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MISSION SAFETY EVALUATION REPORT FOR STS-32

Postflight Edition: July 20, 1990

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Safety Division

Office of Safety and Mission Quality

National Aeronautics and Space Administration

Washington, DC 20546

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REPORT FOR STS-32

Postflight Edition: July 20, 1990

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EXECUTIVE SUMMARY

Trouble with putting the finishing touches on the remodeled launch pad 39A delayed the STS-32 mission 3 weeks past its scheduled mid-December 1989, liftoff. On January 8, 1990, the launch was scrubbed due to weather. On the next day, January 9, 1990, the launch countdown proceeded on schedule, and Space Shuttle *Columbia* was launched at 7:35 a.m. Eastern Standard Time (EST). There were no significant problems, major anomalies, or unplanned holds associated with the countdown and launch. For the 10-day flight, *Columbia* was modified to carry more fuel and supplies, and the crew performed medical and other experiments related to longer duration missions.

On the first day in space, *Columbia's* robot arm, the Remote Manipulator System (RMS), was given a thorough workout to ensure that it was ready to snare the Long Duration Exposure Facility (LDEF) 3 days later. Maneuvering engines were fired to move *Columbia* laterally into LDEF's orbital plane and to slow the rate of closure on LDEF. The 11-ton LDEF spacecraft, holding 57 experiments, was released into orbit by STS-41C in April 1984. The LDEF orbited the earth over 32,000 times, travelling more than 800 million miles.

At 8:20 a.m. EST on Flight Day (FD) 2, the 17,000-pound Synchronous Communications Satellite (SYNCOM)-IV-5 was deployed from *Columbia's* payload bay. SYNCOM was later successfully placed in a geosynchronous orbit using 2 burns of its own booster rockets. Satellite performance has been excellent.

Over the next 2 days, *Columbia* crept nearer to LDEF. The STS-32 rendezvous was one of the most complex the Space Shuttle had ever attempted, requiring 11 major firings of *Columbia's* maneuvering engines. All burns were completed, and LDEF was grappled by the RMS at 10:16 a.m. EST on January 12 at a distance of approximately 35 feet from *Columbia*. For the next 4-1/2 hours, LDEF was manipulated by the RMS through 7 different positions while still photographs and videotapes were taken. The photo survey documented the condition of the LDEF's experiments after almost 6 years in orbit, in case the satellite sustained damage during reentry or could not be locked into the payload bay and had to be reboosted to a higher altitude. Later in the afternoon, the LDEF was guided into the open payload bay (with only 6" to spare on either side of the bulky satellite). Once LDEF was perfectly aligned, 4 latches on the payload bay walls and one on the keel locked it firmly into position for the ride home.

Columbia was scheduled for a predawn landing at Edwards Air Force Base (EAFB) on January 19; however, potential low visibility at touchdown due to developing fog over the lakebed resulted in a NO-GO for landing. On January 20, 1990, at 1:35 a.m. local time, *Columbia* with LDEF made a smooth touchdown on the EAFB concrete runway 22. The rare night landing was the third for the Space Shuttle. The nose of the Space Shuttle was kept high at touchdown because of the 115-ton landing weight with the LDEF aboard; this was almost 5 tons more than any previous shuttle at landing. The landing delay made STS-32 the longest Space Shuttle mission to date, passing STS-9's 10-day 7-hour mark.

FOREWORD

The Mission Safety Evaluation (MSE) is a National Aeronautics and Space Administration (NASA) Headquarters Safety Division, Code QS produced document that is prepared for use by the NASA Associate Administrator, Office of Safety and Mission Quality (OSMQ) and the Space Shuttle Program Director prior to each Space Shuttle flight. The intent of the MSE is to document safety risk factors that represent a change, or potential change, to the risk baselined by the Program Requirements Control Board (PRCB) in the Space Shuttle Hazard Reports (HRs). Unresolved safety risk factors impacting STS-32 flight were also documented prior to the STS-32 Flight Readiness Review (FRR) (FRR Edition) and prior to the STS-32 Launch Minus Two Day (L–2) Review (L–2 Edition). This final Postflight Edition evaluates performance against safety risk factors identified in the previous MSE editions for this mission.

The MSE is published on a mission-by-mission basis for use in the FRR and is updated for the L-2 Review. For tracking and archival purposes, the MSE is issued in final report format after each Space Shuttle flight.

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SECTION 1

INTRODUCTION

1.1 Purpose

The Mission Safety Evaluation (MSE) provides the Associate Administrator, Office of Safety and Mission Quality (OSMQ) and the Space Shuttle Program Director the NASA Headquarters Safety Division position on changes, or potential changes, to the Program safety risk baseline approved in the formal Failure Modes and Effects Analysis/Critical Items List (FMEA/CIL) and Hazard Analysis process. While some changes to the baseline since the previous flight are included to highlight their significance in risk level change, the primary purpose is to ensure that changes which were too late to include in formal changes through the FMEA/CIL and Hazard Analysis process are documented along with the safety position, which includes the acceptance rationale.

1.2 Scope

This report addresses STS-32 safety risk factors that represent a change from previous flights, factors from previous flights that have an impact on this flight, and factors that are unique to this flight.

Factors listed in the MSE are essentially limited to items that affect, or have the potential to affect, Space Shuttle safety risk factors and have been elevated to Level I for discussion or approval. These changes are derived from a variety of sources such as issues, concerns, problems, and anomalies. It is not the intent to attempt to scour lower level files for items dispositioned and closed at those levels and report them here; it is assumed that their significance is such that Level I discussion or approval is not appropriate for them. Items against which there is clearly no safety impact or potential concern will not be reported here, although items that were evaluated at some length and found not to be a concern will be reported as such. NASA Safety Reporting System (NSRS) issues are considered along with the other factors, but may not be specifically identified as such.

Data gathering is a continuous process. However, collating and focusing of MSE data for a specific mission begins prior to the mission Launch Site Flow Review (LSFR) and continues through the flight and return of the Orbiter to Kennedy Space Center (KSC). For archival purposes, the MSE is updated subsequent to the mission to add items identified too late for inclusion in the prelaunch report and to document performance of the anomalous systems for possible future use in safety evaluations.

1.3 Organization

The MSE is presented in seven sections as follows:

Section 1 - Provides brief introductory remarks, including purpose, scope, and organization.

Section 2 - Provides a brief mission description, including launch data, crew size, mission duration, launch and landing sites, and other mission- and payload-related information.

Section 3 - Contains a list of safety risk factors/issues, considered resolved or not a safety concern prior to STS-32 launch, that were impacted or repeated by anomalies reported for the STS-32 flight.

Section 4 - Contains a list of safety risk factors that were considered resolved for STS-32.

Section 5 - Contains a list of Inflight Anomalies (IFAs) that developed during the STS-33 mission.

Section 6 - Contains a list of IFAs that developed during the STS-28 mission.

Section 7 - Contains a list of IFAs that developed during the STS-32 mission. Those IFAs that are considered to represent safety risks will be addressed in the MSE for the next Space Shuttle flight.

Section 8 - Contains background and historical data on the issues, problems, concerns, and anomalies addressed in Sections 3 through 7. This section is not normally provided as part of the MSE, but is available upon request. It contains (in notebook format) presentation data, white papers, and other documentation. These data were used to support the resolution rationale or retention of open status for each item discussed in the MSE.

Appendix A - Provides a list of acronyms used in this report.

SECTION 2

STS-32 MISSION SUMMARY

2.1 Summary Description of STS-32 Mission

Trouble with putting the finishing touches on the remodeled launch pad 39A delayed the STS-32 mission 3 weeks past its scheduled mid-December 1989, liftoff. On January 8, 1990, the launch was scrubbed due to weather. On the next day, January 9, 1990, the launch countdown proceeded on schedule, and Space Shuttle *Columbia* was launched at 7:35 a.m. EST. There were no significant problems, major anomalies, or unplanned holds associated with the countdown and launch. For the 10-day flight, *Columbia* was modified to carry more fuel and supplies, and the crew performed medical and other experiments related to longer duration missions.

