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STS-40 SPACE SHUTTLE MISSION REPORT

July 1991

NASA

National Aeronautics and Space Administration

Lyndon B. Johnson Space Center
Houston, Texas

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ABS: The STS-40 Space Shuttle Program Mission Report contains a summary of the vehicle subsystem operations during the forty-first flight of the Space Shuttle and the eleventh flight of the Orbiter Vehicle Columbia (OV-102). In addition to the Columbia vehicle, the flight vehicle consisted of an External Tank (ET) designated as ET-41 (LWT-34), three Space Shuttle main engines (SSME's) (serial numbers 2015, 2022, and 2027 in positions 1, 2, and 3, respectively), and two Solid Rocket Boosters (SRB's) designated as BI-044. The primary objective of the STS-40 flight was to successfully

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STS-40

SPACE SHUTTLE

MISSION REPORT

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INTRODUCTION

The STS-40 Space Shuttle Program Mission Report contains a summary of the vehicle subsystem operations during the forty-first flight of the Space Shuttle and the eleventh flight of the Orbiter vehicle Columbia (OV-102). In addition to the Columbia vehicle, the flight vehicle consisted of an External Tank (ET) designated as ET-41 (LWT-34), three Space Shuttle main engines (SSME's) (serial numbers 2015, 2022, and 2027 in positions 1, 2, and 3, respectively), and two Solid Rocket Boosters (SRB's) designated as BI-044.

The primary objective of the STS-40 flight was to successfully perform the planned operations of the Spacelab Life Sciences -1 (SLS-1) payload. The secondary objectives of this flight were to perform the operations required by the Getaway Special (GAS) payloads and the Middeck 0-Gravity Dynamics Experiment (MODE) payload.

The sequence of events for the mission is shown in Table I, and the official Orbiter Problem Tracking List is presented in Table II. In addition, each Orbiter subsystem anomaly is discussed in the applicable subsystem section of the report and a reference to the assigned tracking number is provided. Official ET, SRB, and SSME anomalies are also discussed in their respective sections of the report and the assigned tracking number is also shown.

The crew for this forty-first flight of the Space Shuttle vehicle was Bryan D. O'Connor, Col., USMC, Commander; Sidney M. Gutierrez, Lt. Col., USAF, Pilot; James P. Bagian, M.D., Mission Specialist 1; Tamara E. Jernigan, Ph.D., Mission Specialist 2; M. Rhea Seddon, M.D., Mission Specialist 3; F. Drew Gaffney, M.D., Payload Specialist 1; and Millie Hughes-Fulford, Ph.D., Payload Specialist 2. This was the second Space Shuttle flight for the Commander, Mission Specialist 1, and Mission Specialist 3, and the first Space Shuttle flight for the remaining crew members.

SUMMARY

The first launch attempt for the STS-40 mission, originally scheduled for May 22, 1991, was postponed because of three Orbiter issues: the failure of multiplexer/demultiplexer (MDM) FA2; the failure of general purpose computer (GPC) 4; and the concern over possible cracking of temperature probes in the main propulsion system (MPS). The MDM FA2 failure occurred on the primary port; MDM FA2 was removed and replaced. GPC 4 failed out of the redundant set (failure to synchronize) and was removed and replaced. A total of nine suspect temperature probes in the MPS liquid hydrogen and liquid oxygen lines were also removed. The five probes removed from the liquid oxygen lines were replaced. One liquid hydrogen manifold temperature probe was replaced, and the three remaining liquid hydrogen engine feedline probe ports were plugged.

The second launch attempt for STS-40, on Saturday, June 1, 1991, was scrubbed prior to the T-20 minute hold because of an inertial measurement unit (IMU) problem. In IMU 2, the X-Y accelerometer bias shift exceeded the Operations and Maintenance Requirements and Specifications Document (OMRSD) criteria during the preflight calibration. Results of additional calibrations showed that the shifts exceeded the OMRSD retest criteria and a decision was made to remove and replace the IMU prior to lift-off. As a result, the launch was rescheduled for Wednesday, June 5, 1991.

At the planned launch time on June 5, weather conditions did not meet minimum criteria and the countdown was held at T-9 minutes. However, after a delay of approximately 1 hour 25 minutes, weather conditions cleared and the countdown was resumed.

The STS-40 mission, the first Spacelab Life Sciences mission, was successfully launched from launch pad 39B at 156:13:24:51.008 G.m.t. (8:24:51 a.m. c.d.t. on June 5, 1991). All Orbiter subsystems operated nominally, all SSME and SRB start sequences occurred as expected, and the launch phase performance was satisfactory in all respects. SRB separation, main engine cutoff (MECO), and ET separation all occurred nominally. MECO occurred at 156:13:33:20.808 G.m.t. No orbital maneuvering subsystem (OMS)-1 maneuver was required. The dual-engine OMS-2 maneuver was performed at 156:14:07:09.4 G.m.t. Duration of the maneuver was 124.1 seconds, resulting in a velocity change of approximately 197.3 ft/sec that placed the Orbiter in the planned 160 x 150 nmi. orbit with an inclination of 39 degrees.

Shortly after the payload bay door was opened, video of the aft bulkhead showed several thermal blankets that were partially unfastened and a section of the aft bulkhead payload bay door environmental seal that was also displaced between rollers 4 and 3 on the port side of the bulkhead centerline. Video from payload bay cameras B and C, as well as video taken by the crew with the onboard camcorder, was used to aid in the analysis of this problem. A team investigated the payload bay door environmental seal anomaly, and potential concerns for door closure, entry heating, and venting pressure were evaluated. A section of seal material was shipped from KSC to JSC for use in the evaluation of potential extravehicular activity (EVA) tools, if an EVA became necessary.

The results of the analysis and testing on the loose payload bay door seal indicated a high level of confidence that normal payload bay door closure would yield a safe configuration for entry without requiring a contingency EVA. Also, testing on OV-103 at KSC indicated that the proposed contingency EVA tasks (either to cut off the loose seal or to re-insert the seal in its retainer) could be performed, if necessary. The thermal analysis results indicated that no thermal concerns existed for entry using the STS-40 planned attitude timeline.

On flight day 2, the crew reported that the aft port latch on the lithium hydroxide (LiOH) stowage door was stuck closed. In-flight maintenance (IFM) tools were used to pry the latch open, and the latch access was secured with tape. Analysis showed that no structural concerns existed for entry with the latch open. However, the crew was able to close the latch prior to entry using onboard tools.

The OMS crossfeed line heater A failed off at 157:20:01 G.m.t., and the B heater was selected. The B heater operated nominally and remained selected for the remainder of the mission.

The L5L vernier reaction control system (RCS) thruster was failed off by the redundancy management (RM) at 158:00:51 G.m.t. due to low chamber pressure. The thruster was hot-fired a few minutes after the failed indication, and although the chamber pressure was erratic, it did achieve 90 percent of the normal performance level after three firings. The thruster was used for the remainder of the mission even though the chamber pressure remained degraded.

The crew reported that the Orbiter camcorder would not operate with the video interface unit (VIU)-C power cable, but it would operate with batteries. An in-flight maintenance (IFM) procedure was performed on the camcorder VIU. Following this activity, the camcorder operated properly with the VIU. However, whenever the video/power cable assembly was held in certain positions, the camcorder operated intermittently.

A text and graphics system (TAGS) jam occurred at 162:09:30 G.m.t. The TAGS had exhibited a number of false jam indications earlier in the mission. However, the jam conditions that occurred during the uplink of the morning mail on flight day 7 was proven to be a true jam by a subsequent page advance. The crew performed the standard malfunction procedure to clear the jam condition, but the badly wrinkled paper could not be totally removed from the developer and normal TAGS operations could not be restored. The teleprinter was used for uplinking messages in place of the TAGS.

The cryogenic hydrogen tank 3 heater A failed at 163:05:15 G.m.t. Since the hydrogen in tank 3 was still usable, a nominal tank depletion sequence was followed for the remainder of the mission.

Beginning at 157:18:20 G.m.t., and continuing intermittently throughout the mission, communications dropouts were experienced while operating on the lower left and right S-band antennas. The dropouts were on both the forward and return links and caused some inconveniences, but the losses did not impact the successful completion of the mission.

The flight control system (FCS) checkout was initiated at 164:14:08:27.93 G.m.t. Auxiliary power unit (APU) 2 was operated for 7 minutes for the FCS checkout. The RCS hot-fire test was performed at approximately 164:15:46 G.m.t., and during the following 10-minute period all RCS thrusters operated satisfactorily.

