NASA-CR-193056

NASA-CR-193,056

NSTS-08279

NASA-CR-193056
19930016771

STS-47 SPACE SHUTTLE MISSION REPORT

(NASA-CR-193056) STS-47 SPACE SHUTTLE MISSION REPORT (Lockheed Engineering and Sciences Co.) 38 p
N93-25960
Unclas
G3/16 0163575

October 1992

NASA
National Aeronautics and
Space Administration

Lyndon B. Johnson Space Center
Houston, Texas

STS-47

SPACE SHUTTLE

MISSION REPORT

Prepared by

Robert W. Fricke, Jr.
LESC/Flight Evaluation and
Engineering Office

Approved by

Michael Engle
STS-47 Lead Mission Evaluation Room Manager

David W. Camp
Manager, Flight Engineering Office

D. M. Germany
Manager, Orbiter and GFE Projects

Leonard S. Nicholson
Program Manager, Space Shuttle

Prepared by
Lockheed Engineering and Sciences Company
for
Flight Engineering Office

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
LYNDON B. JOHNSON SPACE CENTER
HOUSTON, TEXAS 77058

October 1992

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INTRODUCTION

The STS-47 Space Shuttle Program Mission Report provides a summary of the Orbiter, External Tank (ET), Solid Rocket Booster/Redesigned Solid Rocket Motor (SRB/RSRM), and the Space Shuttle main engine (SSME) subsystem performance during the fiftieth Space Shuttle Program flight; and the second flight of the Orbiter vehicle Endeavour (OV-105). In addition to the Endeavour vehicle, the flight vehicle consisted of an ET which was designated ET-45 (LWT-38); three SSME's which were serial numbers 2026, 2022, and 2029 and were located in positions 1, 2, and 3, respectively; and two SRB's which were designated BI-053. The lightweight/redesigned RSRM that was installed in the left SRB was designated 360L026A, and the RSRM that was installed in the right SRB was 360W026B.

The STS-47 Space Shuttle Program Mission Report fulfills the Space Shuttle Program requirement, as documented in NSTS 07700, Volume VIII, Appendix E, which states that each major organizational element supporting the Program will report the results of its hardware evaluation and mission performance plus identify all related in-flight anomalies.

The sequence of events for the STS-47 mission is shown in Table I, and the Official Orbiter and GFE Projects Problem Tracking List is shown in Table II. In addition, the report also discusses each Orbiter, SSME, ET, and SRB/RSRM subsystem anomaly in the applicable section of the report, and a reference to the official assigned tracking number is mentioned in the body of the report. Additionally, all times in the text of the report are given in both Greenwich mean time (G.m.t.) and mission elapsed time (MET).

The primary objective of the STS-47 flight was to successfully perform the planned operations of the Spacelab-J (SL-J) payload [containing 43 experiments of which 34 were provided by the Japanese National Space Development Agency (NASDA)]. The secondary objectives of this flight were to perform the operations of the Israeli Space Agency Investigation About Hornets (ISAIAH) payload, the Solid Surface Combustion Experiment (SSCE), the Shuttle Amateur Radio Experiment-II (SAREX-II), and the Get-Away Special (GAS) payloads. The Ultraviolet Plume Instrument (UVPI) was flown as a payload of opportunity.

The STS-47 mission was planned as a seven-day flight, however, a decision was made midway through the flight to extend the flight duration approximately 24 hours.

The crew for this fiftieth Space Shuttle flight was Robert L. "Hoot" Gibson, Capt., USN, Commander; Curtis L. Brown, Jr., Major, USAF, Pilot; Mark C. Lee, Lt. Col., USAF, Payload Commander, Mission Specialist 1; Jerome Apt, Ph.D., Civilian, Mission Specialist 2; N. Jan Davis, Ph.D., Civilian, Mission Specialist 3; Mae C. Jemison, M.D., Civilian, Mission Specialist 4; and Mamoru Mohri, Ph.D., Civilian, Payload Specialist 1. STS-47 was the fourth space flight for the Commander, the second space flight for Mission Specialist 1 and Mission Specialist 2, and the first space flight for the Pilot, Mission Specialist 3, Mission Specialist 4, and Payload Specialist 1.

MISSION SUMMARY

The STS-47 mission was launched at 256:14:23:00.010 G.m.t. (10:23:00 a.m. e.d.t. on September 12, 1992) from Launch Complex 39B at Kennedy Space Center (KSC). STS-47 was a Spacelab-J mission, a joint venture between NASA and the NASDA of Japan.

Approximately 7 hours prior to launch and during hydrogen fast-fill, the hydrogen concentration in the aft compartment reached 550 ppm, exceeding the Launch Commit Criteria (LCC) limit of 500 ppm. The leak was in the low-pressure portion of the system and the leak rate was not expected to increase since flight pressures were the same level as those experienced during fast-fill. Based on this logic, a waiver was approved. During replenish, the hydrogen concentration dropped below the LCC limits.

The improved auxiliary power unit (IAPU) 3 fuel test line temperature exceeded the LCC lower limit of 48°F. A waiver was approved which allowed the temperature to go down to 43°F; however, the lowest temperature experienced was 46°F.

All SSME and RSRM start sequences occurred as expected and the launch phase performance was satisfactory in all respects. First stage ascent performance was normal with SRB separation, entry, deceleration, and water impact occurring as anticipated. Both SRB's were recovered. Performance of the SSME's, ET, and main propulsion system (MPS) was also normal, with main engine cutoff (MECO) occurring at approximately 513.6 seconds after lift-off. A determination of 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 3-g throttling was 452.2 seconds as compared to an average engine tag value of 452.27 seconds.

During ascent, problems were experienced with two of the three water spray boilers (WSB's). A slight over-temperature condition was experienced on WSB system 1 when spray initiation began late, but the system recovered while still on controller A. WSB system 3 did not cool IAPU 3 while operating on controller A; a switch to controller B did not appear to recover operation of WSB system 3 and IAPU 3 was shut down early after the completion of ascent. IAPU 1 and 2 were shut down approximately 1 minute 50 seconds later.

During the ET separation maneuver at 256:14:33 G.m.t. (00:00:10 MET), reaction control subsystem (RCS) thruster L3A failed to operate. The thruster was deselected for the remainder of the mission.

With the successful completion of the 159.3-second orbital maneuvering subsystem (OMS) -2 maneuver, the Orbiter was inserted into a 165 by 164 nmi. orbit having an inclination of 57 degrees.

The first fuel cell purge was performed at 23 hours MET, with additional purges performed approximately every 48 hours for the remainder of the mission. A final purge was made within 8 hours of entry. This proved to be a satisfactory mode of operation as no fuel cell voltage degradations greater than 0.1 V were seen between purges.

RCS vernier thruster L5D experienced degraded chamber pressure (80 psia with 110 psia nominal). Mission trend data indicated a slow degradation from 103 psia to 76 psia with some recovery on longer burns. A 4.5-second hot-fire test, followed by a 5-second rate-damping firing of L5D, was performed with no significant improvement in chamber pressure. Following the flight control system (FCS) checkout, the chamber pressure on RCS thruster L5D returned to near nominal values.

The FCS checkout was completed at 262:09:57:57.64 G.m.t. (05:19:34:57.64 MET) using IAPU 3 and all systems operated satisfactorily. IAPU 3 operation was extended to 12 1/2 minutes to verify proper cooling by WSB 3 on both controllers. WSB cooling was attained at nominal temperatures.

The RCS hot-fire test was performed at 264:06:13 G.m.t. (07:15:50 MET). All thrusters operated nominally except L3A which had been deselected since early in the mission.

Because of potentially unsatisfactory weather at KSC, the Orbiter was waved off for the first landing opportunity on flight day 8. Weather conditions were acceptable for the second landing attempt and the decision was made to land at KSC on the second opportunity.

Both payload bay (PLB) doors were closed nominally by 264:09:15:56 G.m.t. (07:18:52:56 MET). The deorbit maneuver was performed at 264:11:52:20.2 G.m.t. (07:21:29:20.2 MET). The maneuver was approximately 153.0 seconds in duration and the differential velocity (ΔV) was 262.4 ft/sec. Entry interface occurred at 264:12:21:43 G.m.t. (07:21:58:43 MET).

Main landing gear touchdown occurred at KSC on concrete runway 33 at 264:12:53:22 G.m.t. (07:22:30:22 MET), followed by Orbiter weight-on-wheels one second later. The Orbiter drag chute was deployed satisfactorily at 264:12:53:30.7 G.m.t. (07:22:23:30.7 MET) which was prior to nose gear touchdown. Nose landing gear touchdown occurred 8.1 seconds after drag chute deployment with wheels stop at 264:12:54:11 G.m.t. (07:22:31:11 MET). After disreefing, the drag chute maintained a position approximately 8 degrees starboard of the Orbiter centerline. This displacement caused a yawing moment to the left on the Orbiter during rollout. The flight duration was 7 days 22 hours 30 minutes 22 seconds. The crew completed the required postflight reconfigurations and exited the Orbiter landing area.

Thirteen of the 14 Development Test Objectives (DTO's) and all 11 of the detailed supplementary objectives (DSO's) were completed.

VEHICLE PERFORMANCE

SOLID ROCKET BOOSTER/REDESIGNED SOLID ROCKET MOTORS

All SRB systems performed as expected throughout ascent. The SRB prelaunch countdown was normal. RSRM propulsion performance was well within the required specification limits, and the propellant burn rate for each RSRM was normal. All SRB thrust vector control (TVC) prelaunch conditions and flight performance requirements were met with ample margins. All electrical functions were performed properly. No SRB or RSRM LCC violations were noted during the countdown. One Operations and Maintenance Requirements and Specifications Document (OMRSD) violation occurred during the Orbiter fuel cell activation sequence. The SRB power transfer busses experienced a slight over-voltage similar to that observed on STS-46. The OMRSD limit of 32.0 Vdc was exceeded by 0.189 Vdc on both A busses, and by 0.106 Vdc and 0.023 Vdc on the right and left B busses, respectively. This condition was officially waived prior to lift-off.

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. For this flight, the heated ground purge in the SRB aft skirt was not needed to maintain the case/nozzle joint and flexible bearing temperatures within the required LCC ranges; however, it was activated at T-15 minutes to inert the aft skirt area of any hydrazine.

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.

Preliminary data indicates that the flight performance of both RSRM's was well within the allowable performance envelopes, and was typical of the performance observed on previous flights. The mean bulk temperature was 82°F at lift-off. Key RSRM propulsion performance parameters are presented in the table on the following page.