During ascent, Auxiliary Power Unit (APU) #3 lubrication oil outlet pressure rose to 90 pounds per square inch (psi) and decreased to normal range at liftoff+9 minutes (min) . This same anomaly was seen on another APU on STS-33. Frequency Modulation (FM) system #1 was lost at liftoff +5 seconds (sec) (no power output), but data was recovered about 10 sec later when switched to FM system #2. There was no impact on mission operations.

On the first day in space, *Columbia's* robot arm, the Remote Manipulator System (RMS), was given a thorough workout to ensure that it was ready to snare the Long Duration Exposure Facility (LDEF) 3 days later. Maneuvering engines were fired to move *Columbia* laterally into the LDEF's orbital plane and to slow the rate of closure on the LDEF. The 11-ton LDEF spacecraft, holding 57 experiments, was released into orbit by STS-41C in April 1984. LDEF orbited the earth over 32,000 times, travelling more than 800 million miles.

At 8:20 a.m. EST on Flight Day (FD) 2, the 17,000-pound (lb) Synchronous Communications Satellite (SYNCOM)-IV-5 was deployed from *Columbia's* payload bay. SYNCOM was later successfully placed in a geosynchronous orbit using 2 burns of its own booster rockets. Three hours later, satellite performance was reported 100% perfect.

During FD 2, the Protein Crystal Growth (PCG) experiment was found unpowered during the night. The power cable had disconnected and was reconnected by the crew. As a result, 2 of the proteins were damaged when the temperature rose 18.9°. Hydraulic system #1 circulation pump cycled ON at 23 and 28 hours (hr) Mission Elapsed Time (MET) to recharge accumulator pressure due to a leaking unloader valve (a waiver was approved at the December 20, 1989, Program Requirements Control Board (PRCB) for all 3 hydraulic system unloader valves). The crew found water during the Lithium Hydroxide (LiOH) canister change. The canister was wet, and water was coming from an exit port of the humidity separator. The crew cleaned up the water and switched from humidity separator "B" to "A". Video of the humidity separator indicated more water than reported by the crew; after viewing video, the Mission Control Center (MCC) instructed the crew to perform free fluid cleanup.

On FD 3, the crew performed the Free Fluid Inflight Maintenance (IFM) Disposal Water Cleanup Procedure. The amount of water was approximately 2 gallons. This Inflight Anomaly (IFA) was very similar to that on STS-27 (Corrective Action Request (CAR) 27RF01) with the same amount of free water. Humidity separator "A", which had been switched on instead of "B", had been performing nominally since its selection. (Flight Rule 9-241 calls for next Primary Landing Site (PLS) if loss of humidity control occurs.) Water Spray Boiler (WSB) systems #2 and #3 indicated decay rates of approximately 0.11 pounds per square inch per hour (psi/hr); allowable leakage is 0.06 psi/hr. It was unknown whether the decay was due to a water or Gaseous Nitrogen (GN_2) leak. If the leak was due to GN_2 leak, there was no mission impact. If the decay was due to a water leak, it was projected based on the current leak rate that 7.5 min of APU operation would be available for the scheduled reentry. The reduced operating time was due to an APU bearing temperature limit of 400°F.

On FD 4, January 12, 1990, all burns were completed, and LDEF was grappled by the RMS at 10:16 a.m. EST at a distance of approximately 35 feet from *Columbia*. The STS-32 rendezvous was one of the most complex the Space Shuttle had ever attempted, requiring 11 major firings of *Columbia's* maneuvering engines. For the next 4-1/2 hr, LDEF was manipulated by the RMS through 7 different positions while still photographs and videotapes were taken. The photo survey documented the condition of the LDEF's experiments after almost 6 years in orbit, in case the satellite sustained damage during reentry or could not be locked into the payload bay and had to be reboosted to a higher altitude. The initial survey indicated discoloration, holes on the panels, and displacement of the Kapton film on panels H3 and H12. Later in the afternoon, the LDEF was guided into the open payload bay (with only 6" to spare on either side of the bulky satellite). Once LDEF was perfectly aligned, 4 latches on the payload bay walls and 1 latch on the keel locked it firmly into position for the ride home.

Also on FD 4, a Fluids Experiment Assembly (FEA) pressure message was received at the peak of the LDEF retrieval activities. The crew turned the FEA heater power off. In troubleshooting the pressure loss, a hairline crack was found in sample ampule #4 containing Indium. Flight Rules indicated that the FEA should remain closed for the remainder of the mission due to the danger of broken glass particles in the crew compartment. The FEA was manifested on STS-41D and STS-30. It is a crystal growth system using microgravity to enhance the effects of floating zone materials processing. The hydraulic system #1 accumulator pressure fell below 1960 pounds per square inch absolute (psia) which caused the circulation pump to run and repressurize the system. The system cycled 3 or 4 times in a 3-hr period. The circulation pump was then operated for 4 hr in order to clear out any accumulator contamination.

On FD 5, WSB systems #2 and #3 continued to decay, but slower than originally predicted. Chances were considered likely that redlines would not be reached before entry. Humidity separator "A" continued to operate nominally. During pre-sleep LiOH changeout, separator "B" was inspected for free water; no water was found. IFM procedures utilizing plastic trash bags were prepared to contain water if needed. IFM procedures to remove the cracked ampule from the FEA (and continue with the experiment) were reviewed. Safety concurred with implementation of the FEA sample #4 ampule removal IFM. Because the ampule was cracked and no fragments were visible, Safety was reasonably certain that the ampule would not fragment during the removal process. Also, it was not believed that toxic gases were contained within the FEA unit.

On FD 6, the FEA IFM procedure was implemented without any anomaly. Sample #4 was replaced by sample #5. No debris was observed during the replacement, and the experiment was reactivated. The crew was advised to monitor the experiment every 10 min and terminate it on time. Eight ounces of water was found around humidity separator "A" during pre-sleep activities. Water tanks were depressed, and the situation was to be assessed at crew wakeup. Contingency IFM procedures were uplinked to the crew. During LiOH canister changeout, the crew reported that no excess water was observed at humidity separator "A". WSB regulator pressure decay had slowed since the beginning of the mission. At the current decay rate, the pressures were predicted to be above the redlines for the scheduled deorbit (system #2 at 17.5 psi and system #3 at 14.7 psi). A problem also arose with an Inertial Measurement Unit (IMU). IMU #1 was deselected by Redundancy Management (RM) during crew sleep due to Y-axis accelerometer transients. However, IMU #1 continued to track the redundant set after deselection, and the crew was able to reselect IMU #1 prior to IMU alignment. After alignment, all 3 IMUs performed nominally, and no other problems were observed.

On FD 7, IMU #1 was again deselected by RM. After reselection and realignment by the crew, IMU #1 operated nominally. Water was reported coming out of humidity separator "A". The unit was turned off, and crew cleanup was initiated. The amount of free water was estimated to be about 2 cups. This small amount of free water was suspected to be due to high crew activity levels during the day. Humidity separator "A" was turned on again and operated nominally. The water tanks were depressed for crew sleep. The crew placed a towel over the humidity separator "A" exit to absorb any water during the night; a bag was placed over the towel to simplify cleanup activities. FES aft zone heater system "B" failed when being enabled; system "A" was selected and performed nominally.

The crew reported on FD 8 that after water dump they removed about 1 cup of water from the bag around humidity separator "A". No water was found outside of the bag. During FEA operations, the crew reported an overtemperature message, and the power was turned off. They also reported that the surface temperature was not hot, which contradicted the message. A transient data condition was suspected. It was decided to power off for the rest of FD 8 and schedule again for the next day. The

Ku-band return link was lost; the Ku-band forward link was still working good. A Tracking and Data Relay Satellite System (TDRSS)-W problem was suspect.