The payload bay door seal was thermally conditioned by placing the Orbiter in a nose-to-sun 1.8-degree pitch-down attitude for a 30-minute period prior to port door closure. The port door was closed and latched at 165:11:20:23 G.m.t. with no interference from the seal, and the starboard door was closed at 165:12:08:53 G.m.t. The crew completed all planned experiment operations, as well as entry preparations and stowage. The deorbit maneuver was performed at 165:14:37:36 G.m.t. The maneuver was approximately 169.5 seconds in duration and the differential velocity was 286.0 ft/sec. Entry interface occurred at 165:15:07:53 G.m.t.

Main landing gear touchdown occurred on Edwards Air Force Base runway 22 at 165:15:39:11 G.m.t. (June 14, 1991). Nose landing gear touchdown occurred 15 seconds later with wheels stop at 165:15:40:05 G.m.t. Data show that the rollout was normal in all respects. The flight duration was 9 days 2 hours 15 minutes 14 seconds. The APU's were shut down by 165:15:58:15 G.m.t., and the crew completed the required postflight reconfigurations and exited the Orbiter landing area in a specially prepared van at 165:16:13:20 G.m.t.

This first Spacelab Life Sciences mission consisted of 20 experiments of which the primary objective was to investigate known fundamental biological problems of manned space flight in an integrated manner. The experiments were conducted in the Spacelab long module and the Orbiter middeck. Also, one middeck 0-gravity dynamics experiment precursor was flown. Twelve GAS payloads were flown in the cargo bay. Data were obtained on all experiments.

Twenty-one DTO's were planned for this mission and data were obtained on 19 of these DTO's. In addition, 10 detailed supplementary objectives (DSO's) were scheduled and data were collected on all of the DSO's.

VEHICLE PERFORMANCE

The vehicle performance section of this report contains a discussion of the operation and performance of the major subsystems of the flight vehicle.

A determination of ascent vehicle performance was made using vehicle acceleration and preflight propulsion prediction data. From these data, the average flight-derived engine specific impulse (Isp) determined for the time period between SRB separation and start of 3g throttling was 452.21 seconds as compared to a fleet average tag value of 452.51 seconds. The relative velocity of the vehicle reached the adaptive guidance/throttling (AGT) reference value at 20.085 seconds, resulting in a calculated time difference, which should be used to adjust the pitch and throttle profiles, of +0.4023 second.

SOLID ROCKET BOOSTERS/REDESIGNED SOLID ROCKET MOTORS

All SRB systems performed as expected, and no SRB anomalies were identified. The SRB prelaunch countdown was normal. Redesigned solid rocket motor (RSRM) overall propulsion performance was well within the required specification limits, and the propellant burn rate for each RSRM was normal. RSRM thrust differential during the buildup, steady-state, and tailoff phases were well within specifications. RSRM propulsion performance parameters are presented in the table on the following page. 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 RSRM launch commit criteria (LCC) or OMRSD violations occurred during the countdown.

The RSRM performance was lower than expected during the first 20 seconds of the STS-40 ascent, but recovered later in the flight. STS-40 was the first motor set to contain ammonium perchlorate manufactured by a new supplier. The chamber pressure for both motors adjusted to 60 °F and 0.368 in/sec burn rate was 15 to 20 psi lower than the block nominal motor for the first 20 seconds of flight, yet all RSRM performance requirements were met. This deviation did not violate specified limits; however, it did affect the adaptive guidance/throttling (AGT) which is used to compensate for off-nominal RSRM performance. The AGT scheme, which was based on previous RSRM performance profiles, incorrectly assumed that the RSRM performance would continue to be low for the entire SRB firing and adjusted the SSME guidance/throttling to compensate, thus causing a high performing vehicle. An evaluation is underway to determine if the AGT logic should be removed from the flight software.

Power-up and operation of all case, igniter and field joint heaters were accomplished routinely. All RSRM temperatures were maintained within acceptable limits throughout the countdown. Ground purges maintained the case/nozzle joint and flexible bearing temperatures within the required LCC ranges.

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 (BSM's) expended and all separation bolts severed. Nose cap jettison, frustum separation, and nozzle jettison occurred normally on each SRB.

Both SRB's separated from the ET at approximately the proper time, and the entry and deceleration sequence was properly performed on both SRB's. Data indicate that all deceleration subsystems performed as designed. Both SRB's were recovered by the retrieval ships and returned to KSC for inspection, disassembly and shipment to the refurbishment facility.

EXTERNAL TANK

All objectives and requirements associated with ET propellant loading and flight operations were met. All ET electrical equipment and instrumentation performed satisfactorily. The operation of the ET heaters and purges was monitored and all performed properly except for the nose cone purge gas temperature measurement no. 1 (T41T1820H), which differed from measurement no. 2 by approximately 20 °F throughout the countdown. No LCC or OMRSD violations were occurred, and no anomalies were identified.

As expected, only the normal ice/frost formations for the June atmospheric environment were observed during the countdown. No frost or ice existed in the acreage areas of the ET. 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 liquid hydrogen protruding air load ramps. All the the ice or frost observations were acceptable as defined in Space Shuttle documentation. The ice/frost "Red Team" reported that no anomalous TPS conditions existed.

The ET flight performance was excellent. The ET pressurization system functioned properly throughout engine start and ascent. The minimum ullage pressure experienced during the period of the ullage pressure slump was 14.7 psid.

The ET tumble system was deactivated for this flight. ET separation was confirmed, and the crew took over 100 photographs of the ET after separation to meet requirements of DTO 312. ET entry and breakup occurred within the predicted footprint.

RSRM PROPULSION PERFORMANCE

Parameter	Left motor, 78 °F		Right motor, 78 °F	
	Predicted	Actual	Predicted	Actual
Impulse gates				
I-20, 10^6 lbf-sec	66.18	64.56	65.96	65.03
I-60, 10^6 lbf-sec	176.22	174.02	175.73	174.18
I-AT, 10^6 lbf-sec	297.41	296.70	297.44	296.04
Vacuum Isp, lbf-sec/lbm	268.6	267.95	268.6	267.33
Burn rate, in/sec (625 psia)	0.3724	0.3705	0.3716	0.3716
Event times, seconds				
Ignition interval	0.232	N/A	0.232	N/A
Web time	109.0	110.0	109.4	109.1
Action time	120.8	122.3	121.2	121.6
Separation command, seconds	124.0	124.9	124.0	124.9
PMBT, °F	78.0	78.0	78.0	78.0
Maximum ignition rise rate, psi/10 ms	90.4	N/A	90.4	N/A
Decay time, seconds (59.4 psia to 85 K)	2.8	3.2	2.8	2.6
Tailoff imbalance Impulse differential, klbf-sec	Predicted N/A		Actual 477.0	

SPACE SHUTTLE MAIN ENGINES

All prelaunch operations associated with the SSME's were executed successfully. Ground support equipment (GSE) provided adequate control for the SSME's during launch preparation. All SSME parameters were normal throughout the prelaunch countdown and compared well with parameters observed on previous flights. The engine-ready indication was achieved at the proper time, all LCC were met, and engine start and thrust buildup were normal.

Preliminary flight data indicate the SSME performance during engine start, mainstage, throttling, shutdown, and propellant dump operations was well within specifications. All three engines started and operated normally. High pressure oxidizer turbopump (HPOTP) and high pressure fuel turbopump (HPFTP) temperatures appeared to be well within specification throughout engine operation. The SSME controllers provided the proper control of the engines throughout powered flight, and no failures have been identified. Engine dynamic data generally compared well with previous flight and test data. All on-orbit activities associated with the SSME's were accomplished successfully.

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 appropriate times. All SRSS measurements indicated that the system performed as expected throughout the flight. The system signal strength remained above the specified minimum (-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 range safety system remained active until ET separation from the Orbiter.

ORBITER SUBSYSTEMS

Main Propulsion System

The overall performance of the MPS was excellent. Liquid oxygen and liquid hydrogen loading was performed as planned with no stop-flows or reverts. No OMRSD violations were noted.

The MPS helium system performed satisfactorily. Throughout the preflight operations, no significant hazardous gas concentrations were detected, and the maximum hydrogen level in the Orbiter aft compartment was 150 ppm. This level was significantly lower than normally experienced on OV-102. The helium concentration in the aft compartment during propellant loading peaked near 10,500 ppm at the start of fast fill, but stabilized at a satisfactory level of 6000 ppm at T-5 hours.

At 156:05:05 G.m.t., about 8 hours prior to launch, all three liquid hydrogen recirculation pump speed indicators dropped to zero because of a loss of power. This loss of power lasted for 17 seconds. About 20 minutes after power returned to the pumps, the secondary power supply was activated. Pump operation was satisfactory for the remainder of the countdown.

A comparison of the calculated and inventory propellant loads at the end of replenish results in a satisfactory loading accuracy of +0.052 percent for liquid hydrogen and +0.096 percent for liquid oxygen.

The gaseous oxygen flow control valves (FCV's) were shimmed to the target position corresponding to a 78-percent flow area. This was the first flight in which the FCV's were fixed in one position. The gaseous oxygen pressurization system performed normally throughout the flight.

