight inspection at Dryden Flight Research Facility (DFRF) revealed free hydraulic fluid throughout the aft compartment, and a ruptured hydraulic line. Data analysis following the flight showed that the hydraulic fluid reservoir pressure did not drop as expected during ascent and entry (Flight Problem STS-36-20).

The water spray boiler operation was nominal throughout the mission with the exception of the vent heater 2A, which failed after two cycles following ascent (Flight Problem STS-36-07). Water spray boiler control was switched to the B controller, and this controller was used for the remainder of the mission.

PYROTECHNICS SUBSYSTEM

The pyrotechnics subsystem operated satisfactorily. One of the pyrotechnic retention yokes on the liquid hydrogen umbilical side was loose in the umbilical cavity, and it fell to the runway when the door was opened.

ENVIRONMENTAL CONTROL AND LIFE SUPPORT SUBSYSTEM

The environmental control and life support subsystem (ECLSS) supported the mission satisfactorily with three anomalies, none of which impacted the successful completion of the mission. The crew reported that approximately 2 to 3 cups of free water was present in the ECLSS bay while humidity separator A was operating (Flight Problem STS-36-11). Humidity separator A had been activated about 7 hours earlier. The free fluid disposal procedure was used to clean up the water. The crew switched back to humidity separator B and it performed nominally for the remainder of the mission.

The flash evaporator, radiator, and ammonia boiler heat rejection systems were nominal except for one nuisance flash evaporator shut down when a water dump was initiated (Flight Problem STS-36-14). The flash evaporator restarted after the controller was recycled on. This condition has occurred on a previous mission under the same conditions and the present analysis indicates that this is normal operation.

SMOKE DETECTION AND FIRE SUPPRESSION

All smoke detection and fire suppression hardware operated nominally.

AVIONICS SUBSYSTEMS

The avionics subsystems performed in an acceptable manner; however a number of problems were noted. The following paragraphs discuss these problems.

At 61:07:07 G.m.t., cathode ray tube (CRT) 4 went blank. Power cycles provided only temporary recovery (Flight Problem STS-36-09). Data initially indicated a power supply bit was set in the BITE status register. The failure was subsequently isolated to the deflection amplifier page. The CRT was powered down for the remainder of the flight with no significant impact.

During the recycle following the launch scrub when transferring onboard control of the software to the launch processing system (LPS), general purpose computer (GPC) 4 had a "failure to synchronize". This condition was caused by a non-universal input/output error when both pulse code modulation master units (PCMMU's) were inadvertently powered on at the same time. PCMMU 2 was powered on by a cockpit switch and PCMMU 1 by a launch data bus command from the LPS. Evaluation showed that no hardware or software problems existed.

During the prelaunch processing at 054:22:44:11 G.m.t., a voltage spike occurred on AC2 phase A inverter (Flight Problem STS-36-01). For about the next 2 minutes, random plus and minus voltage and current spikes continued. These inverter output excursions were directly correlated to the associated increased current spikes on the forward PCA2 main bus B current, and this is indicative of a pending inverter failure. As a result, a decision was made to remove and replace the inverter prior to flight.

The crew noted that during the payload bay closure preparation activities prior to entry, the mid and aft port payload bay floodlights had failed off, and the aft starboard payload bay floodlight was flickering (Flight Problem STS-36-15).

After landing, the right data display unit (DDU) had a bite indication that was intermittently indicated good and bad (Flight Problem STS-36-19).

Five operational instrumentation (OI) failures were noted during the mission. These failures are discussed in the respective subsystem that the particular instrumentation sensor supports.

AERODYNAMICS

The Orbiter vehicle aerodynamic responses were nominal during all phases of the flight with no problems being noted. The control surface responses were normal as was the angle of attack.

MECHANICAL SUBSYSTEMS

Performance of all remotely actuated devices (payload bay doors, vent doors, ET doors, star tracker doors, air data probes, and Ku-band antenna) was nominal.

Performance of the landing/deceleration subsystem was nominal. Landing gear deployment required 4.6 to 5.0 seconds, well within the 10-second maximum limit. Main gear touchdown occurred at a ground speed of 187.8 knots with a sink rate of approximately 1.0 ft/sec on lakebed runway 23 at Edwards Air Force Base. There was a headwind component of 15.4 knots and a crosswind component of 4.3 knots at the time of landing.