Both SRB's were satisfactorily separated from the ET at T + 124.0 seconds, and 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. The entry and deceleration subsystems performed properly on both SRB's. RSRM nozzle jettison occurred after frustum separation, and all subsequent parachute deployments were successfully performed. Both SRB's were retrieved by the recovery ships and returned to KSC for drying, disassembly, and refurbishment.

EXTERNAL TANK

All objectives and requirements associated with ET propellant loading and flight operations were met satisfactorily. ET flight performance was excellent. All electrical and instrumentation equipment performed satisfactorily throughout the countdown and flight. All ET purge and heater operations were monitored and all performed properly. Propellant loading was completed as scheduled, and all prelaunch thermal requirements were met. No LCC or OMRSD violations were identified.

As expected, only the normal ice/frost formations for the September atmospheric environment were observed during the countdown. There was no frost or ice on the acreage areas of the ET. Normal quantities of ice or frost were present on the liquid oxygen (LO_2) and liquid hydrogen (LH_2) feed lines and on the pressurization line brackets. A small amount of frost was also present along the edge of the LH_2 protuberance air load (PAL) ramps. All of these observations were acceptable based on NSTS 08303. The Ice/Frost Red Team also reported that no anomalous TPS conditions were noted.

RSRM PROPULSION PERFORMANCE

Parameter	Left motor, 82°F		Right motor, 82°F	
	Predicted	Actual	Predicted	Actual
Impulse gates				
I-20, 10^6 lbf-sec	66.08	66.18	66.28	66.11
I-60, 10^6 lbf-sec	175.95	176.25	176.40	176.39
I-AT, 10^6 lbf-sec	296.64	295.91	296.81	297.16
Vacuum Isp, lbf-sec/lbm	268.6	267.8	268.6	268.8
Burn rate, in/sec @ 60 °F at 625 psia	0.3673	0.3687	0.3677	0.3673
Event times, seconds				
Ignition interval[a]	0.232	N/A	0.232	N/A
Web time[a]	109.0	109.0	108.7	109.0
Separation cue, 50 psia	118.7	118.0	118.4	118.9
Action time	120.7	120.1	120.5	121.3
PMBT, °F	82.0	82.0	82.0	82.0
Maximum ignition rise rate, psia/10 ms	90.4	N/A	90.4	N/A
Decay time, seconds (59.4 psia to 85 K)	2.8	2.8	2.8	3.1
Tailoff imbalance Impulse differential, klbf-sec	Predicted N/A		Actual[b] 629.4	

Notes:
[a] All times are referenced to ignition command time except where noted by the letter a. These items are referenced to lift-off time (Ignition interval).
[b] Impulse imbalance is equal to left motor minus right motor, and was calculated by MSFC.

The ET pressurization system functioned properly throughout engine start and flight. The minimum ullage pressure experienced during the period of ullage pressure slump was 14.3 psid.

ET separation was confirmed to have occurred properly, and based on the MECO time, entry and breakup occurred within the predicted footprint. Radar data from Bermuda confirmed that the ET did not tumble.

There were no significant ET problems identified; however, during the postflight review of the Orbiter umbilical well camera film, a large divot was observed on the intertank TPS (Flight Problem STS-47-T-1). The missing TPS was located just forward of the LH_2 splice closeout, centered between the -Y and +Y bipods in the two-tone TPS area. Detailed photographic analyses show the divot to be approximately 16 inches in diameter with an indeterminable depth. This ET used the older two-tone TPS configuration (CPR-488 over BX-250 with an isochem adhesive). Historical problems with the two-tone configuration occurred during the manufacturing phase and extensive efforts have been made to resolve the condition. Numerous possible causes of the divot on this ET were postulated, but no positive cause of the divot could be identified. Consequently, this is an unexplained anomaly and an isolated incident.

SPACE SHUTTLE MAIN ENGINE

All SSME parameters appeared to be normal throughout the prelaunch countdown and were typical of prelaunch parameters observed on previous flights. Launch ground support equipment (GSE) provided adequate control for the SSME's during launch preparation. All engine-related conditions for engine start were achieved at the proper time, all LCC were met, and engine start and thrust buildup were normal.

Flight data indicates that SSME performance during mainstage, throttling, shutdown and propellant dump was well within specifications. All three engines started and operated normally. High pressure oxidizer turbopump (HPOTP) and high pressure fuel turbopump (HPFTP) temperatures were well within specification throughout engine operation.

The SSME controllers provided 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. One anomaly was identified in the SSME data that occurred during the SSME start and mainstage phases, when SSME 1 (unit no. 2026) HPOTP secondary turbine seal cavity pressure (channel A) exhibited numerous downward spikes (Flight Problem STS-47-E-1). An in-depth data review revealed approximately 46 spikes of which one occurred on successive frames of data. No spikes occurred during the chill or shutdown phases. The sensor was not disqualified during the mission, indicating that there were not three successive spikes below 4 psia (lower qualification limit). The sensor had 2,588 seconds of firing time plus seven engine starts (two of which were STS-39 and STS-42). The sensor was returned to the vendor where vibration testing and tap checks duplicated the anomaly. During the sensor teardown process, four metallic particles were found in the sensor reference cavity with the largest particle being 0.20 inch long and identified as A-286 material. This large particle was capable of shorting the signal output header pin/wire to the case, and the particles in the sensor reference cavity were the cause of the anomalous data spikes.

SHUTTLE RANGE SAFETY SYSTEM

The Shuttle Range Safety System (SRSS) closed-loop testing was completed as scheduled during the launch countdown. All SRSS safe and arm (S&A) devices were armed, and system inhibits were turned off at the appropriate times. All SRSS measurements indicated that the system performance was as expected throughout the flight.

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

ORBITER SUBSYSTEMS PERFORMANCE

Main Propulsion System

The overall performance of the MPS was excellent. All pretanking purges were properly performed, and loading of LO_2 and LH_2 was completed during the launch countdown with no stop-flows or reverts. The MPS helium system performed satisfactorily. There were no OMRSD violations.

Approximately 7 hours prior to launch and during hydrogen fast-fill, the hydrogen concentration in the aft compartment reached 550 ppm, exceeding the Launch Commit Criteria (LCC) limit of 500 ppm (Flight Problem STS-47-V-01). The 60-ppm increase in the aft compartment concentration associated with the start of the recirculation pumps was normal, indicating that the leak in the aft compartment was within the low-pressure LH_2 system. Since ascent pressures in this system are comparable to those experienced during fast-fill, it was concluded that the leak would not increase during ascent, and that the maximum concentration of 550 ppm was safe to fly and comparable with OV-102 experience. Additionally, experience has shown that each vehicle has a unique leakage signature, with OV-102 having a 600-ppm LCC. OV-105 still has a very small experience base. Based on this logic, a waiver was approved. During replenish, the hydrogen concentration dropped below the LCC limits.

The aft compartment hydrogen concentration dropped to 75 ppm after hydrogen loading proceeded into topping and the ET was vented. Aft compartment concentrations remained below 100 ppm for the duration of loading.

A comparison of the calculated propellant loads at the end of replenish versus the inventory load results in a loading accuracy of -0.034 percent for LH_2 and -0.0083 percent for LO_2.

Ascent MPS performance was satisfactory. Preliminary data indicates that the LO_2 and LH_2 pressurizations systems performed as planned, and that all net positive suction pressure (NPSP) requirements were met throughout the flight; however, the engine 1 LH_2 inlet pressure measurement failed off-scale low at approximately 256:14:25:23 G.m.t. (00:02:23 MET) (Flight Problem STS-47-V-04). Space Shuttle main engine cutoff (MECO) occurred 513.6 seconds after lift-off. Helium consumption of 57.3 lbm was satisfactory during entry and landing.

The gaseous oxygen (GO_2) fixed orifice pressurization system performance was satisfactory. The minimum ullage pressure slump was 14.3 psig. Flow control valve (FCV) performance was nominal, and for this vehicle the FCV's were shimmed to a 77.6-percent flow area. Helium consumption during entry system blowdowns was 57.3 lbm, which is within the historical fleet limits.

The MPS thrust vector control (TVC) isolation valves were not opened prior to initiating the SSME actuator repositioning sequence, and this resulted in a 14-degree differential between the commanded and the actual position. The crew was requested to terminate the sequence and shut down the IAPU's because opening the TVC isolation valves would have resulted in a large step command to the actuators that may have damaged the actuators or hydraulic lines.

Reaction Control Subsystem

The RCS performance was acceptable and the subsystem met all requirements; however, two thruster anomalies were noted. The RCS was also used to perform DTO 251 - Entry Aerodynamic Control Surface Test Alternate Elevon Schedule. RCS propellant consumption for the mission was 3917.2 lb.

During the ET separation maneuver at 256:14:33 G.m.t. (00:00:10 MET), RCS primary thruster L3A failed to operate (Flight Problem STS-47-V-03). Data indicated low chamber pressure (<8 psia) and the thruster was deselected for the remainder of the mission. Injector temperatures indicated that both oxidizer and fuel flow occurred. The low chamber pressure was most likely due to full fuel flow and only partial (pilot-valve only) flow through the oxidizer valve.

RCS vernier thruster L5D experienced degraded chamber pressure (69 psia with 110 psia nominal) (Flight Problem STS-47-V-09). Mission trend data indicated a slow degradation from 103 psia to 69 psia with some recovery on longer burns. A 4.5-second hot-fire test, followed by a 5-second rate-damping firing of L5D, was performed with no significant improvement in chamber pressure. This condition was experienced on a number of previous missions and is believed to be caused by nitrate accumulation at the oxidizer valve trim orifice. However, following the FCS checkout during which a series of longer duration firings were made, the chamber pressure on RCS thruster L5D suddenly increased to nominal values. About 12 hours later, the pressure again began decreasing at the rate of approximately 6 psia per day, and at the end of the mission, the chamber pressure had decayed to 95 psia.

The RCS hot-fire test was performed at 264:06:13 G.m.t. (07:15:50 MET). All thrusters operated nominally except L3A which had been deselected early in the mission.

Orbital Maneuvering Subsystem

The OMS performance was nominal throughout the STS-47 mission with two firings completed normally:

a. OMS-2 - A 159.3-second firing with a ΔV of 261.8 ft/sec.

b. Deorbit - A 153.0-second firing with a ΔV of 262.4 ft/sec.

Gaging system performance was nominal throughout the flight with all post-firing quantities within 1 percent of calculated values. The propellant consumption during the two OMS firings was 7494 lb of oxidizer and 4498 lb of fuel for a total consumption of 11,992 lb.

Power Reactant Storage and Distribution Subsystem

The power reactant storage and distribution (PRSD) subsystem performance was nominal throughout the mission. The potential mission extension time remaining at the end of the mission, based on the average power level of 17.1 kW, was

48.3 hours. A total of 281.1 lb of hydrogen and 2331.9 lb of oxygen was consumed during the mission with 101.8 lb of the total oxygen supplied to the crew for breathing purposes.