Preliminary data indicate that the liquid oxygen and liquid hydrogen pressurization systems performed as planned and that all net positive suction pressure (NPSP) requirements were met throughout the flight.

Postflight evaluation of the film from the camera in the ET umbilical well of OV-102 revealed a shiny, cylindrical object floating past its field of view after ET separation (Flight Problem STS-40-V-16). The object was tentatively identified as the outboard guide pin bushing from the ET liquid hydrogen 17-inch disconnect. Analyses performed on both still photographs and video show that the length-to-diameter ratio of the object matches this bushing. In addition, photographs of the ET liquid hydrogen umbilical after separation show a shiny region at only one of the two bushing locations. Analysis is continuing in an effort to determine how the bushing became dislodged and what can be done to prevent future occurrences.

Reaction Control Subsystem

The RCS performed satisfactorily throughout the mission with one anomaly identified. Propellant consumption totaled 4239.8 lb. The RCS was used to perform the maneuvers in support of DTO 242 (Entry Aerodynamic Control Surface Test).

At 158:00:51 G.m.t., vernier thruster L5L was failed off by the redundancy management (RM) system because of low chamber pressure of 18 psia (Flight Problem STS-40-V-07). The thruster was hot-fired three times a few minutes later with the chamber pressure improving with each pulse. Chamber pressure did achieve the 90-percent level, and as a result, the thruster was reselected for use for the remainder of the flight. However, the thruster chamber pressure remained slightly degraded (about 100 psia vs. nominal of 110 psia). Vernier thruster L5D was also noted to have a very small number of low chamber pressure pulses (80-90 psia), but this condition did not impact the mission.

Orbital Maneuvering Subsystem

The OMS performed satisfactorily throughout the mission. Two OMS maneuvers, OMS-2 and deorbit, were completed. The OMS-2 maneuver was 124.1 seconds in duration with a ΔV of 197.3 ft/sec. The deorbit maneuver was 169.5 seconds in duration with a ΔV of 286.0 ft/sec. Both oxidizer gaging systems and the left pod fuel gaging system operated nominally throughout the mission; however, the right pod fuel gaging system was biased high and caused discrepant right aft gauge and total quantity readings.

Propellant usage for the two firings was 7155 lb of oxidizer and 4236 lb of fuel. The total quantity was biased high by 14 percent after OMS-2, and 3 percent after the deorbit maneuver. This bias occurred on a previous mission and continues to be an ongoing concern.

The left-hand OMS engine gaseous nitrogen system leakage was 40 psi/day during prelaunch operations, and this condition was waived prior to flight. Following OMS-2, the leakage was measured and found to be 20 psi/day. This leakage did not impact the successful completion of the mission.

The OMS oxidizer crossfeed line A heater failed to control at the low set point (66 °F) at 157:20:01 G.m.t., and the B heater was selected (Flight Problem STS-40-V-04). The B heater operated satisfactorily throughout the remainder of the mission.

Power Reactant Storage and Distribution Subsystem

The power reactant storage and distribution (PRSD) subsystem performance was nominal throughout the 218-hour mission with one anomaly identified. The Orbiter was flown in the five-tank-set configuration, and a total of 2717.9 lb of oxygen and 325.9 lb of hydrogen was consumed. The oxygen usage includes 130.5 lb that was used by the crew. Reactants remaining at the end of the mission would have provided a mission extension capability of 73 hours at 17.0 kW.

Hydrogen tank 3 heater A failed off at 163:05:15:53 G.m.t. (Flight Problem STS-40-V-08), and on-orbit troubleshooting verified that the heater would not come on in either the manual or auto modes. Tank 3 depletion was completed first using heater B.

Fuel Cell Powerplant Subsystem

The fuel cell powerplant performance was nominal throughout the mission with no anomalies identified. The total mission energy produced was 3720 kWh at an average power level of 17.0 kWh and 563 A. The fuel cell water production was 2913 lb. The fuel cell 1 hydrogen flowmeter read off-scale high, but this did not affect fuel cell performance. This condition was initially noted on a previous mission of this vehicle.

Auxiliary Power Unit Subsystem

The performance of the APU subsystem was nominal during the STS-40 mission with one anomaly identified that did not impact the mission. The following table presents the cumulative run time and fuel consumption of the APU's during the mission.

Flight Phase	APU 1 (S/N 310)		APU 2 (S/N 312)		APU 3 (S/N 306)	
	Time, min:sec	Fuel consumption, lb	Time, min:sec	Fuel consumption, lb	Time, min:sec	Fuel consumption, lb
Ascent	00:18:55	46	00:18:53	48	00:18:54	51
FCS checkout			00:06:59	20		
Entry	01:24:43	152	01:02:01	125	01:02:01	131
Total[a]	01:43:38	198	01:27:53	193	01:20:55	182

[a] The total includes 18 minutes 44 seconds of APU operation after landing.

During the deorbit maneuver, the APU 1 test line temperature 1 rose to 99 °F which violated the fault detection annunciator (FDA) limit of 95 °F, and a thermal APU message was generated (Flight Problem STS-40-V-12). The temperature began to decline before heater B was turned off.

Other minor problems noted but did not affect the mission included:

a. APU 1 experienced higher than normal vibration during entry, although no limits were violated.

b. APU 2 exhaust gas temperature (EGT) 2 sensor operated erratically during ascent and entry. The erratic operation of the EGT 2 sensor may have caused the APU 3 injector temperature bias discussed in item c.

c. APU 3 injector temperature was biased low during ascent and entry (approximately 200 °F) and remained biased 30 °F below the APU 3 gas generator bed temperature during on-orbit heater operation. Also, the APU 3 injector temperature sensor operated erratically during ascent and entry, and this is similar to the problem that was experienced on STS-38.

Hydraulics/Water Spray Boiler Subsystem

The hydraulics/water spray boiler subsystem operated nominally throughout the STS-40 mission with no anomalies or problems noted. Four recirculation pump actuations occurred during the mission. System 1 and 2 recirculation pumps each actuated one time for thermal conditioning and system recharging, and system 3 pump actuated twice for thermal conditioning.

Pyrotechnics Subsystem

The pyrotechnics subsystem operated satisfactorily throughout the STS-40 mission with no anomalies identified.

Environmental Control and Life Support Subsystems

All environmental control and life support subsystems (ECLSS) operated satisfactorily and no anomalies were noted. The atmospheric revitalization system (ARS) performed nominally and all in-flight checkout requirements were satisfied. Performance of the air and coolant loops was normal, and the carbon dioxide partial pressure was maintained below 2.3 mm Hg. Cabin air temperature and relative humidity peaked at 82 °F and 51 percent, respectively. Avionics bays 1, 2, and 3 air outlet temperatures peaked at 108 °F, 106 °F, and 92 °F, respectively. Avionics bays 1, 2, and 3 water coldplate temperatures peaked at 92 °F, 95 °F, and 82 °F, respectively.

DTO 647 (Water Separator Filter Performance Evaluation) was performed on flight days 3 and 5. The filter was installed between the cabin heat exchanger and the humidity separator and good data were obtained.

The humidity separator A fan speed indication was known to be inoperative prior to launch. When the scheduled humidity separator prefilter DTO was performed, video of the humidity separator wire bundles showed a broken wire in the speed sensor A output signal to the MDM. The wire was taped to prevent inadvertent contact with other components. This problem was known prior to flight and had no impact to the mission.

The humidity separator prefilter detailed test objective (DTO) 647 (Water separator Filter Performance Evaluation) was performed with humidity separator B operating. Evaluation of the data showed that once a majority of the filter was wetted, a volume of water slugged the separator, causing a small amount of water carry-over. At this point of the test, the filter was removed and the DTO terminated. A second test of DTO 647 was completed successfully with humidity separator B operating, after which the filter was removed and the LiOH box was reinstalled. Preliminary results indicate that the filter functioned properly, no evidence of water carry-over occurred, and the DTO requirements were met.

The Orbiter and Spacelab pressure control systems (PCS) were used to control partial pressure of oxygen (PPO_2) and total pressure, and the systems operated nominally.

The active thermal control system (ATCS) controlled temperatures satisfactorily throughout the mission.

The waste collection system (WCS) performed normally until flight day 9 when there was some backup of urine in the WCS mode.

The urine monitoring system was successfully used throughout the mission with nominal performance from the WCS fan separators.

Supply and Waste Water Systems

The supply water system performed normally throughout the mission, and all of the associated in-flight checkout requirements were performed and satisfied by the end of the mission. Supply water was managed through the use of the flash evaporator and overboard dump systems. A total of 13 supply water dumps were made during the mission. The supply water dump line temperature was maintained between 72 and 108 °F throughout the mission with the operation of the line heater.