Nose gear touchdown was at 143 knots ground speed with a pitch rate of 3.8 deg/sec. Braking was initiated at 97 knots, and brake pressures did not exceed 680 psig (1500 psig maximum) during the braking phase. The deceleration ranged between 4.5 and 6 ft/sec/sec during braking, and the brake energies ranged between 6.41 and 8.43 million foot pounds. The low brake initiation velocity, high headwind, and high rolling coefficient of friction on the lakebed contributed to the low brake energy requirement. The rollout was 7900 ft, which was shorter than usual because of the high headwinds at landing and the light weight of the Orbiter vehicle (187,200.2 lb), as well as landing on the lakebed runway.

The postlanding inspection revealed no brake or tire damage. The tire pressures were consistent and nominal, indicating low leak rates.

STRUCTURE SUBSYSTEM

The crew reported that the volume H stowage door could not be opened nominally while on orbit (Flight Problem STS-36-05a). The door was opened using a screwdriver in accordance with the in-flight maintenance (IFM) procedure.

Also, when the crew attempted to gain access to the humidity separator A in accordance with IFM procedures, the lithium hydroxide (LiOH) stowage container could not be removed (Flight Problem STS-36-05b). The crew removed fasteners from three of the four brackets, but the screw in the fourth bracket was stuck and could not be removed. An alternate access panel (MD54G) was removed and the IFM was performed successfully.

THERMAL CONTROL SUBSYSTEM AND AEROTHERMODYNAMICS

The thermal control subsystem maintained temperatures within acceptable limits throughout the mission. When the water spray boiler 2 vent system A heater was enabled about 2 hours into the mission, heater A cycled twice and then failed off (Flight Problem STS-36-07). The system B heater was used for the FCS checkout and entry, and the heater operated properly.

The aerothermodynamic performance was satisfactory. The average heating over the Orbiter lower surface was lower than expected, based on the heavier entry weight of the vehicle; however, the heating was within nominal limits. A possible explanation for this lower average heating level is an apparent lower density atmosphere during entry. Inspection of the Orbiter showed that no significant surface overheating occurred. Analysis of the modular auxiliary data system (MADS) data continues.

THERMAL PROTECTION SUBSYSTEM

The thermal protection subsystem performance was nominal, based on structural temperature response data and some tile surface temperature measurements. The overall boundary layer transition from laminar to turbulent flow was nominal and occurred at 1240 seconds after entry interface.

A detailed postlanding inspection revealed that the Orbiter sustained a total of 81 hits, of which 19 had a major dimension of 1 inch or greater. A total of 61 of the hits were on the lower surface, of which 17 had a major dimension of 1 inch or greater. A comparison of these numbers to statistics from 20 previous missions of similar configuration indicates the total number of hits on the lower surface was lower than average. However, based on the number of hits that have a major dimension of 1 inch or greater, this flight was considered average. The majority of the damage sites larger than 1 inch were aft of the main landing gear. More damage sites occurred on the right side than on the left. Four of the 17 hits larger than 1 inch were 3/4-inch to 1-inch deep; however, no tiles will be replaced because of debris.

Damage to the base heat shield tiles was less than average. Overall, all reinforced carbon carbon (RCC) parts looked good. The nose landing gear door thermal barrier on the centerline forward section was frayed. Three loose Nicalon sleeves were also found. The forward RCS thermal barrier was breached on the left-hand side end cap. The ET door thermal barriers appeared to be in excellent shape. The SSME 1 closeout blanket had minor fraying of the splice area at 6 o'clock. The SSME 2 blanket splice was loose at 12 o'clock. On SSME 3, the top layer of the blanket was loose from 3:30 to 4:30 o'clock, frayed at 6 o'clock, and missing from 6:30 to 10 o'clock.

Several small pieces of gap filler sleeving material were loose on both OMS pods at the leading edges. No detectable damage to adjacent tiles resulted from losing these gap fillers. The elevon-elevon gap appeared better than normal with one frayed gap filler on the left-hand side.