The PRSD oxygen tank 4 heater control pressure began reading off-scale low at 256:15:30 G.m.t. (00:01:07 MET) (Flight Problem STS-47-V-06), but the indication returned to normal during entry. This condition did not impact operations, as the tank 3 heater control pressure transducer was used to control the tank 4 heater. Oxygen tanks 3 and 4 supplied the fuel cells the first day with no impact from the tank 4 heater control pressure. For troubleshooting purposes, oxygen tank 4 was operated independent of oxygen tank 3, decoupling the control logic of the oxygen tanks 3 and 4 heater control boxes. The oxygen tank 4 heaters remained on even though the backup tank pressure measurement indicated that the tank pressure was above the heater-off value. This condition verified that the oxygen tank 4 heater control logic was sensing 515 psia (off-scale low) heater control pressure. Oxygen tanks 3 and 4 were recoupled for the remainder of the mission. The measurement began performing satisfactorily after terminal area energy management (TAEM).

Fuel Cell Powerplant Subsystem

The fuel cell powerplant subsystem performed satisfactorily throughout the mission. A total of 3249.7 kWh of energy was produced with an average power level of 17.1 kW/556.2 amperes. The fuel cells produced 2511 lb of water during the mission.

The first fuel cell purge was performed at 23 hours MET, with additional purges performed approximately every 48 hours for the remainder of the mission. A final purge was made within 8 hours of entry. No fuel-cell voltage degradations greater than 0.1 V were seen between purges.

At approximately 256:17:53 G.m.t. (00:03:30 MET), the fuel cell water overboard relief line temperature began stepping down to a low of 57°F. The fuel cell water relief line temperature remained erratic, indicating minor leakage past the fuel cell 3 relief valve, which had a slightly depressed temperature (Flight Problem STS-47-V-08). Even in the worst-case scenario of the line freezing, this condition could not have impacted the mission because two other paths existed through which fuel cell water could be dispensed (to the potable water tank and to waste water tank B). These other paths were preferable to the overboard relief system. Because the temperature of the relief line was dropping below the fault detection annunciator (FDA) limit of 60°F, this limit was reduced to 53°F to prevent nuisance alarms. Later in the mission, the water relief nozzle heaters cycled, confirming leakage of fuel cell water.

The fuel cell 2 oxygen flowmeter had erratic readings which began about 5 minutes prior to landing (2 minutes 14 seconds after the start of the TAEM) and lasted for approximately 10 1/2 minutes (Flight Problem STS-47-V-14). This condition has been experienced on previous flights.

Fuel cell 3 was inadvertently shut down 13 hours after landing when a headset cord caught in the fuel-cell controller switch and moved the switch to the off position. There was no damage to the fuel cell because of the inadvertent shut down. The other two fuel cells were shut down normally about 23 hours after landing.

Auxiliary Power Unit Subsystem

The IAPU performance was nominal with the exception of two anomalies, neither of which had an impact on the satisfactory operation of the IAPU's. The following table presents run times as well as propellant consumption for the IAPU's.

Flight Phase	IAPU 1 (S/N 303)		IAPU 2 (S/N 401)		IAPU 3 (S/N 207)	
	Time, min:sec	Fuel consumption, lb	Time, min:sec	Fuel consumption, lb	Time, min:sec	Fuel consumption, lb
Ascent	19:48	48	19:48	48	17:56	45
FCS checkout					12:38	34
Entry[a]	58:35	115	80:21	148	58:31	117
Total[a]	78:23	163	100:09	196	89:05	196

[a]The IAPU's were operated for approximately 14 minutes 29 seconds after landing.

Prior to launch, IAPU 3 fuel test line temperature exceeded the LCC lower limit of 48°F (Flight Problem STS-47-V-02). Since heater cycling had been verified, a waiver was approved that allowed the temperature to go down to 43°F, which is the minimum temperature to preclude freezing prior to the time that the crew can activate the heaters after orbital insertion; however, the lowest temperature experienced was 46°F. During ascent, the IAPU 1 fuel test line temperature fell below the FDA limit and an alarm was sounded. This condition is explainable as the heaters are normally not powered for ascent.

IAPU 3 was shutdown early after the completion of ascent when the bearing temperature reached 335°F because WSB 3 was not providing any cooling. A discussion of the WSB cooling anomaly is contained in the Hydraulics/Water Spray Boiler section of this report.

The IAPU 1 drain line temperature 2 consistently exhibited a temperature of 47°F before normal heater cycling resumed (Flight Problem STS-47-V-16). This condition also occurred during STS-49, and at that time the FDA limit was reduced to 45°F to prevent nuisance alarms. For this mission, the FDA limit was reduced to 46°F, and no additional alarms were noted.

The IAPU 3 drain line temperature 2 decreased to 43°F on the first heater cycle. The FDA lower limit is 48°F. The FDA limit was lowered to 43°F and all subsequent cycles were normal. Other than lowering the FDA limit after ascent to 43°F, no other corrective action was required for this measurement.

The IAPU 1 test line temperatures 1 and 2 violated the lower FDA limit for one heater cycle just after IAPU shutdown following ascent. The FDA limit was lowered to 45°F and no further alarms occurred. This same signature was seen on STS-49, and analysis and investigation showed that the heater was not installed in accordance with the print. The heater will be restored to the drawing specification prior to the next flight.

IAPU 3 experienced three gearbox repressurizations during entry: one at the start of entry, one about 16 minutes later, and the third occurred about 32 minutes after IAPU start. No FDA limits were violated and all other lubrication system parameters remained nominal. The gearbox pressure increased during atmospheric flight and while on the runway, indicating that the gearbox pressure was leaking through the turbine seal. This condition has occurred on the previous flights of the IAPU's, and appears to be characteristic of the IAPU's.

Hydraulics/Water Spray Boiler Subsystem

The hydraulics subsystem operation was nominal throughout the flight and WSB subsystem operation was acceptable with three anomalies noted.

During ascent, WSB 1 and 3 displayed anomalous operation with WSB 1 exhibiting a delay in IAPU 1 lubrication oil cooling (Flight Problem STS-47-V-05), and WSB 3 exhibiting no cooling until just prior to the early shut down of IAPU 3 (Flight Problem STS-47-V-07). WSB 1 did not begin spraying until the IAPU 1 lubrication oil temperature reached 280°F. Once cooling started, the WSB over-cooled (below 250°F) to 236°F before beginning to operate properly. The File IX in-flight checkout limit of 275°F was violated; consequently, a WSB 1 checkout as well as a hot-oil flush were performed during postflight turnaround activities because the lubrication oil temperature exceeded 275°F. In addition, the WSB 1 regulator outlet pressure steadily increased throughout the flight, indicating that leakage past the regulator was occurring (Flight Problem STS-47-V-20).

During ascent, WSB 3 failed to cool on controller A, and when switched to controller B, the temperature continued to climb to 335°F when a decision was made to shutdown IAPU 3 early. Cooling began just before IAPU 3 was shut down and for about 2 minutes more before WSB spray cooling was shut off. The WSB performed satisfactorily on controller A and B during the FCS checkout as well as on controller B during entry. All of these conditions are indicative of water spray bar freeze-up during ascent.

Also during ascent, the WSB 2 regulator outlet pressure sensor reading remained at the initial reading while the actual pressure was decreasing (Flight Problem STS-47-V-10). The reading then had an instantaneous 8-psi drop when the relief valve cracked . This same anomaly occurred on STS-49, but with a 16-psi drop, and also on STS-44 and STS-45. After STS-49, the transducer was replaced and the condition was attributed to a sticky rheostat-type transducer. The sensor appeared to work well for the remainder of the STS-47 flight.

After landing and flight crew egress, circuit breaker 134 (boiler hydraulic bypass 2B) on panel L4 was found to be open. Since this condition could result in the inadvertent activation of the WSB core tank heaters (continuously on), the deactivation team was requested to reset the circuit breaker. The breaker remained reset.

Electrical Power Distribution and Control Subsystem

The electrical power distribution and control (EPDC) subsystem performed satisfactorily throughout the mission with no anomalies identified. All data analyzed showed nominal voltage and current signatures, and no specified limits were violated.

Pyrotechnics Subsystem

The pyrotechnics subsystem performed all required functions in a satisfactory manner. The drag chute mortar and retractor performed as expected and deployment and jettison of the drag chute was satisfactory.

Environmental Control and Life Support Subsystem

The atmospheric revitalization system (ARS) performance was nominal. The air and water coolant loops performance was normal. The CO_2 partial pressure was maintained below the highest acceptable level of 4.70 mm Hg. The cabin air temperature and relative humidity peaked at 84°F and 40 percent, respectively. The avionics bays 1, 2, and 3 air outlet temperatures peaked at 106°F, 107°F, and 87.8°F, respectively. Also the avionics bays 1, 2, and 3 water coldplate temperatures peaked at 87.5°F, 91.5°F, and 81.2°F, respectively.

The cabin humidity sensor reading stuck at a constant level at 264:13:13 G.m.t. (07:22:50 MET) (Flight Problem STS-47-V-15). This same signature occurred on STS-49. Likewise, the humidity sensor did not respond to postflight humidity changes. Troubleshooting showed that the manufacturer's plastic wrapping around the humidity sensor was still in place, thus preventing the meter from giving a true reading. After removing the wrapping, a short retest showed the sensor to be in good working order.

While installing the filter for DTO 647 (Water Separator Filter Performance Evaluation), the crew noted that the water line for the liquid cooling and ventilation garment and the water chiller was lacking insulation and experiencing water condensation. Drawings show that this water line should be insulated. KSC investigated this condition after landing and the necessary corrective action was taken.

All pressure control system (PCS) operating parameters remained within normal limits. PCS 1 was used during the pre-Spacelab activation and post-Spacelab deactivation periods. As a result of the limited PCS operation, the PCS 2 redundant component checkout was not performed.

The active thermal control system (ATCS) operated satisfactorily. A primary A topping flash evaporator system (FES) over-temperature shutdown occurred at 259:09:55 G.m.t. (02:19:32 MET). The FES shutdown was caused by a temperature transient from the radiator flow control assembly. After the shutdown, the FES primary A controller power was cycled off and back on, and the FES started up nominally and this condition did not impact this flight. The FES water dump that was in progress at the time of the shutdown was completed with no problems. A second FES shutdown occurred at 263:32:17 G.m.t. (07:17:54 MET). The cause of this shutdown was the same as the first shutdown. The crew recycled the FES controller and it began operating satisfactorily.