Waste water was gathered at the predicted rate. Four waste water dumps were made at a dump rate of 1.99 percent/minute (3.28 lb/minute). The waste water dump line temperature was maintained between 53 and 81 °F throughout the mission, while the vacuum vent line temperature was between 59 and 78 °F.

Smoke Detection and Fire Suppression Subsystems

The Orbiter smoke detection system operated satisfactorily throughout the STS-40 mission, and no use of the fire suppression system was required.

Airlock/Tunnel Adapter Support System

No extravehicular activities were planned or required, and as a result, use of the airlock and associated hardware was not required. Performance of the Spacelab tunnel adapter hardware was satisfactory. Onboard video showed that the hatch C thermal cover was open (Flight Problem STS-40-V-09). Analysis of the video showed that the open cover would not affect the performance capability of the hatch hardware.

Avionics and Software Subsystem

The integrated guidance, navigation, and control system and flight control system performed satisfactorily throughout the mission. DTO 242 (Entry Aerodynamic Control Surfaces Test) was performed using the flight control system; however, the maneuvers scheduled to occur between Mach 11 and 8 were inhibited because of trajectory considerations.

The IMU performance was nominal during the mission. However, prior to the T-20 minute hold during prelaunch operations for the second launch attempt, IMU 2 accelerometer data failed a comparison test. The X-Y accelerometer bias shift between resolver-indicated attitude and accelerometer-indicated attitude exceeded the OMRSD criteria (Flight Problem STS-40-V-01). The calibration was repeated twice, but the data indicated that an instability problem existed in the accelerometer. As a result, a decision was made to replace the IMU prior to launch.

The star tracker performed satisfactorily throughout the flight, although the -Z star tracker failed the initial self-test. The star tracker passed the second self-test. This condition has been noted on previous missions of this star tracker in this vehicle and is acceptable.

The data processing system and flight software operated satisfactorily throughout the STS-40 mission. This was the last flight of the OI-8 software and AP-101B computers.

The electrical power distribution and control subsystem and the displays and controls subsystem both performed nominally throughout the mission.

Communications and Tracking Subsystem

The communications and tracking subsystem performance was satisfactory, although five anomalies were identified with the communications and tracking equipment. Four attempts were made to perform DTO 700-1 associated with Low Power Tracking and Data Relay Satellite (TDRS), and only one was successful. The TDRS was not calibrated for the first two attempts. This problem, together with ongoing computer and refrigerator problems resulted in the DTO being scrubbed on the third of four attempts.

The performance on the S-band lower-left and lower-right antennas was degraded throughout the mission (Flight Problem STS-40-V-10). Numerous dropouts were experienced. The lower-right antenna was operating with an open corrective action report (CAR), and the lower-left antenna was operating with a waiver. The dropouts did not impact normal mission operations. Also, the crew reported that an unusually high amount of S-band noise was present on the headset during sleep periods.

The crew reported that the Orbiter camcorder would not operate with the VIU-C power cable, but it would operate with batteries (Flight Problem STS-40-V-05). An IFM procedure was performed on the camcorder VIU during which the unit was opened, the board removed and inspected, voltages measured, and the unit reassembled. Following this activity, the camcorder operated properly with the VIU, and the reason for the failure and "repair" are not known. However, the video/power cable assembly for the camcorder continued to cause the camcorder to operate intermittently when the cable was held in certain positions.

A TAGS jam occurred at 162:09:30 G.m.t. (Flight Problem STS-40-V-06b). The TAGS had exhibited a number of false jam indications earlier in the mission (Flight Problem STS-40-V-06a). However, the jam indication that occurred during the uplink of the morning mail on flight day 7 was proven to be caused by a true jam. This was verified by a subsequent page advance. The crew performed the standard malfunction procedure to clear the jam condition, but normal TAGS operations could not be restored. Paper was still visible in the right side of the developer and it could not be reached with the IFM tool. The teleprinter was used for uplinking messages in place of the TAGS.

A loss of communications on the air-to-ground loop was experienced by mission specialists 1 and 3 while operating on audio interface unit (AIU) -D, which was located in the Spacelab (Flight Problem STS-40-V-13a). The crew members switched to unit C that was plugged into the Orbiter and used the middeck antenna to restore good communications. Also, the crew experienced a temporary loss of communications on the air-to-ground loop while operating on AIU-E (Flight Problem STS-40-V-13b). The crew were able to use other communication units and maintain satisfactory communications.

The payload data interleaver (PDI) switch scan (V75S5100E) changed state when the PDI off/on uplink commands were sent through the ground command interface logic (GCIL) unit (Flight Problem STS-40-V-15). Initial evaluation indicates a problem in the GCIL circuitry.

The Tactical Air Command and Navigation (TACAN) 3 unit exhibited erratic range data during the FCS checkout. The problem was identified as being caused by an insufficient amount of warm-up time.

Operational Instrumentation

The performance of the operational instrumentation was satisfactory throughout the mission with no anomalies identified.

Structures and Mechanical Subsystem

The structures and mechanical subsystems operated satisfactorily with three anomalies identified. Within the crew module, the LiOH door was stuck closed

(Flight Problem STS-40-V-03). The crew pried the door open as access to this area was required for mission success. Since two crew-member seats rest on the door, it was necessary for the crew to latch and close this door for entry. The crew was able to close the door for entry. Postflight tests indicated that the latch moved freely.

Shortly after the payload bay door was opened, video of the aft bulkhead showed several thermal blankets that were partially unfastened (Flight Problem STS-40-V-02b) and a section of the aft bulkhead payload bay door environmental seal that was also displaced between rollers 4 and 3 on the port side of the bulkhead centerline (Flight Problem STS-40-V-02a).

The results of the analysis and testing on the loose payload bay door seal indicated a high level of confidence that normal payload bay door closure would yield a safe configuration for entry without requiring a contingency EVA.

The payload bay door seal was thermally conditioned by placing the Orbiter in a nose-to-sun 1.8-degree pitch-down attitude for a 30-minute period prior to port door closure. The port door was closed and latched with no apparent interference from the seal. The postflight inspection revealed that the seal had been forced to the bottom of the passive hook at bulkhead latch 4.

The postflight runway inspection revealed thermal damage to the right-hand ET door (Flight Problem STS-40-V-11). The inspection showed significant melting and erosion of the forward centerline latch fitting and adjacent tile. Also, a flow path was identified to a void between the structure and bracket behind the aft right-hand ET/Orbiter door seal.

Main landing gear touchdown occurred at 165:15:39:10.9 G.m.t. on Edwards AFB concrete runway 22 at 203.8 KEAS (ground speed of 199.8 knots), and Orbiter data show that the main landing gear touched down 1615 ft past the runway threshold. Winds at touchdown were 12 knots with gusts to 17 from 227 degrees true. Nose gear touchdown occurred 14.6 seconds later, 5914 ft from the runway threshold at a ground speed of 153.3 knots, and braking was initiated at 135.2 knots. Wheels stop occurred at 165:15:40:05.5 G.m.t. after a rollout distance, as determined from Orbiter data, of 9403 ft. (DFRF data showed 9438 ft.). The sink rate at touchdown was approximately 2 ft/sec and the derotation rate at nose gear touchdown was 3.48 deg/sec.

The maximum brake pressures during rollout ranged from 1024 psi to 1160 psi on the the left main gear, and from 1008 psi to 1248 psi on the right main gear. Brake energies were 30.16 million ft-lb on the left outboard brake, 28.16 million ft-lb on the left inboard brake, 34.20 million ft-lb on the right inboard brake, and 38.24 million ft-lb on the right outboard brake. The Orbiter weighed 226,534 lb at landing.

In support of DTO 517, a high-speed nosewheel steering test was successfully accomplished beginning at 135 knots indicated air speed. The Commander reported a handling quality rating of 2 and stated that the vehicle handling qualities were better than those of the simulator for similar conditions.

Aerodynamics and Heating

The overall aerodynamic performance of the Orbiter was nominal for the STS-40 mission. DTO 242 (Entry Aerodynamic Control Surface Test, Part 5), was performed during entry. Eight programmed test inputs (PTI's) were planned; however, only five (1, 2, 5, 6, and 7) PTI's were completed. The DTO section of this report contains a more detailed discussion.

The ascent aerodynamic and plume heating was nominal, and analysis of the modular auxiliary data system (MADS) data is continuing. Entry aerodynamic heating was within TPS limits, and the preliminary inspection showed some heating damage on the right-hand ET/Orbiter door forward centerline latch fitting and adjacent tile (Flight Problem STS-40-V-11).