Window 3 was heavily hazed with deposits and many streaks. Window 4 was moderately hazed with several streaks. Window 5 was lightly hazed with several streaks. Window 2 was lightly hazed. A laboratory analysis will be made of samples taken from all of the windows.

FLIGHT CREW AND GOVERNMENT FURNISHED EQUIPMENT

All flight crew and government furnished equipment performed satisfactorily, except for two minor anomalies that are discussed in the following paragraphs.

The crew reported that there was evidence of a leak in either the oxygen bleed orifice assembly or the quick disconnect in which it was installed (Flight Problem STS-36-10). The orifice assembly was removed from the quick disconnect, the fittings were tightened and reinstalled, and no further indications of leakage were detected.

The crew reported at 60:03:30 G.m.t., that the fourth page received by the text and graphics system (TAGS) was folded up prior to the silver tray clip (Flight Problem STS-36-18). As a result, the uplinks were limited to 10 pages.

Postflight review of photographs taken with one of the 250mm lens on the Hasselblad camera revealed that the photographs were improperly focused because the infinity setting on the lens was not infinity. Initial analysis revealed that the lenses were calibrated only at the 30-foot position. This lens has been returned to the manufacturer for repair and refurbishment.

PHOTOGRAPHIC AND TELEVISION DATA ANALYSIS

Video data of ascent were received from 21 locations and photographic data were received from 66 cameras. No abnormal conditions were noted in any of the data. Video data of descent and landing were received from six cameras. In addition, 12 documentary 16mm films, one infrared video, and three 35mm engineering films were evaluated. No abnormal conditions were observed, but thermal distortion and mirage from the lakebed hampered the film analysis.

TABLE I.- STS-32 SEQUENCE OF EVENTS

Event	Description	Actual time, G.m.t.
APU activation	APU-1 GG chamber pressure	59:07:45:32.56
	APU-2 GG chamber pressure	59:07:45:33.22
	APU-3 GG chamber pressure	59:07:45:33.95
SRB HPU activation	LH HPU system A start command	59:07:49:54.19
	LH HPU system B start command	59:07:49:54.34
	RH HPU system A start command	59:07:49:54.55
	RH HPU system B start command	59:07:49:54.71
Main propulsion System start	Engine 3 start command to EIU	59:07:50:15.450
	Engine 2 start command to EIU	59:07:50:15.593
	Engine 1 start command to EIU	59:07:50:15.686
SRB ignition command (lift-off)	SRB ignition command to SRB	59:07:50.22.000
Throttle up to 104 percent thrust	Engine 3 command accepted	59:07:50:26:010
	Engine 2 command accepted	59:07:50:26.033
	Engine 1 command accepted	59:07:50:26.006
Throttle down to 98 percent thrust	Engine 3 command accepted	59:07:50:43.131
	Engine 2 command accepted	59:07:50:43.154
	Engine 1 command accepted	59:07:50:43.126
Throttle down to 75 percent thrust	Engine 3 command accepted	59:07:50:50.811
	Engine 2 command accepted	59:07:50:50.834
	Engine 1 command accepted	59:07:50:50.807
Maximum dynamic pressure (q)	Derived ascent dynamic pressure	59:07:51:25
Throttle up to 104 percent thrust	Engine 3 command accepted	59:07:51:15.131
	Engine 2 command accepted	59:07:51:15.155
	Engine 1 command accepted	59:07:51:15.127
Both SRM's chamber pressure at 50 psi	LH SRM chamber pressure mid-range select	59:07:52:22.36
	RH SRM chamber pressure mid-range select	59:07:52:22.56
End SRM action	LH SRM chamber pressure mid-range select	59:07:52:24.390
	RH SRM chamber pressure mid-range select	59:07:52:24:643
SRB separation command	SRB separation command flag	59:07:52:25.50
SRB physical separation	SRB physical separation	
	LH APU A turbine speed LOS*	59:07:52:27.80
	LH APU B turbine speed LOS*	59:07:52:27.76
	RH APU A turbine speed LOS*	59:07:52:27.84
	RH APU B turbine speed LOS*	59:07:52:27.80
Throttle down for 3g acceleration	Engine 3 command accepted	59:07:57:46.822
	Engine 2 command accepted	59:07:57:46.807
	Engine 1 command accepted	59:07:57:46.819
3g acceleration	Total load factor	59:07:57:47
MECO	MECO command flag	59:07:58:52
	MECO confirm flag	59:07:58:53
ET separation	ET separation command flag	59:07:59:10