Throughout the mission, the FES experienced outlet temperature oscillations during startup (Flight Problem STS-47-V-21). These oscillations were similar to (but of a lower magnitude) those seen on the previous flight of this vehicle (STS-49). The FES temperature sensors were repacked prior to this flight to remedy the problem. Investigations are continuing into this phenomenon.

The supply and waste water systems performed nominally. All assigned in-flight checkout requirements were completed. Supply water was dumped through the FES, and the supply water dump line temperature was maintained between 71 and 99°F with the operation of the line heater. No overboard supply water dumps were required.

Two waste water dumps were performed satisfactorily. The average dump rate was 1.95 percent/minute (3.2 lb/hr). The waste water dump line temperature was maintained between 55 and 80°F, while the vacuum vent line temperature was maintained between 56 and 80°F.

The waste collection system (WCS) performed nominally until flight day 5. In addition to normal WCS operations, the fan separator had been used to provide airflow to the urine monitoring system. At 262:05:19:45 G.m.t. (05:14:56:45 MET), fan separator 1 exhibited stall currents similar to those observed when the WCS is flooded. The crew switched to fan separator 2 and used it successfully for a short period of time before performing a fan separator 1 clearing procedure, after which fan separator 1 was used for the rest of the mission. The crew allowed fan separator 1 to run for extended periods of time up to 3 hours 20 minutes following the failure in an attempt to dry out the fan separator. As a result, fan separator 1 start-up times reduced to a nominal 4 seconds as the mission progressed.

A redesign of the fan separator is currently in progress to make the fan separator less likely to flood in-flight. Design improvements include a re-designed bowl with dividers to prevent splashing and liquid bypass, and a delayed shut down mechanism to ensure that all liquid is pumped out prior to the shut down. The redesign will be implemented in February 1993.

Smoke Detection and Fire Suppression Subsystem

All smoke detection subsystem parameters remained within normal limits and the use of the fire suppression system was not required.

Airlock Support System and Tunnel Adapter

Use of the airlock support system was not required for extravehicular activity, but along with the tunnel adapter provided intravehicular access to the Spacelab.

Avionics and Software Subsystems

The integrated guidance, navigation, and control system operated satisfactorily throughout the mission.

All FCS hardware performed satisfactorily throughout the mission. The FCS checkout was completed at 262:09:57:57.64 G.m.t. (05:19:34:57 MET) using IAPU 3 and all systems operated satisfactorily.

Inertial measurement unit performance was nominal throughout the mission.

The star tracker failed two consecutive self-tests in a manner not previously seen shortly after power was applied to the unit (Flight Problem STS-47-V-17). A test was developed to determine if the star tracker self-test failures were thermally induced. The test involved running five self-tests of the -Z star tracker, then powering down the star tracker for two hours, and then running additional self-tests after the unit was repowered. During the pre-powerdown testing, the star tracker failed the second self-test. This failure occurred in an expected manner (a known failure mode) and it was a different failure mode from the two failures that occurred earlier in the mission. A decision was made to stop the testing after the failure was identified.

The data processing system flight software and hardware performed nominally.

The operational instrumentation/modular auxiliary data system hardware encountered three anomalies, none of which had any impact on the successful completion of the mission. The anomalies were:

a. SSME LH_2 inlet pressure indicated off-scale low. This problem is discussed in the Main Propulsion System Section of this report.

b. IAPU 3 test line temperature 2 trended low during the prelaunch time frame. This problem is discussed in the Auxiliary Power Unit section of this report.

c. Left-hand outboard tire pressure showed excessive bias with respect to the new calibration curve used. This anomaly is discussed in the Structures and Mechanical Subsystems section of this report.

Communications and Tracking Subsystem

The communications and tracking subsystem performed nominally throughout the mission with some minor problems that are discussed in the following paragraphs.

Early in the mission, several ground stations reported a weak UHF downlink signal, while the Orbiter received strong UHF uplink signals from the ground stations.

The UHF system had been powered down for on-orbit operations; however, a test of the UHF system was satisfactorily conducted at 257:12:00 G.m.t. (00:21:37 MET) over MILA on orbit 15, and both frequencies (259.7 MHz and 296.8 MHz) were checked and verified. The uplink and downlink voice was good. The UHF system was switched back to 259.7 MHz prior to power down with no more checks performed until landing day. Landing day UHF checks over Oak Hanger were satisfactory.

At 258:05:23 G.m.t. (01:15:00 MET) during orbit 26 Tracking and Data Relay Satellite (TDRS) East operations, intermittent dropouts of the S-band return link occurred. These dropouts continued throughout most of the TDRS East portion of the pass. An external source of radio frequency interference (RFI) was suspected.

The crew reported during postflight debriefings that there was cross-talk between the air-to-ground 1 and air-to-ground 2 communications links throughout the mission (Flight Problem STS-47-V-23).

Closed-circuit television (CCTV) camera A was noted to have a small burn spot. This was a known condition prior to flight that did not affect performance of the camera during the entire mission. Also, during a real-time downlink of video from CCTV camera D, horizontal jitter was noted (Flight Problem STS-47-V-18). This jitter was also noted on a previous transmission. The jitter effect occurred only during the first few minutes after camera power-up, after which the camera operated nominally. Camera D was used for the remainder of the mission.

The crew reported that the tens digit of the Ku-band range rate/azimuth display was blank (Flight Problem STS-47-V-11). A lamp test was performed and all LED segments illuminated.

During entry, the Tactical Air Navigation (TACAN) bearing indication experienced a 40-degree excursion for approximately 13 seconds (Flight Problem STS-47-V-19). Postflight testing will be performed on this TACAN using the bearing simulator.

Structures and Mechanical Subsystems

The structures and mechanical subsystems performed satisfactorily. The nominal landing and braking data are shown in the table on the following page.

The prelaunch side hatch electrical continuity check after hatch closure revealed that two of the continuity measurements were unsatisfactory. A procedure, which involved reopening the hatch and visually checking the latches, verified that the latches were over-center. The same procedure was used prior to the first flight of OV-105 when the same condition was experienced. The hatch was again closed and the continuity checks were completed with satisfactory results.

The left-hand outboard main tire pressure sensors 1 and 2 were biased excessively with respect to the new calibration curve that had been used (Flight Problem STS-47-V-12). All other tire pressure measurement biases were within specifications. Postflight, the actual tire pressures were measured and recorded for comparison and evaluation.

All the brakes were in satisfactory condition with adequate clearance between the brake pucks and the pressure plate.

The landing gear struts were in good condition. All the bungees had fired, all the uplock hooks had released, and the nose landing gear axle nuts were in proper alignment. Some scuffing and cuts were noted on both right-hand main gear tires. The scuffing was located on the inboard and outboard ribs of both tires. The cuts were not deep enough to expose any threads. The left-hand main gear tires were in very good shape with only minor scuffing noted. Also, the nose gear tires were in good condition.

The drag chute was deployed at 264:12:53:30.9 G.m.t. (07:22:30:30.9 MET), which was about 8.8 seconds prior to nose gear touchdown. During the drag chute deployment, the riser contacted the stinger, causing TPS damage. The drag chute suffered damage from the TPS debris in the form of three extremely small holes. The riser also had evidence of scrubbing. In addition, there was some evidence of distress on some of the ribbons, but this appears to have been caused during ground handling.

LANDING AND BRAKING PARAMETERS

Parameter	From threshold, ft	Speed, keas	Sink rate, ft/sec	Pitch rate, deg/sec
Main gear touchdown	2458	204.6	~1.0	n/a
Nose gear touchdown	7651	133.9	n/a	1.92

Braking initiation speed	110.1 knots (keas)
Brake-on time	29.6 seconds
Rollout distance	8,547 feet
Rollout time	50.9 seconds
Runway	33 (concrete) at KSC
Orbiter weight at landing	220,097 lb

Brake sensor location	Pressure, psia	Brake assembly	Energy, million ft-lb
Left-hand inboard 1	1116	Left-hand outboard	19.53
Left-hand inboard 3	1140	Left-hand inboard	17.86
Left-hand outboard 2	1272	Right-hand inboard	27.02
Left-hand outboard 4	1224	Right-hand outboard	24.42
Right-hand inboard 1	1728		
Right-hand inboard 3	1656		
Right-hand outboard 2	1476		
Right-hand outboard 4	1416		

Tire location	Pressure, psia	Tire temperature, °F	Temperature decal, °F
Left-hand outboard	323.0	-5.3	150
Left-hand inboard	326.0	-2.4	None
Right-hand inboard	345.0	21.4	150
Right-hand outboard	344.0	20.5	150
Left-hand nose gear	322.0	17.5	N/A
Right-hand nose gear	324.0	19.5	N/A

Following disreefing of the drag chute and prior to nose wheel touchdown, the Orbiter began to veer to the left (Flight Problem STS-47-V-22). Photography indicated that the drag chute was trailing at approximately 8° starboard during the rollout.

The postflight inspection of the drag chute area revealed that the drag chute riser lines caused significant damage/material loss to the vertical stabilizer stinger area during the drag chute deployment. Also, another tile on the lower (-Z) right-hand edge of the drag chute opening was slightly damaged by the separation of the chute compartment door. All drag chute hardware was recovered and showed no signs of abnormal operation.

Aerodynamics, Heating, and Thermal Interfaces

The ascent and entry aerodynamics were satisfactory with no problems observed in the data. During entry, DTO 251 - Entry Aerodynamic Control Surfaces Test - was completed except for programmed test input (PTI) 3 which could not be performed because a required roll reversal maneuver occurred during the planned Mach window for PTI 3. There was no indication of abnormal aileron trim excursions during the high negative elevon settings as had been experienced on a previous flight.

The integrated aerodynamic and plume heating on the vehicle during ascent was nominal with no unexpected conditions noted. Likewise, the heating during entry was also nominal and within the TPS limits.

The thermal interface temperatures were maintained within the specified limits and no LCC temperature violations occurred.

Thermal Control Subsystem

The performance of the thermal control subsystem was nominal during all phases of the mission with all Orbiter subsystem temperatures being maintained within acceptable limits. Three temperature sensor anomalies occurred, but none of these impacted the mission. These anomalies are as follows:

a. The IAPU 3 fuel test line temperature sensor 2 violated the LCC lower limit of 48°F. This anomaly is discussed in the Auxiliary Power Unit section of this report.

b. Shortly after ascent, the IAPU 1 system A drain line temperature sensor 2 cycled at 46°F, which is below the FDA limit of 48°F. This anomaly is discussed in the Auxiliary Power Unit section of this report.

c. The fuel cell water relief line temperature dropped below the normal heater on setpoint of 70°F and cycled on at temperatures as low as 58°F. This anomaly is discussed in the Fuel Cell Powerplant section of this report.