Thermal Control Subsystem

All structural and component temperatures were maintained within acceptable limits. All Orbiter thermal control subsystem heaters performed nominally with the exception of the on-orbit failure of the OMS oxidizer crossfeed line heater A center thermostat (zone 5). Once on-orbit, several thermal blankets on the upper aft (X_0 1307) bulkhead were noted to be partially unfastened (Flight Problem STS-40-V-02b), and a portion of the payload bay door (PLBD) environmental seal on the aft bulkhead was dislodged (Flight Problem STS-40-V-02a). Also, the Spacelab tunnel adapter EVA thermal cover was unfastened and was free-floating about its hinge during the on-orbit phase of the mission (Flight Problem STS-40-V-09). A review of the video showed that the hatch cover was loose much earlier in the mission. The loose cover did not impact the successful completion of the mission.

The PLBD environmental seal was thermally conditioned by going to a nose-Sun 1.8-degree pitch down attitude for 30 minutes before closing the port door and thereby increase the confidence that normal door closure would be accomplished. The doors were closed satisfactorily as discussed earlier in this report. The unfastened aft bulkhead thermal blankets and tunnel adapter EVA hatch thermal cover did not present thermal control problems during the mission as the as-flown attitude timeline was relatively benign.

The OMS oxidizer crossfeed line heater system A (zone 5) failed off at 157:20:01 G.m.t. as indicated by the thermostat monitoring sensor (V43T6242A) falling below the low set point temperature (66 °F) without the heater cycling on (Flight Problem STS-40-V-04). The B heater was selected and operated nominally for the remainder of the mission.

A fault detection annunciator (FDA) alarm was triggered on the APU 1 test line B heater system (V46T0183A) at 99 °F approximately 5 minutes after APU start for the deorbit maneuver (Flight Problem STS-40-V-12). The temperature of this monitoring sensor jumped 13 °F to trigger the FDA. This phenomenon was not due to a heater failure. The phenomenon coincides with the deorbit maneuver and analysis is continuing to determine if an interrelationship between the two items does truly exist. Analysis of data from previous flights indicates that this same phenomenon was present; however, initial temperatures prior to the jump were lower and consequently, no alarms occurred on those flights.

Aerothermodynamics

The acreage heating during entry was nominal as indicated by the normal structural temperature rise. The chin panel T-seal surface showed some degradation. The payload bay environmental seal area showed no evidence of heating; however, some evidence of flow ingestion was indicated by a small part (6 to 8 inches) of monkey fur turned inward. The right-hand ET/Orbiter door metal centerline latch plate was melted at the forward edge.

Thermal Protection Subsystem

The thermal protection subsystem (TPS) performance was nominal, based on structural temperature responses and some tile surface measurements. The overall boundary layer transition from laminar to turbulent flow was nominal and occurred 1220 seconds after entry interface.

Debris impact damage was moderate. Four tile removals and replacements were identified from the inspection of the debris impacts. The postflight inspection showed a total of 197 hits on the vehicle and 25 of these hits had a dimension of $\geq$ 1 inch. Of the total hits, 153 were located on the lower surface with 23 having a dimension of $\geq$ 1 inch. The largest damage site was located on the right-hand inboard elevon where the area measured 7 3/4 by 1 1/8 by 1/2 inches, and the largest cluster of hits was located on the liquid hydrogen ET/Orbiter umbilical opening that had 30 hits. Two of the hits had a dimension of > 1 inch. The base heat shield peppering was minimal.

Overall, all radial carbon carbon (RCC) parts appeared nominal. The chin panel inspection revealed no significant changes of the surface bubbling recorded on its first flight that was attributed to the enhancement coating applied on the RCC surface. The nose landing gear door TPS was in good condition with only minor fraying of the thermal barrier forward patch and right-hand outboard barrier. The forward RCS bulkhead thermal barrier was heavily breached, and the barrier will be replaced with the removal of the forward RCS module. The left-hand main landing gear door outboard thermal barrier was breached at both ends. The elevon-elevon gap tiles were in good condition, with one breached gap filler. The engine-mounted heat shield thermal curtain was damaged on engine 1. All other engine blankets were nominal.

Windows 3 and 4 had moderate to heavy hazing with a few small streaks, and windows 2 and 5 had light-to-moderate hazing around the window periphery with several small streaks. Evidence of peppering was noted on tiles around these windows.

Shortly after the payload bay door was opened, video of the aft bulkhead showed several thermal blankets that were partially unfastened (Flight Problem STS-40-V-02b) and a section of the aft bulkhead payload bay door environmental seal that was also displaced between rollers 4 and 3 on the port side of the bulkhead centerline (Flight Problem STS-40-V-02a). Video from payload bay cameras B and C, as well as video taken by the crew with the onboard camcorder, was used to aid in the analysis of this problem. A team of Engineering

Directorate; Safety, Reliability and Quality Assurance Office; Astronaut Office; Mission Operations Directorate; Rockwell International; and Orbiter and GFE Projects Office personnel investigated the payload bay door environmental seal anomaly. Potential concerns for door closure, entry heating, and venting pressure were evaluated. A section of seal material was shipped from KSC to JSC for use in the evaluation of potential EVA tools, if an EVA became necessary. A team also traveled to KSC to evaluate the effects of a failed seal on payload bay door closure as well as possible EVA IFM procedures, using OV-103.

The results of the analysis and testing on the loose payload bay door seal indicated a high level of confidence that normal payload bay door closure would yield a safe configuration for entry without requiring a contingency EVA. Although, testing on OV-103 at KSC indicated that the proposed contingency EVA tasks (either to cut off the loose seal or to re-insert the seal in its retainer) could be performed, if necessary. The thermal analysis results indicate that no thermal concerns existed using the STS-40 planned attitude timeline.

The payload bay door seal was thermally conditioned by placing the Orbiter in a nose-to-sun 1.8-degree pitch-down attitude for a 30-minute period prior to port door closure. The port door was closed and latched with no apparent interference from the seal. The postflight inspection revealed that the seal had been forced to the bottom of the passive hook at bulkhead latch 4.

The left-hand ET door thermal barrier performance was nominal. Melting/erosion was noted on the forward right-hand ET/Orbiter door centerline latch fitting and adjacent tile (Flight Problem STS-40-V-11). The forward end of the latch point was eroded 2 inch by 0.1 inch in depth. The internal bulb seal and thermal barrier were intact with no evidence of abnormal damage or severe over-temperature conditions. The adjacent latch patch (thermal barrier) was intact with typical outer mold line (OML) discoloration. Inspections revealed a structural gap opening to the aft compartment in the aft corner of the outboard side of the umbilical cavity. This structural opening coupled with a small void between the latch point and the thermal barrier latch patch (caused by a disparity in latch point to adjacent inconel finger step), caused the plasma flow to ingest into the umbilical cavity and aft compartment and causing the damage to the door. No damage to any other component was observed or recorded.

FLIGHT CREW EQUIPMENT

The flight crew equipment performed in an excellent manner throughout the flight.

During postflight removal of film from the liquid hydrogen umbilical cavity cameras, the film from one of the 16 mm cameras located in the ET/Orbiter umbilical cavity was found to be broken 30 feet from the start of the film. An inspection of the camera revealed that the camera continued to run and had suffered some sprocket damage (Flight Problem STS-40-V-14a).

When the film was removed from the 35 mm camera, the film was found to be broken 6 inches from the start of the film (Flight Problem STS-40-V-14b).

PAYLOADS

The SLS-1 payload consisted of 20 experiments relating to the life sciences. The primary objective of the SLS experiments was to investigate known

fundamental biological problems of manned spaceflight in an integrated manner. The payload used the SLS long module in the payload bay, as well as the Orbiter middeck. In addition to the 20 SLS experiments, one Middeck 0-Gravity Dynamics Experiment (MODE) precursor was flown.

Twelve cargo bay secondary payloads were flown, and these were located in GAS canisters. Each canister contained an individual GAS payload. These were:

a. G-021 - Test Integrated Circuits
b. G-052 - Melt and Regrow Gallium Arsenide Crystals
c. G-091 - Formation of Solid and Hollow Ball Bearings
d. G-105 - Organic and Inorganic Materials Processing
e. G-286 - Production of Lightweight Foamed Metal Samples
f. G-405 - Chemical Precipitates
g. G-408 - Zeolite Crystal Growth and Fluid Behavior
h. G-451 - Flower Bulbs and Seeds
i. G-455 - Structure and Defects of Crystals
j. G-486 - Soldering in Microgravity and in a Vacuum
k. G-507 - Orbiter Stability Experiment
l. G-616 - Floppy Disks and Seeds in Space

SPACELAB

General Performance

As a result of the launch delay of 1 hour 25 minutes, the crew operated on an off-nominal timeline for flight day 1 and focused primarily on metabolic experiments. However, efficient crew operation allowed the performance of the cardiovascular measurements, which included the performance of the echocardiograph sessions on three crew members plus leg volume and central venous pressure measurements.