On FD 9, a smoke alarm with siren was experienced from avionics bay 3A, sensor 3A, which cleared itself after 5-6 sec. Playback data indicated no increase in smoke concentration readings. A fire/smoke detection test was subsequently performed successfully. It was, therefore, concluded that the alarm was most likely caused by an intermittent fault in the smoke detection electronics. The same sensor annunciated a second time during crew sleep, and the ground informed the crew that it would be acceptable to open the associated circuit breaker if the alarm became a nuisance. The Ku-band was turned over to TDRSS-E and provided a good return link. This isolated the problem to TDRSS-W.

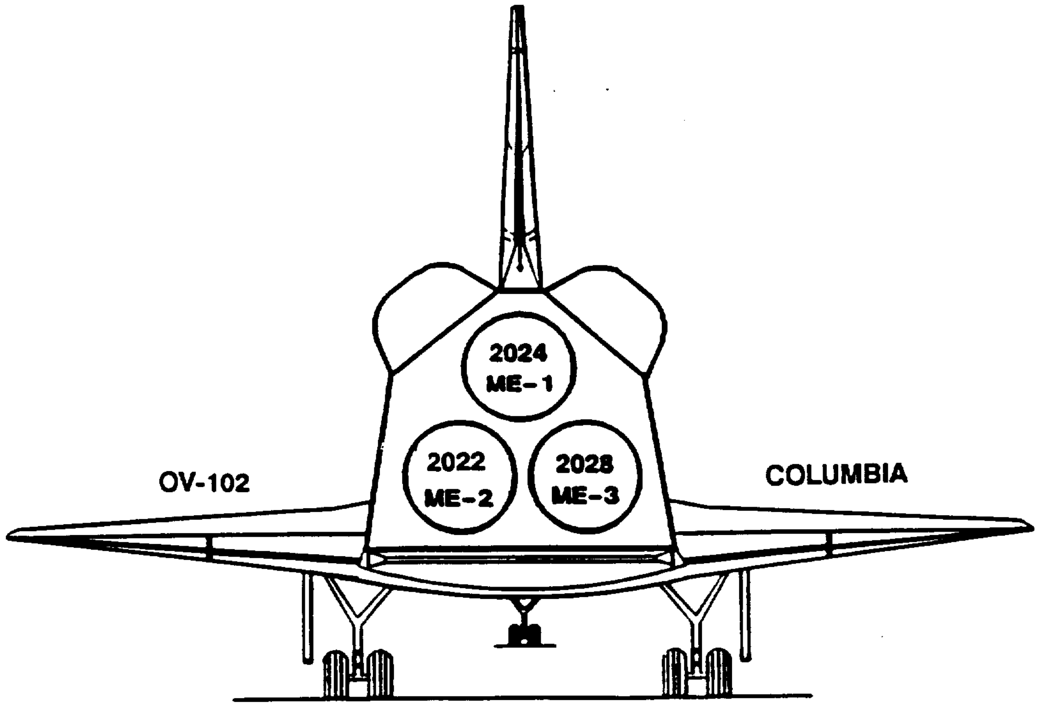
During crew sleep on FD 9, the vehicle began to roll nose-to-tail following a state vector update. The 125-sec jet firing limit was exceeded, and the V-bar was violated. Upon Acquisition of Signal (AOS), the ground instructed the crew to go to manual Digital Autopilot (DAP). However, DAP error remained large; it cleared when the crew went to free drift and then to manual discrete. A new state vector was uplinked and the crew selected auto DAP. Data evaluation was conducted, and the attitude remained nominal in auto DAP on the vernier Reaction Control System (RCS). It was found that vehicle maneuvering resulted in approximately 50-lb propellant usage in the Forward Reaction Control System (FRCS) and 90-lb usage in the right Orbital Maneuvering System (OMS) due to interconnect. Only vernier jets were fired during the vehicle maneuvers. Vernier jet F5R fired for 203 sec and exceeded the certification firing time limit of 125 sec. No jet or structural concern existed because of the certification exceedance.

Several more false alarms from avionics bay 3A, sensor 3A, circuitry prompted the decision on FD 10 to pull the circuit breaker. The plan for reentry was to close this circuit breaker for smoke detection redundancy in all avionics bays. Should an alarm be generated from this sensor during reentry, the crew was to verify the smoke concentration on the onboard display before discharge of the fire extinguishing bottle. Edwards Air Force Base (EAFB) was a NO-GO for landing on January 19, FD 10, due to potential low visibility.

At 1:35 a.m. local time on FD 11, January 20, 1990, *Columbia* with LDEF made a smooth touchdown on EAFB concrete runway 22. The rare night landing was the third for the Space Shuttle. The nose of the shuttle was kept high at touchdown because of the 115-ton landing weight with the LDEF aboard; this was almost 5 tons more at landing than any previous Space Shuttle . The landing delay made STS-32 the longest Space Shuttle mission to date, passing STS-9's 10-day 7-hr mark.

2.2 Flight/Vehicle Data

- Launch Date: January 9, 1990
- Launch Time: 7:35 a.m. EST
- Launch Site: KSC Pad 39A
- RTLS: Kennedy Space Center, Runway 33
- TAL Site: Ben Guerir, Morocco
- Alternate TAL Site: Moron, Spain
- Landing Site: Edwards AFB, CA, Runway 22
- Landing Date: January 20, 1990
- Landing Time: 4:35 a.m. EST
- Mission Duration: 10 Days, 21 Hours
- Crew Size: 5
- Inclination: 28.5 Degrees
- Altitude: 190 Nautical Miles/Direct Insertion
- Orbiter: OV-102 (9) *Columbia*
- SSMEs: (1) #2024, (2) #2022, (3) #2028
- ET: ET-032
- SRBs: BI-035
- SRMs: RSRM Flight Set #8



ENGINE	#2024	#2022	#2028
POWERHEAD	#2026	#2022	#4005
MCC*	#2013	#2022	#2018
NOZZLE	#4006	#4002	#4012
CONTROLLER	F5	F15	F21
FASCOS*	#01	#22	#21
HPFTP*	#6007	#4102R1	#2126
LPFTP*	#2131	#2024	#2026R2
HPOTP*	#4107R1	#2305R1	#2323R1
LPOTP*	#4206	#2104R1	#2027R1

* Acronyms can be found in Appendix A.

2.3 Payload Data

Payload Bay:

- Synchronous Communications Satellite (SYNCOM)-IV-5
- Interim Operational Contamination Monitor (IOCM)
- Long Duration Exposure Facility (LDEF) Retrieval

Middeck:

- American Flight Echocardiograph (AFE)
- Fluids Experiment Assembly (FEA)
- Protein Crystal Growth (PCG)
- Characterization of Neurospora Circadian Rhythms (CNCR) in Space
- Air Force Maui Optical Site (AMOS) Calibration Test
- IMAX Camera System
- Latitude Longitude Locator (L3)
- Mesoscale Lightning Experiment (MLE)

2.4 LDEF Payload Recovery

The Payload Operations Working Group (POWG) reviewed operational requirements for rendezvous, the photo survey scenario, planned operations during approach and grappling of LDEF, and post-berthing flight constraints on the Orbiter so as not to compromise the data collected over the past 5.5 years. All of these operations were actively worked by the flight crew and the appropriate flight planners. The crew was heavily involved in testing and practicing the maneuvers to accomplish rendezvous, grapple the LDEF, maneuver the spacecraft to obtain photo coverage, and dock the spacecraft into the Orbiter bay.

One concern related to the scenarios for being unable to deploy SYNCOM-IV-5 by any means, or where a SYNCOM failure would make deployment meaningless. The flight rules currently in place precluded returning with both LDEF and SYNCOM because the combination would make the Orbiter overweight for landing. There is a high probability that an overweight landing would result in structural damage to the Orbiter. A decision was made at the December 13, 1989, STS-32 Flight Readiness Review (FRR) Action Item Review not to attempt return with both LDEF and SYNCOM.

Fortunately, this situation did not arise. The SYNCOM satellite was deployed as planned, LDEF was retrieved from orbit, and *Columbia* returned safely to Earth with its mission successfully accomplished.