In addition, the IAPU 3 system A drain line temperature sensor 2 cycled below the FDA limit of 48°F during the early on-orbit operations. This condition was noted on the previous flight of this vehicle and was declared acceptable for flight in the as-is condition.

Temperature C on the right main landing gear brake line heaters increased to 237°F about 3 hours 10 minutes after heater activation (approximately 20 minutes prior to the deorbit maneuver). After entry interface, the temperature decreased to 130°F. This behavior was virtually identical to that observed on STS-49 (first flight of this vehicle), and similar to the behavior observed on STS-50 (OV-102). On OV-102, the temperature sensor was found to be located too near the heater.

Aerothermodynamics

Acreage heating was nominal during entry with all structural and TPS temperatures within the experience base. Local heating was also normal and the TPS damage was within the experience base. No effects were expected or noted from the performance of the PTI's as a part of DTO 251.

Thermal Protection Subsystem

The thermal protection subsystem (TPS) performance was nominal, as compared to previous flights of the Space Shuttle fleet. This conclusion is based on structural temperature response data and on some tile surface temperature measurements. The overall boundary layer transition from laminar to turbulent flow was non-symmetric. Transition occurred at 1210 seconds after entry interface on the aft portion of the vehicle (X/L = 0.6) and at 1320 seconds on the forward side of the vehicle (X/L = 0.3). The time of transition was the latest for the forward section of the vehicle since the start of Space Shuttle flights.

The number of hits was much less than average when compared with previous missions. From a debris damage standpoint, STS-47 represents one of the best in the Space Shuttle Program. The detailed evaluation and analysis of the TPS will be documented in a NASA Technical Memorandum - TM 107553.

During the prelaunch inspection, the Ice Inspection Team detected a scratch on the upper surface of the left wing reinforced carbon-carbon (RCC) panel 9, approximately one-third the distance back from the leading edge. The scratch is a turnaround and reuse issue, and was not a safety-of-flight issue.

The Orbiter sustained a total of 107 hits of which 11 had a major dimension of one inch or greater. This total does not include the numerous hits on the base heat shield that were attributed to SSME vibration/acoustics and exhaust plume recirculation. A comparison of these numbers to statistics from 34 previous missions of similar configuration indicates that both the total number of hits and the number of hits one inch or greater were much less than average.

The Orbiter lower surface sustained a total of 47 hits, of which three had a major dimension of one inch or greater. The distribution of hits on the lower surface does not suggest a single source of ascent debris, but indicates a shedding of ice and TPS debris from random sources. A large gap was detected between the RCC chin panel and the adjacent nose cap angle seal gap filler during postflight inspections (Flight Problem STS-47-V-26). A similar gap was noted after flight 1 of OV-105. The OV-105 gap filler is being redesigned to prevent future occurrences of this condition.

No TPS damage was attributed to material from the wheels, tires, or brakes. The ET/Orbiter separation device plunger (EO-3) for the liquid oxygen line was obstructed by two ordnance fragments and did not seat properly. The EO-1 and EO-2 separation devices functioned properly, and no flight hardware was found on the runway below the umbilicals after the ET doors were opened.

Damage to the base heat shield tiles was less than average. The SSME 1 dome-mounted heat shield (DMHS) closeout blanket splice exhibited minor fraying at the 6:00 o'clock position. All of the remaining DMHS closeout blankets were in excellent condition.

The redesigned, mechanically attached ET door thermal barriers performed well and showed no signs of degradation. The room temperature vulcanizing (RTV) shims which had been installed to increase the environmental pressure seal contact also showed no signs of deterioration. No evidence of flow paths was found, indicating that the door had sealed properly.

At 262:18:49 G.m.t. (06:04:26 MET), the crew downlinked a description of the thermal barrier in the upper/lower speedbrake split line. The barrier was standing out approximately 1 inch from the outer mold line with room temperature vulcanizing (RTV) material showing for the full length of the thermal barrier (Flight Problem STS-47-V-13). Evaluation showed that this condition posed no problem for the remainder of the flight. The postflight inspection of the rudder speedbrake split line thermal barrier showed the barrier to be protruding slightly and some evidence of minor fraying was also noted. However, the thermal barrier did not appear to be significantly damaged or deformed.

Orbiter windows 3 and 4 exhibited light hazing with a few streaks. Hazing on the other windows was less than usual. Surface wipes were taken from all of the forward facing windows (1 through 6) for laboratory analysis. Twenty-eight tile impact sites (including three larger than one inch) were noted on the perimeter tiles around windows 2 through 6. All of these hits were shallow in depth and may have been caused either by the RTV material used to bond paper covers to the forward RCS nozzles, or by exhaust products from the SRB booster separation motors, or by ice/TPS debris from the ET LO_2 tank.

The runway inspection was completed immediately following the landing, and the only unexpected flight hardware found were numerous pieces of tile material (from the vertical stabilizer stinger area) and a piece of red RTV material from the right-hand outboard main landing gear tire pressure instrumentation cable.

The drag chute deployed as planned; however, the drag chute riser lines caused significant damage/material loss to the vertical stabilizer stinger area during the drag chute deployment. Also, another tile on the lower (-Z) right-hand edge of the drag chute opening was slightly damaged by the separation of the chute compartment door.

A portable Shuttle thermal imager (STI) was used to measure the surface temperatures of three areas on the Orbiter in accordance with OMRSD requirements. Eighteen minutes after landing, the Orbiter RCC nosecap temperature was 165°F. Twenty-one minutes after landing, the right-hand wing leading edge RCC panel 9 temperature was 113°F, and panel 17 temperature was 112°F.

REMOTE MANIPULATOR SYSTEM

The remote manipulator system (RMS) was flown on this mission, but was not deployed because there was no requirement for its use.

GOVERNMENT FURNISHED EQUIPMENT/FLIGHT CREW EQUIPMENT

All flight crew equipment operated nominally. The galley package in-place microswitch was very sticky in its operation (Flight Problem STS-47-V-24). The galley was returned to JSC for troubleshooting and disassembly. Disassembly of the package-in-place microswitch assembly revealed that a layer of sediment had formed on the stop for the level mechanism preventing the package-in-place switch lever from returning completely. After removing the sediment, the package-in-place switch functioned properly.

During the STS-52 (OV-102) Shuttle Orbiter Repackaged Galley (SORG) functional test at KSC on September 18, 1992, a failure of the galley hot water tank occurred in which two of the six electrically resistive heater strips debonded from the water tank heat sink. Investigation into the condition revealed a design deficiency in the manner that the six strips are bonded to the heat sink. As a result of this design deficiency, a decision was made on flight day 8 to turn the power off on the STS-47 galley, including the water tank heaters and the oven. In addition, a decision was made to fly low-usage heater strips from the original galley water tanks on STS-52, STS-53, and STS-54. Newly designed heater strips that correct the design deficiency will be flown beginning with STS-55.

During prelaunch operations after the crew entered the Orbiter, the Mission Specialist 3 launch/entry suit (LES) oxygen hose became disconnected from the suit (Flight Problem STS-47-V-25). The hose could not be relocated, and consequently, was not reconnected for ascent. The crew person decided to use the emergency oxygen if conditions arose that required the use of breathing air.

CARGO INTEGRATION

All cargo integration hardware and systems performed nominally. Real-time technical support was provided to aid in coordination of responses to payload requests, and in the evaluation and approval of payload in-flight maintenance (IFM) procedures.

PAYLOADS

SPACELAB-J

The Spacelab-J mission was an overwhelming success. The science return for the mission was greater than expected and most of the experiment objectives were accomplished. The mission also contributed to the formation of increased international cooperation between NASA and NASDA. Table III presents a listing of all experiments contained in the Spacelab J module.

Forty-three experiments in microgravity and life sciences were conducted with NASDA's portion of the mission, known as the First Materials Processing Test (FMPT), consisting of 34 experiments. This complement of experiments allowed a maximum number of Japanese scientists to participate in space-based research, to train in mission operations, and to demonstrate the effective use of the space environment for research. Spacelab-J was also the first space flight for a NASDA payload specialist. For NASA, nine experiments allowed the expansion of knowledge gained on previous missions while helping to prepare for research on Space Station Freedom.

Science operations began when the crew initiated Spacelab activation at 256:16:34 G.m.t. (00:02:11 MET), with experimentation beginning almost immediately to ensure maximum exposure to the microgravity environment. Spacelab-J operations were concluded with Spacelab deactivation at 264:01:43 G.m.t. (07:11:20 MET).

SHUTTLE AMATEUR RADIO EXPERIMENT

During the course of the mission, the Shuttle Amateur Radio Experiment (SAREX) was used to make contacts with schools in the United States and Australia. Over 30 student questions were answered by various crew members on this seventh flight of the SAREX. The schools contacted were:

a. Australian Maritime College, Launceston, Tasmania Australia;

b. Wesley College, South Perth, Western Australia;

c. Del-Mar Middle School, Santa Cruz, California;

d. McKinley High School, Honolulu, Hawaii;

e. Flinders University, Bedford Park, Australia;

f. Cary High School, Cary, North Carolina; and

g. Queensland University of Technology, Brisbane, Queensland, Australia.

In addition, over 5,000 packet radio contacts were logged by the Orbiter from amateur radio operators on all continents. The SAREX provided communications between the Orbiter and the Mission Control Center (MCC) through an amateur radio station in Brisbane, Australia, during a loss of NASA air-to-ground communications on revolution 92. Also, the SAREX supported two successful crew-requested radio contacts with Reno, Nevada.

GET AWAY SPECIALS

All nine of the planned GAS experiment operations were completed satisfactorily. The GAS experiments flown and their sponsors were:

a. G-102 - Sponsored by the Boy Scouts of America's Exploring Division (in cooperation with the TRW Systems Integration Group of Fairfax, VA.

b. G-255 - Sponsored by the Kansas University Space Program of Lawrence, Kansas.

c. G-300 - Sponsored by the Matra Marconi Space/Laboratorie De Genie Electrique De Paris of Paris, France.

d. G-330 - Sponsored by the Swedish Space Corporation of Solna, Sweden.

e. G-482 - Sponsored by the Spar Aerospace Limited of Quebec, Canada.

f. G-520 - Sponsored by the Ashford School of Kent, England.

g. G-521 - Sponsored by the Canadian Space Agency of Ottawa, Canada.

h. G-534 - Sponsored by the NASA Lewis Research Center of Cleveland, Ohio.

i. G-613 - Sponsored by the University of Washington of Seattle, Washington.

ISRAELI SPACE AGENCY INVESTIGATION ABOUT HORNETS

The ISAIAH was the first experiment/investigation that has been flown for the Israeli Space Agency, and was to investigate the effect of weightlessness on combs built by oriental hornets.