The lymphocyte and jellyfish experiments were successfully activated. The crew reported that the jellyfish were alive and well, seemed to adapt to 0-g, and swam in circles. On flight day 3, 5, 6, and 7, videos were taken of the pulsating behavior of the jellyfish.

On flight day 2, the crew continued to focus most of their attention on metabolic and cardiovascular activities. Crew members received isotopes for experiments investigating body fluid volume, protein metabolism, iron uptake, and total body water. Analyses of blood, urine, and saliva samples, which were taken after the crew received the isotopes, traced the rate of removal of the isotopes from the body.

Payload specialist crew members performed the baroreflex test and the pulmonary function test, participated in echocardiograph activities, and had cardiovascular measurements made during resting and sub-maximal exercise.

On flight day 3, the first human vestibular experiments of the mission were performed. The crew continued gathering metabolic and cardiovascular/cardio-pulmonary data. Also, several engineering evaluations of new life sciences equipment and systems were performed successfully. Evaluations included particulate containment demonstration tests (PCDT) in the general purpose work station (GPWS) and the research animal holding facility (RAHF).

The crew continued cardiovascular/cardiopulmonary and metabolic investigations on flight day 4. The crew accomplished all planned activities plus some experiments of opportunity, including a vestibular study using a rotating chair. All of the PCDT activities were successfully completed, and particulate containment was demonstrated. The medical restraint system and the small mass measurement instruments were also evaluated.

Spacelab activities during flight day 5 concentrated primarily on gathering cardiovascular and cardiopulmonary data that will help scientists determine the extent of cardiovascular deconditioning at the midway point of the mission. Again, the crew completed all scheduled operations successfully. The crew was able to conduct several experiments of opportunity, producing additional data for cardiovascular/cardiopulmonary and human vestibular investigations.

During flight day 6, crewmembers participated in the rotating dome investigations of the mission, adding to the vestibular data gathered on flight day 3, 4 and 5. The crew also completed the baselined cardiovascular and metabolic experiments.

Flight day 7 was a day of "bonus science" and Earth observations. While science activities on flight day 7 were originally limited to mandatory operations so that Shuttle resources could be conserved for an extra day in orbit, actual available resources allowed the crew to work in Spacelab and complete all planned and shopping list activities.

Activities included repairs to the vestibular dome electromyogram (EMG) cable connector, dome tests, a repeat of the intravenous pump verification demonstration, and performance of the RAHF and GPWS test with an animal cage containing rodents. The crew reported that the animal handling procedures went extremely well and that containment was satisfactory.

The RAHF water pressure sensor loss and the elevated rodent water consumption led to a request for the crew to place gel packs in all rodent cages to ensure that the animals had sufficient fluids should the flight be extended past nine days. Using the GPWS, the crew inserted three gel paks per rodent into the RAHF cages during flight day 8 activities. Other flight day 8 activities included a repeat of the flight day 1 and 2 metabolic studies, resting and exercise for cardiovascular assessment, and performance of the baroreflex experiment.

During the last day (flight day 9) of on-orbit science operations, the crew performed the final cardiovascular/cardiopulmonary and metabolic experiments. The data information gathered on flight day 9 will be compared with data collected before launch, early and midway through the mission, and after landing.

The crew stowed all science equipment located in the Spacelab module and deactivated the laboratory.

Gas Analyzer Mass Spectrometer

On flight day 1, the gas analyzer mass spectrometer (GAMS) experienced a number of automatic shutdowns after which the crew performed procedures to restart, but it would not continue to run. It was left in a bake-out mode overnight. On flight day 2, the GAMS was successfully calibrated. On flight day 3, GAMS 1 experienced multiple automatic shutdowns and the data on the downlink was noisy. GAMS 2 was brought up, but it stopped working on flight day 4. Operations were switched to GAMS 1 and troubleshooting procedures were developed. The primary GAMS 1 was used for flight day 5 pulmonary function tests. The data received on the ground continued to be degraded, although acceptable. The backup GAMS 2 troubleshooting was not successful. A significant number of GAMS calibrations were required to successfully perform the experiments.

Although data from the primary GAMS 1 for pulmonary function tests have been good, the data were noisy and sometimes repeat sessions were requested for the In-flight Study of Cardiovascular Deconditioning experiment.

Research Animal Holding Facility and Animal Enclosure Modules

The animal enclosure modules (AEM) functioned properly. The temperature inside the modules was maintained at 80 °F. The RAHF operated nominally. The crew reported the RAHF cages remained "remarkably clean." Water consumption by the animals in the AEM's was elevated and the crew refilled the AEM water bags on flight day 4 and 8. The water tank pressure transducer in the RAHF used to measure the water level of the reservoir apparently failed. A workaround was found by keeping track of the number of times the rodents accessed their water dispensers.

The crew reported that all the rodents in the AEM's and RAHF remained healthy and active. On flight day 8, the crew inserted three gel packs in each RAHF animal cage enclosure to ensure adequate fluids for up to a 2-day mission extension.

Refrigerator/Freezer

The Orbiter refrigerator/freezer (ORF) began warming up toward the end of flight day 2. The crew transferred the samples back to the Spacelab Freezer (SLF) and turned off the ORF. The ORF was reactivated early on flight day 3 and operated well. The Spacelab Freezer (SLF), at the L9I location also had trouble maintaining temperature and was allowed to warm to ambient, then restarted in the refrigerator mode. The Spacelab Refrigerator (SLR), at the L8I location, was converted to the freezer mode on flight day 2.

The ORF failed to maintain its temperature during flight day 4 and the odor that was reported several days earlier had apparently intensified. The disagreeable odor was thought to be emanating from the unit's door seals and was only a problem when the door was open. The ORF was shut down and its samples transferred to the module units. The SLF operated well in the refrigerator mode. The Spacelab refrigerator (SLR) was operating in the freezer mode.

The ORF remained off and sealed. A troubleshooting procedure was uplinked for the crew. In this procedure, the crew was instructed to discontinue operation of the ORF if any odor was detected, and within 40 seconds of turning on the ORF, the odor was again noticed. The ORF was immediately powered down and remained powered down for the remainder of the flight.

Early on flight day 8, the SLF temperature sensors indicated slight increases in freezer (L8I) temperatures. The L8I unit was reconfigured as the refrigerator and, what was previously the refrigerator (L9I), was set in the freezer mode, and samples were switched. Later, the temperature of the L9I unit also began to rise. The crew then performed a procedure to clear possible obstructions from the Freon system. This effort produced no change in monitored values. The L8I unit was then configured again as a freezer, the filter cleaned, and the samples loaded. During crew sleep, the rising temperature in the L8I unit (in freezer mode and holding the samples) necessitated the awakening of the crew to perform an IFM on the L9I unit. The crew was again awakened to switch samples into the L9I unit when it reached an acceptable freezer temperature.

Early on flight day 9, the crew performed a repair procedure that quickly thawed out the L8I unit and recovered it as a freezer. Meanwhile, the L9I unit was turned off to keep the electronics from providing a heating source. Once the L8I unit returned to acceptable freezer temperatures, the samples were loaded and a procedure was implemented to do a "slow fix" on the L9I unit to recover freezer capability.

After the quick fix, the L8I unit ran well during the day; the L9I unit was powered off, allowed to return to ambient temperature, and the IMAX floodlight was used to warm air flowing over the evaporator to melt any remaining ice. The unit was wiped dry and was then configured as a freezer. Both units operated well in the freezer mode for the remainder of the flight.

Spacelab Computer

On flight day 4, the experiment computer (EXC) crashed but was successfully re-initial-program-loaded (IPL'd) within 10 minutes; therefore, the momentary loss had minimal impact on payload monitoring.

The EXC crashed again during crew sleep on flight day 6. The signature for this anomaly was similar to the EXC anomaly of flight day 4. The EXC was re-IPL'd by the crew early on flight day 7 and operated normally for the remainder of the flight. Data dumps from the Spacelab mass memory unit were studied for troubleshooting and problem isolation.

PHOTOGRAPHIC AND TELEVISION ANALYSIS

The photographic and television analysis team analyzed all launch and landing films and video plus provided support in the investigation of two anomalies during and after the STS-40 mission.

On launch day, 23 videos (out of 25 expected) were screened. No anomalies were observed in any of the video. Cloud cover obscured the view of the vehicle on several of the tracking cameras beginning approximately 43.5 seconds after lift-off.

All 71 of the expected launch films were reviewed and no major anomalies were detected. No Castglance film of the SRB was acquired.

Analysis of the launch films revealed two occurrences of a white puff on the underside TPS of the Orbiter to the left of the liquid hydrogen disconnect at 156:13:24:46.1 G.m.t. and 156:13:24:47.4 G.m.t. The tiles that were involved were identified and were examined after landing and showed no damage.

Eleven 16 mm films, two 35 mm films and five videos of landing were screened, and no anomalies were detected.