* = loss of signal

TABLE I.- CONTINUED

Event	Description	Actual time, G.m.t.
OMS-1 ignition	Left engine bi-prop valve position	None required/ Direct insertion
APU deactivation	APU-1 GG chamber pressure	59:08:04:14.68
	APU-2 GG chamber pressure	59:08:04:15.65
	APU-3 GG chamber pressure	59:08:04:16.39
OMS-2 ignition	Left engine bi-prop valve position	59:08:22:20.1
	Right engine bi-prop valve position	59:08:22:20.1
OMS-2 cutoff	Left engine bi-prop valve position	59:08:24:05.5
	Right engine bi-prop valve position	59:08:24:05.5
Flight control system checkout		
APU start	APU-2 GG chamber pressure	62:12:22:24.61
APU stop	APU-2 GG chamber pressure	62:12 29:03.34
APU activation for entry	APU-3 GG chamber pressure	63:17:06:31.85
	APU-2 GG chamber pressure	63:17:24:46.69
	APU-1 GG chamber pressure	63:17:24:47.87
Deorbit maneuver ignition	Left engine bi-prop valve position	63:17:11:17.24
	Right engine bi-prop valve position	63:17:11:17.33
Deorbit maneuver cutoff	Left engine bi-prop valve position	63:17:13:23.44
	Right engine bi-prop valve position	63:17:13:23.12
Entry interface (400k)	Current orbital altitude above reference ellipsoid	63:17:37:39.56
Blackout end	Data locked at high sample rate	No blackout because of TDRS
Terminal area energy management	Major mode change (305)	63:18:02:28.84
Main landing gear contact	RH MLG tire pressure 1	63:18:08:44
	LH MLG tire pressure 1	63:18:08:44.1
Main landing gear weight on wheels	LH MLG weight on wheels	63:18:08:45.12
	RH MLG weight on wheels	63:18:08:44.22
Nose landing gear contact	NLG tire pressure 1	63:18:08:54
Nose landing gear weight on wheels	NLG WT on Wheels -1	63:18:08:54.20
Wheels stop	Velocity with respect to runway	63:18:09:37.32
APU deactivation	APU-1 GG chamber pressure	63:18:10:06.54
	APU-2 GG chamber pressure	63:18:23:57.56
	APU-3 GG chamber pressure	63:18:23:58.37