On flight day 2, the humidity in the experiment elevated to 99 percent, which was deemed unacceptable. The use of the suit fan attached to the left air inlet of the unit was initiated, and the humidity was reduced to 94 percent. However, the humidity began to rise immediately after the suit fan was removed.

An IFM procedure to remove one small screw on each side of the payload was accomplished after Safety Panel approval. Monitoring every 15 minutes was continued for one hour and then once every two hours. Humidity began dropping in the experiment and stabilized at 78 percent within 24 hours. Nominal operation returned after the 2-hour monitoring cycle.

On flight day 5, the humidity elevated to 87 percent and on flight day 6 to 89 percent, and on flight day 7, the humidity dropped to 84 percent, all of which were acceptable.

On flight day 7, the no. 2 container (bottom) showed hornets attending the nest well. However, all others showed little or no activity with the hornets huddled in corners and in bunches.

SOLID SURFACE COMBUSTION EXPERIMENT

The SSCE, which helped the investigators study how flames spread in microgravity, was successfully activated on flight day 5. A good burn was achieved, but with an uneven flame. STS-47 was the fifth flight of this experiment.

DEVELOPMENT TEST OBJECTIVES AND DETAILED SUPPLEMENTARY OBJECTIVES

Thirteen of the 14 scheduled DTO's and all 11 of the scheduled DSO's were completed satisfactorily.

DEVELOPMENT TEST OBJECTIVES

DTO 251 - Entry Aerodynamic Control Surfaces Test - Alternate Elevon Schedule (Test 3) - This DTO was completed during entry except for one PTI of the six planned. PTI 3 was scheduled at the same time as a roll reversal maneuver, which took precedence over the PTI, and the PTI was not performed. The aileron trim was as expected for each PTI performed.

DTO 301D - Ascent Structural Capability Evaluation - This was a data-only DTO and the data were given to the Sponsor for evaluation.

DTO 305D - Ascent Compartment Venting Evaluation - This was a data-only DTO and the data were given to the Sponsor for evaluation.

DTO 306D - Descent Compartment Venting Evaluation - This was a data-only DTO and the data were given to the Sponsor for evaluation.

DTO 307D - Entry Structural Capability - This was a data-only DTO and the data were given to the Sponsor for evaluation.

DTO 312 - ET TPS Performance - Good photographic data were obtained from the flight deck as well as from the two cameras located in the ET/Orbiter umbilical wells. A detailed evaluation of the ET photography is contained in a report pubished by the DTO sponsor.

The Payload Commander, using the 70-mm camera with a 250-mm lens, obtained 70 excellent-quality photographs of the ET after separation from the Orbiter. The first picture was taken 4 minutes 40 seconds after ET separation, and the distance to the ET was calculated to be 1,018.3 meters. The last picture was taken 13 minutes 53 seconds after separation, and the calculated distance to the ET was 3,862.86 meters. The separation velocity between the Orbiter and ET was calculated to be 5.14 meters/second.

All aspects of the ET were photographed; however, back-lighting caused much of the ET surface to be in shadow on some frames after the twelfth frame. The ET tumbled from a nose-down to a nose-up attitude around the Y-axis with a period of 4 minutes. The rotation around the X-axis was very slight. Other than the divot described in the following paragraph, the overall condition of the ET was satisfactory.

The 35-mm and 16-mm cameras, located in the umbilical wells, provided good photography of the ET and SRB's. The 35-mm photographs provided an excellent view of the large divot that was found on the ET. This divot was located on the ET -Y axis on the intertank/LH_2 closeout area and was declared an anomaly after evaluation (Flight Problem STS-47-T-1). A discussion of this anomaly is contained in the External Tank section of this report.

DTO 521 - Orbiter Drag Chute System - The drag chute was deployed prior to the Orbiter nose gear touchdown. The chute deployed nominally, but just after disreef and prior to nose gear touchdown, the chute pulled the vehicle to the left of the runway centerline. This condition is still being evaluated.

DTO 623 - Cabin Air Monitoring - The cabin air monitoring DTO equipment was activated at 256:22:43 G.m.t. (00:08:20 MET), and the data are being evaluated by the sponsor.

DTO 647 - Water Separator Filter Performance Evaluation - The filter for DTO 647 was installed and the filter initially appeared to not be wicking the water as expected; however, later observations showed very satisfactory operations. Filter operation from flight day 3 through flight day 7 was nominal.

DTO 651 - Cycle Ergometer Hardware Evaluation - All scheduled evaluations of the hardware were completed successfully.

DTO 655 - Foot Restraint Evaluation - The foot restraints were evaluated by crew members during the flight. The sponsor has received this information and the DTO is being evaluated.

DTO 663 - Acoustical Noise Dosimeter Data - Data were collected for this DTO, and are being analyzed by the sponsor.

DTO 665 - Acoustical Noise Sound Level Data - Data were collected for this DTO, and are being analyzed by the sponsor.

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

DETAILED SUPPLEMENTARY OBJECTIVES

DSO 317 - Collection of Shuttle Humidity Condensate for Analytical Evaluation - The data collection was successful; however, some samples were lower volume than expected. Indications are that all data were collected successfully.

DSO 323 - Evaluation of Samples Obtained from the Urine Monitoring System - Data collection from the Urine Monitoring System (UMS) was successful; however, problems with the UMS prevented samples from being collected on flight day 7. The crew again began collecting data on flight day 8 and used all sample kits provided. Unfortunately, the samples were later found to be contaminated with waste water from the WCS, rendering the samples useless for data analysis.

DSO 469 - In-Flight Radiation Dose Distribution - The crew confirmed that the instrument was deployed at 256:18:38 G.m.t. (00:04:15 MET), and the data are being evaluated by the sponsor.

DSO 603 - Orthostatic Function During Entry, Landing, and Egress - Monitoring of the designated crew person was performed during the planned periods, and the data are being evaluated by the sponsor.

DSO 611 - Air Monitoring Instrument Evaluation And Atmosphere Characterization - Data collection was successful and complete.

DSO 612 - Energy Utilization - Data collection was completed with no problems reported.

DSO 802 - Educational Activities - This DSO was completed.

DSO 901 - Documentary Television - This DSO was completed.

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

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

DSO 904 - Assessment of Human Factors - Data collection was successful and complete.

PHOTOGRAPHIC AND TELEVISION ANALYSIS

LAUNCH DATA ANALYSIS

On launch day, 24 videos were received and evaluated, and no anomalies were found. During the course of the mission, all 57 of the expected launch films were received and analyzed. No in-flight anomalies were noted.

ON-ORBIT DATA ANALYSIS

The crew obtained numerous photographs of the ET after separation in support of DTO 312. One of the divots in the insulation has been identified as an anomaly. This anomaly is discussed in the External Tank section of this report.

LANDING DATA ANALYSIS

Eight landing videos were received for evaluation about three hours after landing. No anomalies were noted. The landing videos did contain excellent coverage of the drag chute deployment and full inflation. The landing videos show the anomalous performance of the drag chute following disreefing.

TABLE I.- STS-47 SEQUENCE OF EVENTS

Event	Description	Actual time, G.m.t.
APU activation	APU-1 GG chamber pressure	256:14:18:10.67
	APU-2 GG chamber pressure	256:14:18:13.10
	APU-3 GG chamber pressure	256:14:18:14.99
SRB HPU activation	LH HPU system A start command	256:14:22:32.110
	LH HPU system B start command	256:14:22:32.270
	RH HPU system A start command	256:14:22:32.430
	RH HPU system B start command	256:14:22:32.590
Main propulsion System start	Engine 3 start command accepted	256:14:22:53.458
	Engine 2 start command accepted	256:14:22:53.583
	Engine 1 start command accepted	256:14:22:53.693
SRB ignition command (lift-off)	SRB ignition command to SRB	256:14:23:00.010
Throttle up to 100 percent thrust	Engine 3 command accepted	256:14:23:03.898
	Engine 2 command accepted	256:14:23:03.903
	Engine 1 command accepted	256:14:23:03.893
Throttle down to 67 percent thrust	Engine 3 command accepted	256:14:23:27.899
	Engine 2 command accepted	256:14:23:27.903
	Engine 1 command accepted	256:14:23:27.894
Maximum dynamic pressure (q)	Derived ascent dynamic pressure	256:14:24:00
Throttle up to 104 percent thrust	Engine 3 command accepted	256:14:24:00.060
	Engine 2 command accepted	256:14:24:00.064
	Engine 1 command accepted	256:14:24:00.055
Both SRM's chamber pressure at 50 psi	RH SRM chamber pressure mid-range select	256:14:24:58.750
	LH SRM chamber pressure mid-range select	256:14:24:59.010
End SRM action	RH SRM chamber pressure mid-range select	256:14:25:00.349
	LH SRM chamber pressure mid-range select	256:14:25:01.622
SRB separation command	SRB separation command flag	256:14:25:04
SRB physical separation	LH rate APU A turbine speed LOS	256:14:25:04.130
	RH rate APU A turbine speed LOS	256:14:25:04.130
Throttle down for 3g acceleration	Engine 3 command accepted	256:14:30:28.867
	Engine 2 command accepted	256:14:30:28.865
	Engine 1 command accepted	256:14:30:28.864
3g acceleration	Total load factor	256:14:30:33.6
Throttle down to 67 percent thrust	Engine 3 command accepted	256:14:31:27.428
	Engine 2 command accepted	256:14:31:27.425
	Engine 1 command accepted	256:14:31:27.425
MECO	Command flag	256:14:31:33
	Confirm flag	256:14:31:34
Engine Shutdown	Engine 3 command accept	256:14:31:33.669
	Engine 1 command accept	256:14:31:33.665
	Engine 2 command accept	256:14:31:33.665
ET separation	ET separation command flag	256:14:31:52

TABLE I.- STS-47 SEQUENCE OF EVENTS (Continued)