SECTION 3

SAFETY RISK FACTORS/ISSUES IMPACTED BY STS-32 ANOMALIES

This section lists safety risk factors/issues, considered resolved (or not a safety concern) for STS-32 prior to launch (see Sections 4, 5, 6, and 7), that were repeated or related to anomalies that occurred during the STS-32 flight. The list indicates the section of this Mission Safety Evaluation (MSE) Report in which the item is addressed, the item designation (Element/Number) within that section, a description of the item, and brief comments concerning the anomalous condition that was reported.

	ITEM	COMMENT
Section 4: Resolved Safety Risk Factors		
Integration 2	Orbiter/External Tank (ET) separation bolt exceeded torque specification.	During Orbiter/ET mechanical mate, the Liquid Hydrogen (LH_2) aft separation bolt exceeded the torque specification. The Left-Hand (LH) side LH_2 bolt exceeded the torque specification during final torque operation. New bolt and nut were installed and checked satisfactorily. No Orbiter/ET separation bolt anomalies were reported on STS-32. However, postflight inspection found the Right-Hand (RH) stop bolt slightly deformed (but not bent) on the centering ring of the forward ET attach/separation assembly. Deformations or flat spots similar to those seen on STS-32 have been found on other flight and qualification bolts.
Integration 5	Mercury Aerospace fasteners failed lot testing.	Mercury Aerospace fasteners failed lot testing for Spacelab hardware [non-uniform grain size (hot formed) and surface irregularities]. An alert was prepared for the Government, Industry Data Exchange Program (GIDEP). The Inspector General confiscated the defective hardware, and Marshall Space Flight Center (MSFC) Materials and Processes (M&P) tested the bolts. It was determined that the type of failures found in the lot tested could cause stress rupture in the part; however, MSFC did not consider this to be a problem because most of the applications were not in the high-temperature area. No anomalies attributed to Mercury Aerospace fasteners were reported on STS-32. However, during postflight disassembly of the STS-32 Solid Rocket

	ITEM	COMMENT
Section 4: Resolved Safety Risk Factors		
Integration 5 (Continued)		Boosters (SRBs), a broken fastener was found in the LH upper strut fairing or "milk can". Proper fastener material properties and heat treatment were confirmed by analysis of the failed fastener, and material analysis concluded that the failure was due to torsional overload. The failed fastener was not specifically identified as a Mercury Aerospace part.
Orbiter 9	Unloader valves on hydraulic systems #1, #2, and #3 are leaking above the allowable leak rate.	Prior to this flight, it was known that all 3 OV-102 unloader valves were experiencing out-of-specification leakage. Hydraulic systems #1, #2, and #3 unloader valves were leaking above the allowable leak rate of 30 pounds per square inch/hour (psi/hr), as high as 64 psi/hr, in the operational range from 2300 to 2400 pounds per square inch (psi). System #1 unloader valve was also leaking above the allowable leak rate in the operational range from 1870 to 2050 psi, at a rate of 402 psi/hr versus the 20 psi/hr allowable rate. Continuous leakdown of accumulator pressure results in excessive run time required from the circulation pump. Excessive pump run time would require a large amount of consumables from the fuel cells because the electrical circulation pump draws approximately 2000 watts. The leaking condition was waived for 1 flight, STS-32, with the understanding that hydraulic accumulator pressures would be closely monitored during prelaunch activities. However, approximately 1 hr prior to circulation

ITEM		COMMENT
Section 4: Resolved Safety Risk Factors		
Orbiter 9 (Continued)		pump #2 deactivation during the launch scrub turnaround (scrub due to weather conditions), there was a significant increase in unloader valve #2 cycling. Approximately 45 minutes (min) after deactivation of circulation pump #2, all bootstrap fluid pressure was lost. Because of a similar anomaly on STS-28, the decision was made to replace the hydraulic system #2 unloader valve prior to the STS-32 launch. The hydraulic system #1 unloader valve also had failed during testing; it was removed, replaced, and successfully retested. It is believed that contamination in the unloader valve pilot seat area caused the leakage problems. The hydraulic systems operated satisfactorily for the STS-32 flight.
SRB 1	Integrated Electronic Assembly (IEA) test failures.	While performing normal receiving inspection electrical tests at United Space Boosters, Inc. (USBI), the aft IEA, Serial Number (S/N) 55, failed the power bus isolation test due to a hard short of the power bus "A" return to the chassis; resistance to chassis should be 160,000 ohms minimum. The unit had tested "good" during the vendor's Acceptance Test Procedure (ATP). The unit was sent back to Bendix where it was determined that one bundle of 49 wires was wedged between a standoff and another wire bundle. This had caused the power cable to rub against the standoff, and a short-to-ground resulted. Three wires in the bundle of 49 carry Criticality 1 functions; the other 46 wires have no flight-critical effect.

ITEM		COMMENT
Section 4: Resolved Safety Risk Factors		
SRB 1 (Continued)		It was determined that this configuration was allowable in the applicable drawing and the problem was, therefore, not just the result of technician error. Both STS-32 aft IEAs were removed in the Vehicle Assembly Building (VAB) at Kennedy Space Center (KSC). IEAs S/N 29 and 49 were inspected for adequate wire bundle clearance prior to installation in STS-32. No IEA anomalies associated with wire bundle shorts to ground were reported on STS-32. However, during postflight disassembly, the right IEA connector was found damaged. Two pins were bent, probably during mating of the cable to the IEA. The pins were wired spares; therefore, they were not checked out during final functional testing after final mate of cables to the IEA.
Section 5: STS-33 Inflight Anomalies		
Orbiter 1	Auxiliary Power Unit (APU) #1 lube oil output pressure was high.	On STS-33, APU #1 experienced higher than normal lube oil pressure during ascent. Pressure peaked at approximately 85 psi, 25 psi higher than normal. The pressure returned to normal just prior to Main Engine Cutoff (MECO). Two waivers, one for high APU gearbox delta pressure and the other for high APU gearbox blanket pressure, were approved prior to STS-33 launch. It was found that the seal cavity pressure was higher than the gearbox pressure due to a procedural error, thereby allowing hydrazine seepage into the gearbox. A wax substance, pentaerythritoral, forms when hydrazine

ITEM		COMMENT
Section 5: STS-33 Inflight Anomalies		
Orbiter 1 (Continued)		mixes with the lube oil. This substance goes back into solution between 175-200°F, which is the nominal APU operating temperature. A similar anomaly was observed on STS-32. APU #3 experienced slightly high lube oil output pressure during ascent. The outlet pressure rose to 90 psi, and then decreased to a normal pressure range at L+9 minutes when the APU reached full operating temperature.
Orbiter 5	Hydraulic systems #1 and #2 accumulator ascent pressure locked-up low.	During STS-33 ascent, hydraulic systems #1 and #2 accumulator pressure locked-up low. This was similar to a problem on STS-26 and STS-29 where priority valves #1 and #2 experienced low reseats at APU shutdown. Lockups had been repeatable during OV-103 flights since reflight and showed no sign of further degradation. There was no immediate system concern; therefore, these valves were allowed to fly as is for STS-33 even though they were known to be out-of-specification. It is believed that the valves were set low during acceptance testing at the vendor, or they changed with time. This condition was waived with the understanding that for 1 flight, STS-32, accumulator pressures would be closely monitored during prelaunch activities. Hydraulic systems #1 and #2 also exhibited anomalous operation on STS-32 during launch scrub turnaround