The STS-40 crew members took 103 hand-held 70mm pictures of the ET after it separated from the Orbiter. Also, three cameras were located in the umbilical cavity of the Orbiter; however, two of these cameras failed shortly after being started (Flight Problem STS-40-V-14). Film from the one 16 mm camera plus the hand-held photography was used to partially accomplish DTO 312. The analysis of these films has shown two or three divots on the flange between the intertank area and the liquid hydrogen tank. This condition has been seen on previous mission photography and did not impact the successful completion of the ET mission objectives.

ORBITER AFT BULKHEAD AND PAYLOAD BAY DOOR DAMAGE ASSESSMENT

On-orbit video downlink of the Orbiter payload bay aft bulkhead showed at least two thermal blankets that were partially detached. Also, the video showed a portion of the payload bay door seal that was detached.

The break occurred approximately 31 inches left (-Y side) of the vehicle centerline. Three-dimensional analysis of the two ends of the damaged payload bay door seal showed that the piece towards the starboard (left) side was sticking forward from the aft bulkhead about 6 inches and the other piece was sticking forward about 2 inches with a small amount of displacement upwards. Further analysis showed the change in position was caused by heating during exposure to sunlight and cooling when in shadow. The seal tips moved further away from the bulkhead when cooled and closer to their normal position when heated. The amount of this displacement was determined to be approximately 1.1 inches on the starboard piece and 0.4 inch on the port piece.

DEBRIS SEEN IN UMBILICAL CAMERA FILM AFTER ET SEPARATION

A cylindrical object was observed approximately 43.7 seconds after ET separation, and the object was tumbling across the field of view of the 16 mm umbilical-cavity camera. The debris traveled from the top right to the center bottom edge of the field of view. The object has been identified as a small guide pin sleeve (bushing) from the ET half of the 17-inch disconnect (Flight Problem STS-V-40-16). Photographic analysis of the cylindrical object continues in an effort to positively identify the object and determine its range of size, length-to-width ratio, and trajectory.

DEVELOPMENT TEST OBJECTIVES AND DETAILED SUPPLEMENTARY OBJECTIVES

A total of 21 DTO's were scheduled for the STS-40 mission. Two DTO's were not performed and these were:

a. DTO 624 - Radiator Performance

b. DTO 805 - Crosswind Landing Performance

DEVELOPMENT TEST OBJECTIVES

Ascent Development Test Objectives

DTO 236 Ascent Wing Aerodynamic Distributed Loads - Data were collected and are being evaluated.

DTO 301 Ascent Structural Capability Evaluation - Data were collected and are being evaluated.

DTO 312 ET TPS Performance - A total of 103 photographs were taken by the crew and an evaluation of the photographs has been made and the results are discussed in the Photographic and Television Analysis section of this report. No further analysis will be performed.

On-Orbit Development Test Objectives

DTO 623 Cabin Air Monitoring - This DTO was successfully completed and data are being evaluated by the sponsor.

DTO 624 Radiator Performance - This DTO was not performed because the radiators were not deployed.

DTO 630 Camcorder Demonstration - This DTO was successfully completed. There were intermittent failures of the lapel microphone and the video interface unit. Also, the 0.5 diopter wide angle lens resulted in significant vignetting. The video as well as the camcorder are being evaluated by the sponsor.

DTO 637 On-Orbit Cabin Air Cleaner Evaluation - This DTO was successfully completed and the data are being evaluated by the sponsor.

DTO 647 Water Separator Filter Performance Evaluation - This DTO was performed successfully. Good video of the separator was received, and the sponsor is evaluating the data.

DTO 700-1 TDRS S-Band Forward Link RF Power Level Evaluation - This DTO was performed successfully. Good results were obtained, and the sponsor is further evaluating the received data.

DTO 785 Head Up Display (HUD) Backup to Crewman Optical Alignment Sight (COAS) - This DTO was successfully completed and the data will be evaluated by the sponsor.

DTO 796 Vent Uplink Capability - Data were collected for this DTO, and the data will be evaluated by the sponsor.

DTO 823 Additional Stowage Evaluation for Extended Duration Orbiter (EDO) - This DTO was completed, and the results are being evaluated by the sponsor.

DTO 901 Orbiter Experiments (OEX) Shuttle Infrared Leeside Temperature Sensing (SILTS) - Data were collected, and the data are being evaluated by the sponsor.

DTO 902 OEX Shuttle Upper Atmosphere Mass Spectrometer (SUMS) - This DTO was performed successfully during on-orbit operations. The data will be evaluated by the sponsor.

DTO 903 OEX Shuttle Entry Air Data System (SEADS) - Data were collected for this DTO, and the data will be evaluated by the sponsor.

DTO 910 OEX Orbital Acceleration Research Experiment - This DTO was successfully performed during on-orbit operations, and the data are being evaluated by the sponsor.

DTO 911 OEX Aerothermal Instrumentation Package - Data were collected for this DTO and are being evaluated by the sponsor.

Entry/Landing Development Test Objectives

DTO 242 Entry Aerodynamic Control Surfaces Test - Only five of the eight programmed test inputs (PTI's) were performed. Data were collected from these PTI's and are being evaluated by the sponsor.

DTO 307 Entry Structural Capability - Data were collected for this DTO and are being evaluated by the sponsor.

DTO 517 Hot Nosewheel Steering Runway Evaluation - This DTO was performed. The Commander assigned a handling quality rating of 2 to the high speed steering task, stating that the vehicle handled "better than the simulator" for the same test conditions.

DTO 805 Crosswind Landing Performance - This DTO was not performed because the crosswinds were less than the minimum requirements of the DTO.

DETAILED SUPPLEMENTARY OBJECTIVES

Ten DSO's were scheduled for the STS-40 mission, and all were performed successfully.

DSO 469 In-Flight Radiation Dose Distribution (Tissue Equivalent Proportional Counter (TEPC) Only, Activation on Flight Day 2 - Data were collected and are being evaluated by the sponsor.

DSO 476 In-Flight Aerobic Exercise - The treadmill was used satisfactorily and no malfunctions of the treadmill were observed.

DSO 601 Changes in Baroreflex Function - Data were collected for this experiment and will be evaluated by the sponsor.

DSO 605 Postural Equilibrium Control During Landing/Egress - Data were collected at the landing site and are being evaluated by the sponsor.

DSO 606 Muscle Size and Lipids (MRI/MRS) - Data were collected for this experiment and will be evaluated by the sponsor.

DSO 611 Air Monitoring Instrument Evaluation and Atmospheric characterization (Microbial Air Sample and Archival Organic Sampler - Data were collected for this experiment are will be evaluated by the sponsor.

DSO 901 Documentary Television - All documentary television data will be evaluated by the sponsor.

DSO 902 Documentary Motion Picture Photography - Much data were collected for this experiment and will be evaluated by the sponsor.

DSO 903 Documentary Still Photography - Much data were collected for this experiment and will be evaluated by the sponsor.

DSO 904 Assessment of Human Factors - Data were collected for this experiment and are being evaluated by the sponsor.

TABLE I.- STS-40 SEQUENCE OF EVENTS

Event	Description	Actual time, G.m.t.
APU activation	APU-1 GG chamber pressure	156:13:20:09.33
	APU-2 GG chamber pressure	156:13:20:08.40
	APU-3 GG chamber pressure	156:13:20:07.34
SRB HPU activation	LH HPU system A start command	156:13:24:23.198
	LH HPU system B start command	156:13:24:23.358
	RH HPU system A start command	156:13:24:23.518
	RH HPU system B start command	156:13:24:23.678
Main propulsion System start	Engine 3 start command accepted	156:13:24:44.466
	Engine 2 start command accepted	156:13:24:44.558
	Engine 1 start command accepted	156:13:24:44.708
SRB ignition command (lift-off)	SRB ignition command to SRB	156:13:24:51.008
Throttle up to 104 percent thrust	Engine 3 command accepted	156:13:24:55.107
	Engine 2 command accepted	156:13:24:55.078
	Engine 1 command accepted	156:13:24:55.108
Throttle down to 98 percent thrust	Engine 3 command accepted	156:13:25:11.427
	Engine 2 command accepted	156:13:25:11.399
	Engine 1 command accepted	156:13:25:11.429
Throttle down to 71 percent thrust	Engine 3 command accepted	156:13:25:20.707
	Engine 2 command accepted	156:13:25:20.679
	Engine 1 command accepted	156:13:25:20.709
Maximum dynamic pressure (q)	Derived ascent dynamic pressure	156:13:25:43
Throttle up to 104 percent thrust	Engine 3 command accepted	156:13:25:51.428
	Engine 2 command accepted	156:13:25:51.400
	Engine 1 command accepted	156:13:25:51.430
Both SRM's chamber pressure at 50 psi	LH SRM chamber pressure mid-range select	156:13:26:50.808
	RH SRM chamber pressure mid-range select	156:13:26:50.448
End SRM action	LH SRM chamber pressure mid-range select	156:13:26:53.498
	RH SRM chamber pressure mid-range select	156:13:26:52.748
SRB separation command	SRB separation command flag	156:13:26:55.XXX
SRB physical separation	SRB physical separation	156:13:26:55.848
Throttle down for 3g acceleration	Engine 3 command accepted	156:13:32:20.718
	Engine 2 command accepted	156:13:32:20.674
	Engine 1 command accepted	156:13:32:20.722
3g acceleration	Total load factor	156:13:32:21
MECO	MECO command flag	156:13:33:21
	MECO confirm flag	156:13:33:22
ET separation	ET separation command flag	156:13:33:40
OMS-1 ignition	Left engine bi-prop valve position	N/A
	Right engine bi-prop valve position	Not performed - direct insertion trajectory flown