Event	Description	Actual time, G.m.t.
OMS-1 ignition	Left engine bi-prop valve position	Not performed - direct insertion trajectory flown
	Right engine bi-prop valve position	
OMS-1 cutoff	Left engine bi-prop valve position	
	Right engine bi-prop valve position	
APU deactivation	APU-3 GG chamber pressure	256:14:36:10.99
	APU-1 GG chamber pressure	256:14:37:58.88
	APU-2 GG chamber pressure	256:14:37:00.74
OMS-2 ignition	Right engine bi-prop valve position	256:14:59:12.1
	Left engine bi-prop valve position	256:14:59:12.0
OMS-2 cutoff	Left engine bi-prop valve position	256:15:01:51.2
	Right engine bi-prop valve position	256:15:01:51.3
Payload bay door open	PLBD right open 1	256:15:57:19
	PLBD left open 1 position	256:15:58:39
Flight control system checkout		
APU start	APU-3 GG chamber pressure	262:09:45:20.14
APU stop	APU-3 GG chamber pressure	262:09:57:57.64
Payload bay door close	PLBD left close 1	264:09:13:54
	PLBD right close 1	264:09:15:56
APU activation for entry	APU-2 GG chamber pressure	264:11:49:26.60
	APU-1 GG chamber pressure	264:12:09:08.37
	APU-3 GG chamber pressure	264:12:09:15.49
Deorbit maneuver ignition	Left engine bi-prop valve position	264:11:52:20.2
	Right engine bi-prop valve position	264:11:52:20.2
Deorbit maneuver cutoff	Right engine bi-prop valve position	264:11:54:53.2
	Left engine bi-prop valve position	264:11:54:53.2
Entry interface (400K)	Current orbital altitude above reference ellipsoid	264:12:21:43
Blackout ends	Data locked at high sample rate	No blackout

TABLE I.- STS-47 SEQUENCE OF EVENTS (Concluded)

Event	Description	Actual time, G.m.t.
Terminal area energy management	Major mode change (305)	264:12:47:00
Main landing gear contact	LH MLG tire pressure RH MLG tire pressure	264:12:53:22 264:12:53:22
Main landing gear weight on wheels	LH MLG weight on wheels RH MLG weight on wheels	264:12:53:23 264:12:53:23
Drag chute deploy	Drag chute deploy 1 CP Volts	264:12:53:30.9
Nose landing gear contact	NLG tire pressure	264:12:53:39
Nose landing gear weight on wheels	NLG WT on Wheels -1	264:12:53:39
Drag chute jettison	Drag chute jettison 1 CP Volts	264:12:53:57.3
Wheels stop	Velocity with respect to runway	264:12:54:11
APU deactivation	APU-1 GG chamber pressure APU-2 GG chamber pressure APU-3 GG chamber pressure	264:13:07:42.87 264:13:07:44.67 264:13:07:45.76

TABLE II.- STS-47 PROBLEM TRACKING LIST

Number	Title	Reference	Comments
STS-47-V-01	Aft Compartment Helium Concentration Exceeded 500 ppm Launch Commit Criteria (LCC) Limit	256:07:00 G.m.t. IPR 54V-0003	During the initial LH_2 fastfill prior to recirculation pump activation, the aft compartment GH_2 concentration peaked at 550 ppm (corrected), violating the LCC limit for OV-105 of 500 ppm. After transition to replenish, the concentration decayed to 75-100 ppm, below the limit of of 150 ppm. KSC: Troubleshooting in work.
STS-47-V-02	APU 3 Fuel Test Line Temperature Low (Prelaunch)	256:08:45 G.m.t. IM47RF04 PR-APU-A0004	APU 3 test line temperature 2 (V46T0384A) trended low during prelaunch. prelaunch activities. The temperature reached as low as 46° F. The LCC lower limit was waived from 48° F to 43° F.
STS-47-V-03	RCS Thruster L3A Failed Off	256:14:33 G.m.t. IM47RF01 PR LP03-14-0361	Thruster L3A failed off when first commanded to fire after ET separation. Both oxidizer and fuel flowed, but chamber pressure only reached 8 psia. Most probable failure mode is partial (pilot only) flow through the oxidizer valve with full fuel flow. KSC: Will boroscope the pressure transducer prior to thruster replacement. Spare assets available on shelf.
STS-47-V-04	SSME 1 LH_2 Inlet Pressure Transducer Fail (V41P1100C)	256:14:25 G.m.t. IM47RF02 PR-MPS-0243	The pressure transducer failed off-scale low. Troubleshooting complete. KSC: Perform leak and electrical checks. Remove and replace transducer. Spare transducer on the shelf.
STS-47-V-05	Water Spray Boiler (WSB) 1 Over Temperature	256:14:34 G.m.t. IM47RF13 PR HYD-5-03-0094	During ascent, WSB 1 did not spray until the APU 1 lubrication oil temperature reached 280°F. Once cooling started, the WSB overcooled (to 236°F), then operated nominally. The File IX in-flight checkout limit of 275°F was violated. KSC: JSC will request hot flush.
STS-47-V-06	Oxygen Tank 4 Heater Control Pressure Off-Scale Low	256:15:30 G.m.t. IM47RF05 IPR-54-0007	Oxygen tank 4 control pressure indicated off-scale low. The crew checked the tank 4 controller circuit breaker and found it closed. The crew cycled the circuit breaker 10 times, but the controller output could not be recovered. Oxygen tank 4 works with oxygen tank 3 as a paired set. Normal readings returned five minutes prior to touchdown (at TAEM). KSC: KSC will troubleshoot controller, wiring, and transducer.
STS-47-V-07	WSB 3 Failed To Cool on Controller A	256:14:34 G.m.t. IM47RF13 PR-HYD-5-03-0094	WSB 3 failed to cool on the A controller. Switched to B controller and cooling did not occur until 311°F; consequently, APU 3 was shutdown before WSB 3 was turned off. WSB 3 remained on for two more minutes. The WSB sprayed and cooled the APU 3 lubrication oil. Good FCS checkout on APU 3. WSB 3 cooled normally on both controllers, and there was good cooling on B controller during entry.
STS-47-V-08	Fuel Cell Water Relief Line Temperature Erratic	256:18:09 G.m.t. IPR 54V-0008	The fuel cell water relief line temperature dropped below the normal heater activation setpoint of 70°F. In addition, the fuel cell 3 water relief line temperature appeared to be dropping with the relief line temperature. Most likely cause was a small amount of water dribbling through the fuel cell 3 water relief valve, resulting in a temperature decrease. Spare relief valve panel is available at KSC. No water was visible during postflight walkaround. KSC: Perform troubleshooting.

TABLE II.- STS-47 PROBLEM TRACKING LIST

Number	Title	Reference	Comments
STS-47-V-09	RCS Thruster L5D Has Low Chamber Pressure	259:20:15 G.m.t. IM 47RF03 PR-LP03-14-0362	RCS thruster L5D chamber pressure was consistently low (85 psia vs. 110 psia nominal). A 5-second hot fire of the thruster did not improve the chamber pressure. Analysis shows that mixture ratios are very low. Following FCS checkout, chamber pressure recovered to nominal levels (103 psi) with some intermittent pulses below nominal. KSC: Remove and replace thruster.
STS-47-V-10	WSB 2 Regulator Outlet Pressure Erratic	256:14:24 G.m.t. PR-HYD-5-03-0093	During ascent, the GN_2 regulator outlet pressure reading stuck at its initial reading while the actual pressure decreased. The reading unstuck and jumped to the lower correct reading. Troubleshooting will include cycling the regulator 10 times (vs. the usual 1 cycle). KSC: Perform troubleshooting.
STS-47-V-11	Ku-Band Range Rate/Azimuth Display Failure	259:03:20 G.m.t. IPR 54V-0013 IM47RF07 PR COM-0047	The crew reported that the tens digit of the Ku-Band range rate/azimuth digital display was blank. A lamp test was performed and the LED segments all illuminated. KSC: Remove and replace indicator. Spare hardware on the shelf.
STS-47-V-12	Left-Hand Outboard Tire Pressure Bias	261:15:00 G.m.t. IPR 54V-0014 IM47RF04	Both left-hand outboard tire sensors (1 and 2) have an excessive bias with respect to the new calibration curve used. All other tire pressure measurement biases are within specifications. KSC inspected sensors and recorded actual tire pressures. Data review in progress. KSC: Pressure transducer will be pulled and sent to Rockwell-Downey for analysis.
STS-47-V-13	Rudder Speedbrake TPS Displaced	263:04:49 G.m.t. 06:04:26 MET	The crew transmitted video showing a portion of the thermal barrier which appeared to be protruding. The debonded portion was described as extending 1.5 inches from the structure hinge line to 3 inches away at the trailing edge.
STS-47-V-14	Fuel Cell O_2 Flowmeter Erratic	262:12:48 G.m.t. IPR 54V-0016 IM 47RF14	Erratic flow reading occurred during entry (about 2 to 3 minutes after start of TAEM), lasted approximately 10 minutes. Fly as is.
STS-47-V-15	Humidity Sensor Failure	264:13:13 G.m.t. 49RF17-010 PR ECL-268	Humidity reading stuck at constant reading. Same signature as on STS-49. Didn't respond to postflight humidity changes. Postflight inspection revealed that the sensor still had factory wrapping on it. Wrapping removed and sensor checked out satisfactorily. Fly as is.
STS-47-V-16	APU 1 Drain Line Temperature 2 Low	257:00:23 G.m.t. IM 47RF06 IPR 54V-0023	The APU 1 drain line temperature 2 measurement consistently decreased to 47°F before the thermostat turned on the heater. The FDA limit of 48°F was TMBU'd to 45°F for the remainder of the flight. KSC: Will perform a detailed inspection of the heater system.
STS-47-V-17	-Z Star Tracker Self-Test Failure	256:18:24 G.m.t. IPR 54V-0021 IM 47RF08	The -Z star tracker failed the first two self-tests during post-insertion activation. Subsequent self-tests passed. An additional self-test failure occurred later in the flight. The star tracker operated nominally throughout the mission. KSC: Will perform series of self-tests to troubleshooting.

TABLE II.- STS-47 PROBLEM TRACKING LIST

Number	Title	Reference	Comments
STS-47-V-18	CCTV D Jitter	260:23:00 G.m.t.	Pan and tilt motion of the camera was slow. Motion should be 1.2 deg/sec and observed motion was between 0.3 and 0.5 deg/sec. Camera and pan/tilt assemblies and cables will be sent back to vendor for analysis.
STS-47-V-19	TACAN Bearing Excursion	264:12:46:30 G.m.t. IPR 54V-0029 IM 47RF11	During entry, the TACAN bearing indication experienced a 40° excursion for 13 seconds. KSC: Will perform ground testing using bearing simulator. Remove and replace TACAN 2, and return to vendor.
STS-47-V-20	WSB 1 Regulator Outlet Pressure Leakage	258:00:00 G.m.t. PR-HYD-5-03-0091	Regulator outlet pressure steadily increased throughout the flight, indicating leakage past the regulator.
STS-47-V-21	FES Temperature Excursions	264:12:00 G.m.t.	Several oscillations in the FES outlet temperature were seen after FES start up. Similar signature seen on STS-49. Temperature sensors were repacked following STS-49.
STS-47-V-22	Orbiter Pulled to Left After Drag Chute Disreef	264:12:53:30 G.m.t.	Following drag chute de-reef and prior to nose landing gear tires touching down, the Orbiter began to veer to the left.
STS-47-V-23	Air-to-Ground 1/Air-to-Ground 2 Cross Talk	260:00:00 G.m.t.	During the mission, the crew noticed some crosstalk from Air-to-Ground 1 to Air-to-Ground 2 voice channels.
STS-47-V-24	Galley Package In-Place Switch	261:00:00 G.m.t.	The galley package in-place microswitch was very sticky during in-flight operations. KSC: Will return galley to JSC.
STS-47-V-25	Mission Specialist 3 Launch Entry Suit Oxygen Hose	256:14:20 G.m.t.	During prelaunch operations, the Mission Specialist 3 (MS3) launch entry suit oxygen hose became disconnected. MS3 could not relocate and reconnect hose.
STS-47-V-26	Chin Panel Thermal Effects	264:13:00 G.m.t. PR-FWD-0452	The chin panel gaps expanded. Similar signature seen on STS-49. Chin panel removed, and gap filler removal and replacement in work.