ITEM		COMMENT
Section 5: STS-33 Inflight Anomalies		
Orbiter 5 (Continued)		(scrub due to weather conditions). However, the hydraulic systems operated satisfactorily for the STS-32 flight. (See the discussion in Section 4/Orbiter 9 above in this section of the Mission Safety Evaluation (MSE) Report.)
Orbiter 9	Flash Evaporator System (FES) "B" outlet temperature oscillation.	During STS-33 deorbit preparation, when FES B was reconfigured from the "PRI B ON" to the "PRI B GPC" position, it shut down because FES "B" was above the temperature limits. This was due to the inability of FES "B" to bring control band temperatures within shutdown logic limitations. A similar occurrence was experienced on STS-29. This anomaly was believed to have been caused by a tolerance buildup in the lead/lag times of controller B and its 3 temperature sensors. No similar anomaly was reported on STS-32. However, FES topping duct B string heater failed on day 7 of the STS-32 mission. FES topping duct heater A was selected and operated nominally for the remainder of the mission.
Orbiter 11	Hydraulic system #2 Water Spray Boiler (WSB) Gaseous Nitrogen (GN_2) leakage was out-of-specification.	During STS-33 on-orbit preparations, the WSB for hydraulic system #2 demonstrated excessive GN_2 leakage. A similar anomaly was experienced on STS-29 WSB #1. On STS-32, GN_2 regulator pressure on WSB boilers #2 and #3 indicated pressure decay rates of approximately 0.11 psi/hr over a 16-hr period; the allowable specification decay rate is

ITEM		COMMENT
Section 5: STS-33 Inflight Anomalies		
Orbiter 11 (Continued)		0.06 psi/hr. However, the decay rate approached zero by the end of the mission. It is believed that the pressure decays were due to GN_2 relief valves not being fully seated and not due to water leaks. The poppets in the relief valves were removed and replaced. GN_2 24-hr decay check on system #2 indicated leakage of 0.06 psi/hr that was just within the specification limits.
SRB 1	Holddown Post (HDP) anomalies.	Orbiter accelerometer readings at STS-33 SRB ignition indicated a holddown bolt anomaly. The launch film showed the stud at HDP #3 hung-up, similar to the occurrence on STS-34. The stud extended approximately 8" and contacted the aft skirt stud hole wall. This may have caused a piece of the epon shim to pull loose and separate from the skirt foot. An area of epon shim material (approximately 34 in^2) on the bottom of the right SRB HDP #3 was observed falling off during the launch. A Rockwell International (RI) evaluation of this type of anomaly concluded that the probability of shim material ricocheting and impacting the vehicle is extremely remote as the primary forces acting on the shim particles are gravity, plume impingement, and aspiration. Postflight inspection of the RH aft skirt found that it had been broached on the aft side of the HDP #3 bolt hole. Thread impressions were also visible on the forward side of the same hole. HDP broaching occurred on several previous flights, most recently on STS-34.

ITEM		COMMENT
Section 5: STS-33 Inflight Anomalies		
SRB 1 (Continued)		No HDP stud hangups were reported on STS-32. However, a large amount of debris (approximately 7 pounds) escaped from the HDP Debris Containment System (DCS) during STS-32 Liftoff. This was directly attributed to removal of the frangible link from the DCS.
SRB 2	LH External Tank Attachment (ETA) Ring IEA end cover and cable sooted.	Upon removal of the LH IEA covers from STS-33, sooting was noted on 16 cables and interior painted surfaces of the end cover. Examination of the cable jacket indicated no heating effects (no erosion, clouding of material, or degradation). It was determined that the gap in the RTV-133 sealant allowed hot gases to enter the ETA ring and the IEA cable areas through the aft side of the IEA end cover. The gases entered at the aft side of the end cover, traveled across the wire bundles, and exited through the opposite (forward) side of the end cover. This was evidenced by the heaviest sooting deposits on the aft side of the IEA end cover and the flow pattern. The direction of hot gas flow entering the end cover indicated that this condition occurred during reentry or descent. The RTV-133 material was missing at the area of soot entry and exit. All cables functioned properly during the mission. Insufficient heat was present to damage the cables or impair the cable function. Corrective action consisted of a Field Engineering Change (FEC) effective for STS-32, STS-36, STS-31, and STS-35. Engineering Change Proposal (ECP)-2670 will make this

	ITEM	COMMENT

Section 5: STS-33 Inflight Anomalies

SRB 2 (Continued)		change to the closeout procedures permanent. It clarifies the Thermal Protection System (TPS) closeout, assuring proper closeout and preventing anomaly recurrence. Minor sooting of the ETA ring aft IEA middle cover was found on STS-32; IEA functioning was not affected. The sooting was attributed to installation of larger Hi-Lok fasteners, preventing proper fit of the cover.
KSC 1	Improper installation of cable connector assemblies.	During STS-33 postflight assessment, 2 cable connectors were found incorrectly installed, and 2 ground straps were loose due to omitted washers. The RH forward skirt Range Safety System (RSS) Ground Support Equipment (GSE) cable [Radio Frequency (RF) signal to the Integrated Receiver/ Decoder (IRD)] was not fully seated on its mating connector at the forward feedthrough. The connector was engaged only 3/4 of a turn; 3 1/2 turns are required for full engagement. The connector was lockwired correctly. The connector insert showed signs of moisture and contained K5NA debris. This cable is not used in flight, but is used during range safety ground checkout. The LH upper strut separation ordnance connector was finger-loose. The connector was lockwired correctly. The jam nut was retorqued to determine the relationship of the lockwire to the properly-torqued connector. Slack in the lockwire indicated that the connector had not been properly torqued prior to lockwire

ITEM		COMMENT
Section 5: STS-33 Inflight Anomalies		
KSC 1 (Continued)		installation. Two ground straps located between the RH SRB aft IEA bracket and the Solid Rocket Motor (SRM) were loose. The ground strap fasteners bottomed out due to omitted washers. Some washers had not been installed on the fasteners on the forward end of the IEA, but those fasteners had not bottomed out and the ground straps were not loose. All 4 bolts were torqued properly (125-150 inch-pound (in-lb)). The LH brackets had washers installed. During STS-32 postflight disassembly, 2 bent pins were found on the right SRB IEA connector. This was considered to have occurred during mating of the cable to the IEA. The pins were wired spares that were not checked out during functional testing after final cable mate.
Section 6: STS-28 Inflight Anomalies		
Orbiter 13	Hydraulic system #2 unloader valve operated out-of-specification.	During STS-28/OV-102 prelaunch, the unloader valve cycled when the accumulator pressure reached 2350 psi; this is higher than the 2100-psi specification limit. During the mission, accumulator pressure dropped sharply from 2500 to 2350 psi, and the unloader valve cycled. Valve leakage or striction were considered possible causes of this anomaly. The MC284-0438-0001 configuration unloader valve has a history of leakage. The Orbiter Project Office (OPO) directed replacement of -0001 valves with -0002 valves on an attrition basis. KSC removed and replaced this valve; it was returned to

ITEM		COMMENT
Section 6: STS-28 Inflight Anomalies		
Orbiter 13 (Continued)		the vendor for failure analysis. Leak check of the replacement valve was satisfactory. On STS-32, OV-102 hydraulic systems #1 and #2 unloader valves also experienced similar anomalous operation during prelaunch. See the discussion in Section 4/Orbiter 9 above in this section of the MSE Report for details.
SRM 1	Gask-O-Seal void found during postflight inspection.	During postflight disassembly and inspection of the STS-28 right SRM igniter, a small depression was found at 210° on the inner primary seal on the aft face of the inner Gask-O-Seal (360H005B). The crown of the seal was depressed inward and measured approximately 0.100" long circumferentially by 0.025" radially; it extended across the crown width. It appeared that a possible subsurface void may have existed in the inner primary seal prior to flight. There was no evidence of a leak path in the putty (primary seal not pressurized). The joint passed preflight low- and high-pressure leak test. No blowby past the inner primary seal or pressure path to the seal was found. However, leak test may not be sufficient if an indentation exists in the seal. The joint gap is predicted to open 3.5 mils at the outer gasket, 3.0 mils at the inner gasket. Indentation, if present, may not dynamically track the gap opening on pressurization, and the leak test is not flight dynamic. Additionally, crown indentations were also discovered during disassembly of

ITEM	COMMENT
Section 6: STS-28 Inflight Anomalies	
SRM 1 (Continued)	new gaskets on Development Motor (DM)-9 and Qualification Motor (QM)-6. Subsurface void was found in both cases; contamination was also present on DM-9. Standard Nondestructive Inspection (NDI) techniques, such as X-ray, cannot reliably detect subsurface voids. Current known gasket defects are detectable by visual and touch inspection at disassembly. Indentation is easily detectable after gasket removal. It should be noted that indentations have never been detected on reused gaskets. Corrective action was initiated to develop an inspection technique to detect subsurface voids: design a plexiglass fixture for seal test; reinvestigate N-ray and x-ray; and investigate ultrasonics and background scatter. For the STS-32 flight, the left and right SRM igniter seals were inspected and replaced. All 360L008 seals were reused and had flown previous missions; one was flown 3 times. They passed thorough visual and touch inspection upon removal from the compressed state; no indentations were detected. The seals passed all certification inspection criteria and leak tests. Resiliency tests demonstrated that a minimum crown height of 0.021" will meet a 1.4 tracking factor at Launch Commit Criteria (LCC) temperatures. All STS-32 igniter gaskets met the crown height requirement of 0.021-0.031".