TABLE II.- STS-36 PROBLEM TRACKING SUMMARY

Number	Title	Reference	Comments
STS-36-01	Ac 2 Phase 2 Inverter Failure	54:22:44 G.m.t. PR-EPD-4-06-0747 IM 36RF01 IPR-36RV-159 Prelaunch CAR 36RF01	Ac 2 phase A had numerous voltage spikes and current fluctuations in a 2-minute period. Inverter serial number 51 removed and replaced with serial number 42. Retest nominal. Failed unit at vendor for failure analysis. Problem isolated to loose connection caused by 4 loose screws. Other suspected units will be inspected for proper screw torquing.
STS-36-02	Liquid Hydrogen 17-inch Disconnect B Indication Intermittent (V41X1445X)	55:22:25 G.m.t. Prelaunch IPR-36RV-0170 IPR-38V-0002 IM36RF02	The main propulsion system 17-inch disconnect "B" open indication dropped out for approximately 11 seconds during fast fill. Indication has been normal since. KSC troubleshooting postflight. No impact to ferry.
STS-36-03	Operational Instrumentation Failures		
	a) APU 1 EGT 1 Sensor (V46T0142A)	a) 56:05:53 G.m.t. Prelaunch IPR-36RV-0191 PR APU-4-06-0160 IM36RF03	a) Immediately following APU startup, EGT 1 began to give erratic readings. KSC to remove and replace during postflight activities. Spare is available. No impact to ferry.
	b) APU 1 Injector Temperature Erratic (V46kT0174A)	b) 56:05:58 G.m.t. Prelaunch IM36RF04 IPR-38V-0011	b) APU 1 injector temperature sensor operated erratically. KSC will troubleshoot during postflight activities. No impact to ferry.
	c) APU 1 GGVM T1 Biased High (V46T0171A)	c) 56:05:58 G.m.t. Prelaunch IM36RF05 IPR 38V-0010	c) Gas generator valve module T1 biased high by 20 to 30 °F. KSC will troubleshoot during postflight activities. No impact to ferry.
	d) Deleted		
	e) APU 3 EGT 2 Sensor Operated Erratically (V46T0340A)	e) 63:18:25 G.m.t. IM36RF20	e) APU 3 EGT 2 sensor failed after landing. Nominal failure signature. KSC will remove and replace sensor during postflight activities. No impact to ferry.
STS-36-04	RCS Thruster R3D Failed	59:07:59 G.m.t. IM36RF07 IPR-38V-0013	Chamber pressure did not reach the required pressure within the required time period - redundancy management deselected the thruster. Suspect real fail-off due to oxidizer poppet valve not opening. DFRC visual inspection - no contamination observed. KSC will remove pod during postflight activities. No impact to ferry.
STS-36-05	a) Volume H Door and Door Latch Binding	59:10:54 G.m.t. IM 36RF08	a) Crew reported latch and door binding. Crew used screwdriver to unlatch and open the door. DFRC inspection found no problem. Suspect thermal/pressure effects caused binding. No impact to ferry.
	b) LiOH Stowage Volume Could Not Be Removed	PR LAF-4-07-0110	b) Crew could not remove LiOH stowage container to clean up free water. KSC will check for screw/fastener binding. No impact to ferry.

TABLE II.- STS-36 PROBLEM TRACKING SUMMARY

Number	Title	Reference	Comments
STS-36-06	RCS Valve Position Indications Intermittent a) Right RCS Manifold 1 Oxidizer Isolation Valve Open Indication (V42X3226X) b) Left RCS 3/4/5 B Oxidizer Tank Isolation Valve Open Indication c) Left RCS 1/2 Oxidizer Crossfeed Valve Closed Indication	59:07:50:16 G.m.t. IM36RF09 59:07:50:29 G.m.t. IM36RF09 59:07:51:07 G.m.t. IM36RF09 IPR 38V-0021	a) Open indication changed to not open. Crew cycled switch from GPC to manual open - indication recovered. No impact to ferry. b)Open indication changed to not open then back to open over a 2-second period. Recovered with no crew action at the time. No impact to ferry. c) Close indication changed to not close. Crew cycled switch from GPC to manual close - recovered closed indication. No impact to ferry. KSC will troubleshoot during turnaround activities.
STS-36-07	Water Spray Boiler 2 Vent System A Heater Failed (V58T0265A)	59:11:15 G.m.t. PR-UA-4-06-0044 IM36RF10	Water spray boiler 2 vent heater A began to degrade about 1 hour and 15 minutes after activation. Heater B activated and operated nominally. Repeat of in-flight anomaly STS-34-18. Heater A reselected, was slow to come up, and operated erratically during entry. KSC will remove and replace controller - spare available. KSC troubleshooting showed nozzle heater operating nominally. No impact to ferry.
STS-36-08	Hydraulic System 1 Reservoir Quantity and Pressure Failed To Respond As Expected	59:07:50 G.m.t. IPR-38V-0004 CAR 36RF11	Reservoir quantity did not increase during ascent. Pressure dropped and did not increase as expected. Temperature responded nominally. Reservoir quantity decreased to 27 percent by time of APU 1 shutdown after landing. Flex Hose shipped on 3/7/90 to Rockwell-Downey. Found pin hole leak near one of the kinked areas of Teflon liner.
STS-36-09	Cathode Ray Tube 4 Went Blank	61:07:10 G.m.t. IPR 38V-0009 PR DIG-4-07-0159 CAR 36RF12	Cathode Ray Tube (CRT) 4 went blank. Power cycles provided only temporary recovery. Data indicate DU LVPS Bite. Unit inoperative for remainder of the mission. KSC removed and replaced unit and sent failed unit to vendor for failure analysis. No impact to ferry.
STS-36-10	Government Furnished Equipment: Pressure Control System Oxygen Bleed Orifice Leak	FAIR-BFCE-026F001	Crew tightened elbow fitting B nut and reduced leak. Normal oxygen flow rates followed. Removed and shipped to JSC for analysis. KSC to leak check Orbiter half of quick disconnect. No impact to ferry.
STS-36-11	Free Water Near Humidity Separator A	61:17:46 G.m.t. IPR 38V-0005 PR ECL-4-07-0399 IM36RF13	Crew reported finding 1 to 2 cups of water outside humidity separator A. WWMS wand was used for free fluid disposal. Reconfigured to humidity separator B. Ferry configuration is without humidity separator package. OMRSD exception approved. Vendor inspection of humidity separator A (tear down) at DFRC did find contamination at inlet of pitot tube before shipping unit to vendor for analysis.