XXX = Data loss

TABLE I.- CONTINUED

Event	Description	Actual time, G.m.t.
OMS-1 cutoff	Left engine bi-prop valve position	N/A
	Right engine bi-prop valve position	Not performed - direct insertion trajectory flown
APU deactivation	APU-1 GG chamber pressure	156:13:39:04.14
	APU-2 GG chamber pressure	156:13:39:02.39
	APU-3 GG chamber pressure	156:13:39:01.97
OMS-2 ignition	Left engine bi-prop valve position	156:14:07:09.4
	Right engine bi-prop valve position	156:14:07:09.3
OMS-2 cutoff	Left engine bi-prop valve position	156:14:09:13.9
	Right engine bi-prop valve position	156:14:09:14.0
Payload bay door open	PBD right open 1	156:15:00:07
	PBD left open 1	156:15:00:07
Flight control system checkout		
APU start	APU-2 GG chamber pressure	164:14:08:27.93
APU stop	APU-2 GG chamber pressure	164:14:15:27.94
Payload bay door close	PBD left close 1	165:11:20:23
	PBD right close 1	165:12:05:38
APU activation for entry	APU-1 GG chamber pressure	165:14:32:53.94
	APU-2 GG chamber pressure	165:14:55:54.10
	APU-3 GG chamber pressure	165:14:55:55.19
Deorbit maneuver ignition	Left engine bi-prop valve position	165:14:37:36.2
	Right engine bi-prop valve position	165:14:37:36.0
Deorbit maneuver cutoff	Left engine bi-prop valve position	165:14:40:26.0
	Right engine bi-prop valve position	165:14:40:26.0
Entry interface (400k)	Current orbital altitude above reference ellipsoid	165:15:07:49
Blackout ends	Data locked at high sample rate	No blackout
Terminal area energy management	Major mode change (305)	165:15:33.00
Main landing gear contact	LH MLG tire pressure	165:15:39:11
	RH MLG tire pressure	165:15:39:11
Main landing gear weight on wheels	LH MLG weight on wheels	165:15:39:12
	RH MLG weight on wheels	165:15:39:11
Nose landing gear contact	NLG tire pressure	165:15:39:25

TABLE I.- CONTINUED

Event	Description	Actual time, G.m.t.
Nose landing gear weight on wheels	NLG WT on Wheels -1	165:15:39:25
Wheels stop	Velocity with respect to runway	165:15:40:05
APU deactivation	APU-1 GG chamber pressure	165:15:57:36.68
	APU-2 GG chamber pressure	165:15:57:55.13
	APU-3 GG chamber pressure	165:15:57:55.85

TABLE II.- STS-40 PROBLEM TRACKING LIST

Number	Title	Reference	Comments
STS-40-V-01	IMU 2 Failed Preflight Calibration (Caused Scrub)	152:06:00 G.m.t. Prelaunch CAR 40RF01	During the second launch attempt, the first preflight calibration showed shifts in the IMU 2 accelerometer data. The calibration was repeated twice and the data indicated a problem with the stability of the accelerometer. IMU 2 was removed and replaced. The IMU that was removed checked out satisfactorily in the laboratory.
STS-40-V-02	Aft Bulkhead/Payload Bay Interface Damage a) Payload Bay Door Environmental Seal Damage b) Loose blankets on 1307 bulkhead	156:15:55 G.m.t. IM 40RF03 IM 40RF02	Several thermal blankets on the 1307 bulkhead became partially unfastened. A section of the aft bulkhead payload bay door environmental seal (port side) was also debonded and was protruding into the payload bay. No ferry impact. Chit J3595A. Seal separated at splice. Identified substandard bond to RTV base.
STS-40-V-03	Lithium Hydroxide (LiOH) Door Aft Port Latch Won't Close	157:10:47 G.m.t. IM 40RF04	Crew reported that the aft port latch on the LiOH stowage door was closed. IFM tools were used to pry the latch open. Tools used to close for entry. Latch operated freely postflight.
STS-40-V-04	OMS Crossfeed Line Heater A Failed Off (V43T6242A)	157:19:40 G.m.t. IM 40RF05 IPR 50V-0004	OMS crossfeed center thermostat on heater A system would not control in its normal range. KSC: Normal heater checks per V43CAO.020 No ferry impact. Heaters off for ferry.
STS-40-V-05	Video Interface Unit-C Malfunction	158:23:10 G.m.t.	Power cable didn't work until after an IFM was performed on the unit. Interface cable loses signal when cable jiggled. Ship VIU and cable to JSC FEPC.
STS-40-V-06	TAGS Problems: a) False Jam Indicator Light b) Real Jam	 Throughout mission until TAGS jam 162:09:52 G.m.t.	 TAGS jam indication was initiated during initial TAGS uplink and several times thereafter. Indication was confirmed to be false. Indication cleared by uplinking page advance. TAGS jam occurred most likely at the end of a Mode 1 uplink as previous page entered the developer. Subsequent page advance proved the jam to be a true jam. KSC: Send TAGS unit to JSC FEPC
STS-40-V-07	L5L Thruster Failed Off	158:00:51 G.m.t. IM 40RF06	Vernier thruster L5L failed off by redundancy management (RM) due to low chamber pressure. The thruster was hot fired and reselected. Thruster was used remainder of flight with erratic chamber pressure Thruster removed and replaced and sent to Marquardt. Fuel sample analysis required. Chit J-3705
STS-40-V-08	Hydrogen Tank 3 Heater A Failed Off	163:05:45 G.m.t. IM 40RF07 IPR 50V-0005	Heater failed after several cycles on automatic. KSC is to troubleshoot.
STS-40-V-09	Loose Thermal Cover on Tunnel Adapter Top Hatch	162:13:53 G.m.t. IM 40RF08	The cover on the EVA hatch was noticed to be loose after the fifth orbit began. Postflight inspection is required.
STS-40-V-10	Lower Left and Lower Right S-Band Quad Antennas Had Erratic Communications	PR 2-A0027 PR UA 2-A0012 IM 40RF09	Degraded performance on these antennas during the entire flight. MCR approval required to work at Palmdale during major modification.

TABLE II.- STS-40 PROBLEM TRACKING LIST

Number	Title	Reference	Comments
STS-40-V-11	Right ET/Orbiter Door Thermal Damage	Postlanding IM 40RF10	Forward centerline latch fitting and adjacent tile exhibited significant melting/erosion. Hot air flow path traced to exit gap in in RTV seal at aft corner of fixed structure.
STS-40-V-12	APU 1 Service Line Temperature Rise	165:14:38 G.m.t. IM 40RF11	During the deorbit maneuver following APU 1 start, V46T0183A rose to 99 °F (FDA limit = 95 °F). Generated THRM APU message. Temperature began to decline before heater B was turned off. Inspection of heater wrap required.
STS-40-V-13	a. Loss of Communications on Audio Interface Unit (AIU) -D	161:22:00 G.m.t.	AIU's and SAGI (Spacelab Audio Ground Isolator) to be returned to JSC for troubleshooting. Audio Control Interface Unit to be returned to MSFC.
	b. Temporary Loss of Communications on AIU-E	163:10:20 G.m.t.	
STS-40-V-14	a. 16 mm ET Umbilical Camera Anomaly b. 35 mm ET Umbilical Camera Anomaly	Postlanding Inspection	a. Film was broken 30 ft. from the start. Camera continued to run and camera had some sprocket damage. b. Film broken 6 inches from the start.
STS-40-V-15	Ground Command Interface Logic PDI Command Anomaly	156:22:25 G.m.t. IM 40Rf12	PDI switch scan (V75S5100E) changed state when PDI off/on uplink commands were issued. Suspect reverse current leakage across ground interface command logic driver.
STS-40-V-16	Umbilical Separation Pin Guide Fitting Detached at ET Separation	Film Analysis	Object observed at ET separation in umbilical well camera film. Analysis of photography shows item appearing to be outboard guide pin bushing from liquid hydrogen umbilical.

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