ITEM	COMMENT
Section 6: STS-28 Inflight Anomalies	
SRM 1 (Continued)	However, SRM Gask-O-Seal anomalies were also reported on STS-32. During postflight inspection of the right SRM Safe and Arm (S&A) gasket, a small depression was found in the crown of the secondary seal aft face. Small raised areas or bulges were also found on the cushion and in the valleys of the igniter inner Gask-O-Seal. (See Section 7, SRM 1 and SRM 2 for more details.)

SECTION 4

RESOLVED STS-32 SAFETY RISK FACTORS

This section contains a listing of the safety risk factors that were considered resolved for STS-32. These items were reviewed by the NASA safety community. A description and information regarding problem resolution are provided for each safety risk factor. The safety position with respect to resolution is based on findings resulting from System Safety Review Panel (SSRP) and Program Requirements Control Board (PRCB) reviews (or other special panel findings, etc.). It represents the safety assessment arrived at in accordance with actions taken, efforts conducted, and tests/retests and inspections performed to resolve each specific problem.

SECTION 4 INDEX

RESOLVED STS-32 SAFETY RISK FACTORS

RESOLVED STS-32 SAFETY RISK FACTORS

RESOLVED STS-32 SAFETY RISK FACTORS

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
INTEGRATION		
1	Unitrode diodes alert. HR No. ORBI-038 INTG-113 INTG-145A B-50-26 Rev. C-DCN2 ***No anomalies attributed to Unitrode diodes were reported on STS-32.***	Unitrode diodes were investigated against several alerts and evaluated for Space Shuttle applications. Generic Unitrode diode failures with DO-35, soft glass, silver button construction were identified. Recent evaluations by Marshall Space Flight Center (MSFC), the Department of Defense (DoD), and the aerospace industry have determined that this type of construction cannot be upgraded for use in space. Additional background on this issue may be found in the STS-33 Mission Safety Evaluation (MSE) Report. Rationale for STS-32/BI-035 flight with Unitrode diodes was based on the low failure rate (4-out-of-1478 total for Orbiter and Solid Rocket Booster (SRB)), no failure history other than Multiplexer-Demultiplexers (MDMs), and MDM redundancy (port moding provides redundancy in the core power supply, and redundant MDMs are used for the Input/Output Module (IOM) power supply function). Prelaunch testing and checkout verified operation and redundancy through launch countdown. Maximum stress for critical diodes occurs during MDM bench test and not during countdown or flight. Diode failure is detectable during all subsequent testing and through countdown. ***This risk factor was resolved for STS-32.***

RESOLVED STS-32 SAFETY RISK FACTORS

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
<u>INTEGRATION</u>		
2	Orbiter/External Tank (ET) separation bolt exceeded torque specification. HR No. INTG-051A ORBI-304A *No Orbiter/ET separation bolt anomalies were reported on STS-32. However, postflight inspection of STS-32 found the Right-Hand (RH) stop bolt slightly deformed (but not bent) on the centering ring of the forward ET attach/separation assembly (IFA No. STS-32-26). Deformations or flat spots similar to those seen on STS-32 have been found on other flight and qualification bolts.*	During Orbiter/ET mechanical mate, the Liquid Hydrogen (LH_2) aft separation bolt exceeded the torque specification. The torquing operation consists of several incremental steps to reach the final value. The steps include 215K to 270K pounds and 315K to 370K lb to establish flight loads on the bolts. The torque is measured by the tension load on the bolt. Three torque multipliers are used during the operation to eliminate calibration concerns. The Left-Hand (LH) side LH_2 bolt exceeded the torque specification during the final torque operation. The bolt and pryo nut were removed and inspected, and no grease was observed on 2 1/2" threads but was present on 3 3/4" threads. Grease wipe samples of the bolt and the nut were sent to the laboratory for analysis, and the analysis verified grease on 3 3/4" threads and a lesser amount on 2 1/2" threads. New bolt and nut were installed with grease on 2 1/2" threads. No anomalies were encountered during the torquing operation of the properly lubricated assembly. Review of the Operations and Maintenance Instruction (OMI) indicated no changes were required. *This risk factor was resolved for STS-32.*

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
INTEGRATION		
3	Liquid Oxygen (LO_2) 2" poppet vented. ***No anomalies were reported on STS-32.***	During Orbiter/ET mechanical mate, the LO_2 2" poppet vented while the umbilicals were retracted. The LO_2 and LH_2 umbilical hydraulic actuators were retracted for rollover (the umbilical actuators were mechanically locked and in free float). The belleville washer modification required the aft LO_2/LH_2 actuators to be unlocked to remove the preload from the umbilical plate for washer alignment. Downward motion after the actuator unlocked was: LH_2 0.568"; LO_2 no movement. After washer modification, the LH_2 plate was pushed up with the Ground Support Equipment (GSE) jacks and verified to be locked. The LO_2 side was assumed to be locked since it did not move during the unlock steps (locking sleeve in unlock position). A procedure deviation was implemented to not perform LO_2 actuator movement. Inspections in the Orbiter Processing Facility (OPF) and the Vehicle Assembly Building (VAB) transfer aisle verified the horizontal positioning. During mating operation, the LO_2 plate (aft) was observed to be extended in the -Z direction. The mating operation continued until the 2" poppet depressor tool contacted the 2" ET poppet, thereby venting the tank. After reconfiguring the Orbiter, the plate was realigned to lock the actuator. Mechanical mate was then completed with no other anomalies. Rationale for STS-32 flight was: • The LO_2 aft umbilical actuator extension was caused by improper lock configuration. • In the future, the flows will require actuator recycle and verification prior to rollout if the locks are disturbed. ***This risk factor was resolved for STS-32.***

RESOLVED STS-32 SAFETY RISK FACTORS

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
<u>INTEGRATION</u>		
4	Flasher software problems. HR No. INTG-165 ORBI-066 *No anomalies were reported on STS-32.*	A coding error in disk compaction utility control cards caused user status and control utility (Flasher) to overwrite data on disk data sets in the Software Production Facility (SPF). The control card error was introduced on August 25, 1989, and fixed on November 8, 1989. Overwrites were limited to a single disk volume (1 of 200 in the SPF). Overwrites were only possible between running the compaction utility and restart of the Flasher utility (6 instances, with multiple overwrites possible in each instance). Two incidents were detected: STS-38 downlist data set – November 2; STS-37 Initial Program Load (IPL) assembly source – November 28. This was initially assessed as only affecting 01-8D data sets, and a Criticality 1 Discrepancy Report (DR) was opened against 01-8D on November 2. This was not presented at the STS-32 Flight Readiness Review (FRR) since the STS-32 data set was 01-8C. However, on December 5 it was recognized that other SPF activities could be impacted. The Criticality 1 DR was, therefore, extended to all SPF production on December 5. In addition to affecting flight software, there was also potential impact to the Johnson Space Center (JSC) Mission Control Center (MCC) and Shuttle data tape products. A 5-strategy approach was taken to clear concerns for STS-32. • Identify all data sets on the suspect disk pack during the vulnerable period and audit to determine if any were used in STS-32 production. If specific STS-32 data sets were vulnerable, verify that there were no overwrites. • Analyze the process to determine areas where the process was vulnerable to single undetected overwrite anywhere in the system. Revalidate any vulnerable components. • Rebuild the mass memory from known good products (unexposed to vulnerability or regenerated) and compare to final load.