TABLE III.- SPACELAB-J EXPERIMENTS LISTING

EXPERIMENT TITLE	EXPERIMENT SPONSOR
Sponsored by NASA	
Material Sciences	
Space Acceleration Measurement System	Dr. Richard DeLombard Lewis Research Center
Fluid Therapy System: In-flight Demonstration of the Space Station Freedom Health Maintenance Facility Fluid Therapy System	Dr. Charles Lloyd Johnson Space Center
Magnetic Resonance Imaging After Exposure to Microgravity	Dr. Adrian LeBlanc Methodist Hospital, Houston, Tx.
Life Sciences	
Protein Crystal Growth	Dr. Charles Bugg, University of Alabama, Birmingham
Autogenic Feedback Training Equipment: A Preventative Method for Space Motion Sickness	Dr. Patricia Cowings Ames Research Center
Bone Cell Growth and Mineralization in Microgravity	Dr. Nicole Partridge St. Louis University Medical School
Effects of Weightlessness in the Development of Amphibian Eggs Fertilized in Space	Kenneth A. Souza Ames Research Center
Lower Body Negative Pressure: Countermeasure for Reducing Postflight Orthostatic Intolerance	Dr. John Charles Johnson Space Center
Plant Culture Research (Gravity, Chromosomes, and Organized Development in Aseptically Cultured Plant Cells)	Dr. Abraham Krikorian State University of New York Stony Brook
Sponsored by National Space Development Agency of Japan	
Materials Science	
Growth Experiment of Narrow Band-Gap Semiconductor Pb-Sn-Te Single Crystals in Space (M-1)	Dr. Tomoaki Yamada Nippon Telegraph and Telephone Corp.
Growth of Pb-Sn-Te Single Crystal by Travelling Zone Method in Low Gravity (M-2)	Dr. Souhachi Iwai Nippon Telegraph and Telephone Corp.
Growth of Semiconductor Compound Single Crystal in Floating Zone Method (M-3)	Dr. Isao Nakatani National Research Institute for Metals
Casting of Superconducting Filamentary Composite Materials (M-4)	Dr. Kazumasa Togano National Research Institute for Metals
Formation Mechanism of Deoxidation Products in Iron Ingot Deoxidized With Two or Three Elements (M-5)	Dr. Akira Fukuzawa National Research Institute for Metals
Preparation of Nickel Base Dispersion Strengthened Alloys (M-6)	Dr. Yuji Muramatsu National Research Institute for Metals
Diffusion in Liquid State and Solidification of Binary System (M-7)	Dr. Takehiro Dan National Research Institute for Metals

TABLE III.- SPACELAB-J EXPERIMENTS LISTING

EXPERIMENT TITLE	EXPERIMENT SPONSOR
High Temperature Behavior of Glass (M-8)	Dr. Naohiro Soga Kyoto University
Growth of Silicon Spherical Crystals and Surface Oxidation (M-9)	Dr. Tatau Nishinaga University of Tokyo
Study on Solidification of Immiscible Alloy (M-10)	Dr. Akihiko Kamio Tokyo Institute of Technology
Fabrication of Very-Low-Density, High-Stiffness Carbon Fiber/Aluminum Hybridized Composites (M-11)	Dr. Tomoo Suzuki Tokyo Institute of Technology
Study on the Mechanisms of Liquid Phase Sintering (M-12)	Dr. Shiro Kohara Science University of Tokyo
Fabrication of Sl-As-Te:Ni Ternary Amorphous Semiconductor in Micro-gravity Enviaronment (M-13)	Dr. Yoshihiro Hamakawa Osaka University
Gas-Evaporation in Low Gravity Field: Congelation Mechanism of Metal Vapors (M-14)	Dr. Nobuhiko Wada Nagoya University
Drop Dynamics in Space and Interference with Acoustic Field (M-15)	Dr. Tatsuo Yamanaka National Aerospace Laboratory
Study of Bubble Behavior (M-16)	Dr. Hisao Azuma National Aerospace Laboratory
Preparation of Optical Materials Used in Non-Visible Region (M-17)	Junji Hayakawa Government Industrial Research Institute
Marangoni Induced Convection in Materials Processing Under Micro-gravity (M-18)	Dr. Shintaro Enya Heavy Industries
Solidification of Eutectic System Alloys in Space (M-19)	Dr. Atsumi Ohno Chiba Institute of Technology
Growth of Samarskite Crystal in Micro-gravity (M-20)	Dr. Shunji Takekawa National Institute for Research in Inorganic Materials
Growth Experiment of Organic Metal Crystal in Low Gravity (M-21)	Dr. Hiroyuki Anzai National Electorotechnical Laboratory
Crystal Growth of Compound Semi-conductors in a Low-Gravity Environment (M-22)	Dr. Masami Tatsumi Sumitomo Electric Industries, Ltd.
<u>Life Sciences</u>	
Endocrine and Metabolic Changes in Payload Specialist (L-1)	Dr. Hisao Seo Nagoya University
Neurophysiological Study on Visuo-Vestibular Control of Posture and and Movement in Fish During Adaptation to Weightlessness (L-2)	Dr. Masao Kuroda Osaka University
Comparative Measurment of Visual Stability in Earth and Cosmic Space (L-4)	Dr. Kazuo Koga Nagoya University
Crystal Growth of Enzymes in Low Gravity (L-5)	Dr. Yuhei Morita Kyoto University

TABLE III.- SPACELAB-J EXPERIMENTS LISTING

EXPERIMENT TITLE	EXPERIMENT SPONSOR
Life Sciences (Continued)	
Studies on the Effects of Microgravity on the Ultrastructure and Functions of Cultured Mammalian Cells (L-5)	Dr. Atsushige Sato Tokyo Medical and Dental University
The Effect of Low Gravity on Calcium Metabolism and Bone Formation (L-7)	Dr. Tatsuo Suda Showa University
Separation of the Animal Cells and Cellular Organella by Means of Free Flow Electrophoresis (L-8)	Dr. Tokio Yamaguchi Tokyo Medical and Dental University
Genetic Effects of HZE and Cosmic Radiation (L-9)	Dr. Mituo Ikenaga Kyoto University
Space Research on Perceptual Motor Functions Under Zero Gravity Condition (L-10)	Akira Tada National Aerospace Laboratory
Study on the Biological Effect of Cosmic Radiation and the Development of Radiation Protection Technology (L-11)	Dr. Shunji Nagaoka National Space Development Agency of Japan
Circadian Rhythm of Conidiation in Neurospora Crassa (L-12)	Dr. Yasuhire Miyoshi University of Shizuoka

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for Corporate Technology
Grumman Aerospace Corp
Bethpage, NY 11714

Dr. Seymour C. Himmel
12700 Lake Avenue, #1501
Lakewood, OH 44107

Mr. John F. McDonald
Vice President-Technical
Services
TigerAir, Inc.
3000 North Claybourn Ave
Burbank, CA 91505

Dr. John G. Stewart
Manager, Office of
Planning and Budget
TVA E6C9
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Knoxville, TN 37902

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Attn: C. Peterson/H5

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1995 Ferndale Place
Thousands Oaks, CA 91360

Darryl Strickland
P. O. Box 1940
North Highlands, CA
95660-8940

Ames Research Center
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233-17/J. Hart

C. Woodland, Prog. Mgr.
SPAR Aerospace Limited
9445 Airport Road
Brampton, Ontario,
Canada, L6F4J3

A. S. Jones (2)
SPAR Aerospace Limited
9445 Airport Road
Brampton, Ontario
Canada L6F4J36

J. Middleton
SPAR Aerospace Limited
1700 Ormont Drive
Weston, Ontario,
Canada M9L 2W7

N. Parmet
5907 Sunrise Drive
Fairway, Kansas 66205

R. Peterson
3303 San Gabriel
Clearwater, FL 34619

Aerospace Corporation
P. O. Box 92957
Los Angeles, CA 90009
Attn: W. Smith, M5/619

McDonnell Douglas-Houston
T3A/A. D. Hockenbury

T. Myers, Sys Tech, Inc.
13766 So. Hawthorne Blvd.
Hawthorne, CA 90250

D. Molgaard
2525 Bay Area Blvd.
Suite 620
Houston, TX 77058

L. R. Adkins/IBM Bldg
Mail Code 6206
3700 Bay Area Boulevard
Houston, TX 77058

James R. Womack
JPL/233-307
4800 Oak Grove Dr
Pasadena, CA 91109

James V. Zimmerman
NASA European Rep
c/o American Embassy
APO New York, NY 09777

Capt. J. Behling
6555 ASTG/SMSP
Cape Canaveral AFS, FL.
32925

LESC-Houston
BO8/P. Davis
C07/LESC Library
C12/D. Harrison
C12/R. W. Fricke (10)
C87/D. Weissinger

GE Government Services
1050 Bay Area Blvd.
Houston, TX 77058
Attn: A. Verrengia

TRW
1 Space Park Drive
R11/1850 - L. Stytle
Redondo Beach, CA 90278

HQ AFSPACECOM/DOSL
Bldg 1 Stop 7
Peterson AFB
Colorado Springs, Co 80914
Attn: Capt. S. M. Young

Lockheed Advanced
Development Co.
P.O. Box 250
Sunland, CA. 91041
Attn: D. Urie D/7212,
B375, P/D6

R. Birman
General Electric Co.
Space Division
P. O. Box 8555
Philadelphia, PA 19101

Headquarters, SMC
Attn.: SMC/CULO
Major D. Joslyn
Los Angeles AF Base
P. O. Box 92960
Los Angeles, CA 90009-2960

Notify VF2/R. W. Fricke (713-483-3313) of any correction, additions, or deletions to this list.