TABLE II.- STS-36 PROBLEM TRACKING SUMMARY

Number	Title	Reference	Comments
STS-36-12	RCS Thruster R4R Failed Off During Hot Fire Test	62:15:17 G.m.t. IPR-38V-0012 IM36RF14	Same characteristics as RCS thruster R3D failure discussed in problem STS-36-04. DFRC visual inspection - no contamination observed. KSC will remove pod during turnaround activities. No impact to ferry.
STS-36-13	Supply Water Tank A and B Check Valve Reverse Leakage Prelaunch	Prelaunch IPR 36RV-0126 PR ECL-4-06-0397 IM36RF15	This problem was deleted as the condition was known preflight.
STS-36-14	Flash Evaporator System Primary Controller A Shut Down	60:19:46 G.m.t. IPR 38V-0014 IM36RF16	Shutdown occurred when water dump mode was initiated. KSC troubleshoot during turnaround activities. Troubleshooting could not duplicate the anomaly. No impact to ferry.
STS-36-15	Payload Bay Floodlights: a) Mid Port Failure b) Aft Port Failure c) Aft Starboard Flickered	63:13:35 G.m.t. IPR 38V-0007 IM36RF17 IPR 38V-0008 IM36RF17 IPR 38V-0006 IM36RF17	a) Crew reported failure prior to payload bay door closure. KSC will troubleshoot during turnaround activities. No impact to ferry. b) Crew reported failure prior to payload bay door closure. KSC will troubleshoot during turnaround activities. No impact to ferry. c) Crew reported failure prior to payload bay door closure. Crew cycled power. Flickering was more rapid - Did not wait the required 45 minutes to reapply power. KSC will troubleshoot during turnaround activities. No impact to ferry.
STS-36-16	APU 1 Shut Down Off Nominal	63:18:10 G.m.t. IM36RF18	This problem was deleted because the shutdown condition was explained.
STS-36-17	Hydraulic System 1 Low Pressure Operations Exhibited Off-Nominal	63:17:38 G.m.t. IPR-38V-0022 PR HYD-4-07-0250 (Filter) PR HYD-4-07-0251 (Main Pump) IM36RF19	During low pressure operations, the hydraulic system 1 pressure stayed at 2400 psi instead of dropping to 800 psi, then pressure slowly dropped to 600 psi and remained steady. KSC will remove and replace system 1 main hydraulic pump and filter. Inspection at vendor revealed the outer piston of pump was galled. No impact to ferry.
STS-36-18	TAGS Paper Folding	60:03:30 G.m.t.	Fourth page folded up prior to silver tray clip - uplinks limited to 10 pages. This was the only occurrence on this flight. Known design deficiency. No fix available. Fly as is. No KSC action. No impact to ferry.
STS-36-19	Right DDU Had Intermittent BITE (V73X3051X)	63:18:10 G.m.t. IPR 38V-0023	After touchdown, BITE indication was intermittently good/bad. KSC removed and replaced unit during postflight turnaround. No impact to ferry.
STS-36-20	Hydraulic 1 Reservoir Pressure (V58P0131A)	59:07:50 G.m.t.	Reservoir pressure did not drop as expected during ascent and entry. No impact to ferry.

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Notif- -2/R. W. Fricke (FTS-525-3313) of any correction, additions, or dele- - to this list.