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
INTEGRATION		
4 (Continued)		• Identify and perform additional testing on delivered products, if required. • Perform a general coarse search for overwrites. As a result of this effort, all suspect data sets were identified (1493); evaluation of contamination was completed by December 15, 1989. Vulnerabilities to overwrite in executables were identified, and all executables were cleared by master comparisons. All Mass Memory Unit (MMU) components were cleared by comparison between independent copies. The Mission Support Directorate (MSD)/International Business Machines (IBM)-built MMU image was from known good components. It was identical to the SPF final load. It was also confirmed that software released in the final load on September 21 was identical to the current SPF final load. Normal post-final release testing did not reveal any Flasher-related problems. Coarse search was performed for the "Flasher" pattern in all STS-32 components. Search and investigation of all critical support software and the 1493 data sets on the suspect disk were performed. No problems were found. Rationale for STS-32 flight was: • It was determined on December 5, 1989, that STS-32 flight software on OV-102 was good for hazardous ground testing. • The flight software was ready for STS-32 based on results of the 5-strategy investigation described above. • MCC products were ready for STS-32 based on identification of suspect data sets and validation of their contents. ***This risk factor was resolved for STS-32.***

RESOLVED STS-32 SAFETY RISK FACTORS

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
<u>INTEGRATION</u>		
5	Mercury Aerospace fasteners failed lot testing. *No anomalies attributed to Mercury Aerospace fasteners were reported on STS-32. However, during postflight disassembly of the STS-32 SRBs, a broken fastener was found in the LH upper strut fairing or "milk can" (IFA No. STS-32-B-03 and STS-32-K-04). Proper fastener material properties and heat treatment were confirmed by analysis of the failed fastener, and material analysis concluded that the failure was due to torsional overload. The failed fastener was not specifically identified as a Mercury Aerospace part.*	Mercury Aerospace fasteners failed lot testing for Spacelab hardware (non-uniform grain size (hot formed) and surface irregularities). McDonnell Douglas purchased the fasteners from Emanon (a distributor), and an independent test laboratory Nondestructive Evaluation (NDE) tested samples. The testing revealed extreme grain size differences between the head and shank of the first 2 lots and surface irregularities on 3 consecutive thread roots of the third lot. McDonnell Douglas Space Systems Company (MDSSC) prepared an Alert for the Government, Industry Data Exchange Program (GIDEP). The Inspector General confiscated the defective hardware, and MSFC Materials and Processes (M&P) performed testing on the bolts. M&P determined that this failure could cause stress rupture in the part. MSFC did not consider this to be a problem because most of the applications were not in the high-temperature area. Nine Mercury part numbers used for SRB component installations were tested. Chemistry and tensile tests of all samples were within specifications (183-213 KSI vs 180-220 KSI required). Two of 7 double-shear tests were marginally below minimum specification, but all yield margins were well above 1.4. Metallurgy was acceptable for grain size (cold formed); however, thread laps-slivers were found to be out-of-specification on 3 parts. All installations were for shear applications and were normally torqued to 40% of design tensile strength. Thread irregularities do not affect shear applications. The torque preloads are the highest load the bolts will see and serve as a proof load for the installation.

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
INTEGRATION		
5 (Continued)		Rationale for STS-32 flight was: • Martin Marietta Manned Space Systems (MMMSS) (ET) - Failure mode, stress rupture, was not a concern on the ET. • United Space Boosters, Inc. (USBI) (SRB) - Tested several other lots, found no problems. Fastener strength and chemistry were within specification. All Mercury installations were shear applications and successfully passed torque preload. • Rocketdyne (Space Shuttle Main Engine (SSME)) - Did not use the specified part numbers; had not procured from Mercury. • Thiokol (Solid Rocket Motor (SRM)) - Had not procured specific part numbers from Mercury. • Teledyne Brown Engineering - Did not use Mercury fasteners. • Rockwell International (Orbiter) - Did not use Mercury fasteners. ***This risk factor was resolved for STS-32.***

RESOLVED STS-32 SAFETY RISK FACTORS

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
<u>ORBITER</u>		
1	17" disconnect main actuator drive link bearing cracks. HR No. ORBI-302A *No anomalies were reported on STS-32.*	During Operational Maintenance Requirements and Specifications Document (OMRSD) OV-104 preflight inspection, main actuator drive link bearings in the 17" disconnect were found to be cracked. In the LH_2 actuator, 1 of 4 bearings was cracked; 2 of 4 LO_2 actuator bearings also had cracks. Inspection of OV-102 found 2 of 4 LO_2 actuator drive link bearings cracked. No cracks were found in the OV-102 LH_2 side. During the 1981-1982 Qualification Test Program, 4 drive link bearings were reported cracked. These cracks did not impair proper 17" disconnect functioning and were accepted as satisfactory by Space Shuttle Program Management. Additional background on this issue may be found in the STS-33 MSE Report. As part of OV-102 turnaround for STS-32, the 17" disconnect actuators were inspected to determine if the snap rings were in place. The snap rings hold the bearings on the actuator pins. The actuator drive link bearing cracks on OV-102 were not considered a constraint to flight. Rationale for flight was based on previous experience which demonstrated that cracked link bearings do not impair actuator performance. *This risk factor was resolved for STS-32.*
2	Loose connector backshells. HR No. INTG-144B *No anomalies associated with connectors were reported on STS-32.*	Inspection of 500 OV-102 connectors found 50 connector backshells that were not tightened properly. Discrepancies were also noted in proper use of safety wires, spot ties, and loctite. Backshell torquing was a problem due to the low 80 inch-ounce torque level required. Backshells were hand tightened, because torque wrenches for these low torque levels were not available. There is no Electromagnetic Interference (EMI) shielding concern if backshell threads engage the main body of the connector. There is no structural concern if the spot tie of the harness to the backshell strain relief is properly made.

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
<u>ORBITER</u>		
2 (Continued)		All accessible connectors were brought up to the installation drawing specifications and inspected per ML0303-0040, except for one tang ring shield termination connector (ME127-0081). All remaining connectors will be inspected and repaired prior to the next OV-102 flight. Action to improve personnel job performance was also taken to ensure proper connector assembly. ***This risk factor was resolved for STS-32.***
3	Brakes locked during carbon brake system verification testing. HR No. ORBI-234 ***No brake anomalies were reported on STS-32.***	The carbon brake system was undergoing verification testing on a dynamometer at Wright Patterson Air Force Base (WPAFB). During test #14 of 35 planned verification tests, the tires skidded for 8 to 10 seconds (sec). The anti-skid subsystem did not relieve pressure to prevent skidding. The pressure relieved only enough to reduce braking to the 50% level. Extensive skidding resulted in blowout of both tires, and tire debris broke the hydraulic line. It was noted that this particular test had a nonflight configuration orifice installed between the pressure regulator and the carbon brake module. Prior to this test, hydraulic resonance problems were experienced which led to a complete flushing of the system. Gross contamination was also found on the system inlet. Rationale for STS-32 flight was: • This test was not representative of the carbon brake system flight configuration. • STS-32 was to fly with beryllium brakes. The beryllium brake systems are unable to skid tires with 50% braking when landing on either concrete or lakebed runways. ***This risk factor was resolved for STS-32.***

RESOLVED STS-32 SAFETY RISK FACTORS

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
<u>ORBITER</u>		
4	Water deluge of STS-32/OV-102. HR No. ORBI-085 *No anomalies attributed to the effects of the inadvertent dumping of water on OV-102 in the OPF were reported on STS-32.*	On September 24, 1989, the OPF High Bay #2 water deluge system was inadvertently activated, resulting in dumping of an extensive amount of water on OV-102. The water in the system was tap water with a high concentration of iron and zinc. The Orbiter was inspected to determine the extent of possible damage from the deluge. Inspection results can be found in the deluge investigation report and in the backup material for this STS-32 MSE (Section 8). Rationale for STS-32 flight was: • Water was removed from the affected areas, and critical areas were purged with dry Gaseous Nitrogen (GN_2). • All OV-102 areas were thoroughly inspected and cleaned, as required. • The water inspection plan was documented and approved at Level II. • There were no known concerns for flight due to water intrusion. Vehicle power-up tests found no wiring or electrical problems, and all OMRSD recertification requirements were successfully met. *This risk factor was resolved for STS-32.*

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
5	Dome heat shield blanket damage. HR No. INTG-020 ME-B4A ME-B4C ME-B4S *No anomalies were reported on STS-32.*	The dome heat shield blankets on all 3 STS-33 Main Engines (MEs) were found to be damaged. • Engine #1: The blanket was severely torn from the 2:30 to the 6:00 o'clock position. • Engine #2: The 1" bumper strip that attaches the blanket to the heat shield broke loose. The blanket was detached from about the 12:30 to the 3:00 o'clock position and dropped down on top of the nozzle. The flexible seal beneath the blanket was exposed; however, inspection found that the seal was only slightly discolored and was still flexible. • Engine #3: The outer blanket cover was torn from the 9:00 to the 10:00 o'clock position. Damage occurs in this area of the dome heat shield blankets on every flight. Blanket damage is caused by buffeting from ME shock waves. The outer covering is a lightweight material. It is being replaced with a heavier material that is tightly woven and has the appearance of canvas. The dome heat shield blankets on STS-34/OV-104 had the new outer covering material; these blankets did not need repair. OV-103 blankets will be replaced/repaired with the new material. The blankets on STS-32/OV-102 had a mixture of the old and the new blankets.

RESOLVED STS-32 SAFETY RISK FACTORS

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
5 (Continued)		The blankets protect the ME flex seal that prevents Hydrogen (H_2) Ingestion into the aft compartment. The outer covering, stuffing, and inner covering must be missing to get a direct flow path to the flex seal and cause damage. To date, an entire dome heat shield blanket had not been lost. The worst case experienced was the damage to the engine #2 blanket on the STS-33 flight. ***This risk factor was resolved for STS-32.***
6	Elevon tile improperly bonded. HR No. ORBI-249A ***No anomalies associated with improperly bonded tiles were reported on STS-32.***	OV-104 postflight inspection found 130 loose/improperly bonded tiles. Some of the tiles were loose enough to be removed by hand. OV-103 was also inspected, and similar conditions were found. Examination of the removed tile bond lines indicated that the Strain Isolator Pad (SIP) had not made full contact with Room Temperature Vulcanizate (RTV) in the cavities. Other tiles were found to have "fuzzy" type bonds. It should be noted that even though RTV penetration into the SIP in the "nominal" bonds was adequate for structural integrity, the bond line characteristics still indicated marginal RTV penetration into the SIP. OV-102 elevon tile wiggle tests were performed. No tile problems were found. ***This risk factor was resolved for STS-32.***
7	Nose Landing Gear (NLG) slapdown load. HR No. ORBI-021 ORBI-179 ***No anomalies attributed to the NLG slapdown load were reported on STS-32.***	The NLG could have exceeded the 90K lb design limit load (lakebed landing) during the Orbiter landing with the Long Duration Exposure Facility (LDEF) on board. Simulations have indicated derotation pitch rates greater than 8° per sec for a lakebed landing. JSC data ranged from 8.5 to 9.2° per sec for a lakebed landing, while the Ames data ranged from 7.4 to 8.7° per sec.

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE

ORBITER

7 (Continued)

A slapdown "worst-case" run yielded the following results:

• Main Landing Gear (MLG) touchdown speed (knots)	173.0
• Orbiter starts derotation (knots)	171.0
• Speed at NLG impact (knots)	152.0
• Pitch rate (° per sec)	9.5
• NLG limit load (K lb)	108.0

Pitch rate limit required to maintain the 90K lb certified limit is indicated for a range of expected lakebed landing conditions by the 2 cases shown below:

• MLG touchdown speed (knots)	200.0	190.0
• Orbiter starts derotation (knots)	185.0	165.0
• Speed at NLG impact (knots)	163.0	145.0
• Pitch rate (° per sec)	8.0	8.4
• NLG limit load (K lb)	90.0	90.0

The Orbiter structure is certified for a 90K lb nose gear vertical load limit. The NLG successfully demonstrated an off-limit reserve energy drop test at 109K lb in accordance with the Federal Aviation Regulation (FAR)-25 certification requirement. The Orbiter derotation limit was 8.8° per sec for the STS-32 landing weight of 229,273 lb and center of gravity of 1079.4" in benign (zero crosswind) conditions in order not to violate the 90K lb NLG design load limit.

A postlanding inspection is required if the landing load exceeds the 90K lb limit. The NLG loads are reduced if the landing is on a concrete runway; therefore, runway 22 at Edwards Air Force Base was the selected primary landing site. The alternate landing priority order was Edwards lakebed, Northrup, and KSC. The extent of the inspection, if required, is dependent on the loads experienced.

This risk factor was acceptable for STS-32.

RESOLVED STS-32 SAFETY RISK FACTORS

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
<u>ORBITER</u>		
8	OV-102 has a history of high H_2 concentrations during tanking. HR No. ORBI-306 ***No anomalies associated with exceedance of the LCC limits established for H_2 concentrations were experienced on STS-32.***	OV-102 has a history of high H_2 concentrations in the aft compartment during tanking. During STS-28 tanking operations, H_2 concentrations approached the Launch Commit Criteria (LCC) of 500 parts per million (ppm), peaking at 485 ppm. LCC limits have been established so that H_2 concentration of 4% is not exceeded during ascent prior to the point where the aft compartment pressure drops below 0.5 pounds per square inch absolute (psia). LCC limits were revised for OV-102 only. For the period from T−6 hours (hr) to the start of replenish fill, the LCC limit of 500 ppm was increased to 600 ppm. From the start of replenish through T−31 sec, the LCC was lowered from 500 ppm to 300 ppm. If a hold occurs at T−31 sec for reasons other than high H_2 concentrations, the LCC is now 600 ppm. If 300 ppm is exceeded at T−31 sec, the Countdown (CD) clock would hold for 2 minutes (min). The redline at the end of the 2-min hold is 600 ppm. Data collected to date indicates that leakage is from the low-to-medium pressure joints. Normal leak check procedures have not pinpointed the leak source(s). No further checks were scheduled prior to STS-32 launch, provided that a launch scrub was not promulgated by H_2 LCC limit exceedance. ***This risk factor was acceptable for STS-32.***

RESOLVED STS-32 SAFETY RISK FACTORS

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
9	Unloader valves on hydraulic systems #1, #2, and #3 are leaking above allowable leak rate. HR No. ORBI-052 ***The out-of-specification unloader valve leakage was waived for 1 flight, STS-32, with the understanding that hydraulic accumulator pressures would be closely monitored during prelaunch activities. Unloader valve anomalies were experienced during STS-32; systems #1 and #2 unloader valves were replaced prior to STS-32 launch (IFA No. STS-32-16). (See Section 7, Orbiter 8 for more details.)***	Hydraulic systems #1, #2, and #3 unloader valves were leaking above the allowable leak rate of 30 pounds per square inch/hour (psi/hr), as high as 64 psi/hr, in the operation range of 2300 to 2400 pounds per square inch (psi). System #1 unloader valve was also leaking above allowable in the operation range of 1870 to 2050 psi, at a rate of 402 psi/hr versus the 20 psi/hr allowable rate. Continuous leakdown of the accumulator pressure results in excessive run time required from the circulation pump. Excessive run time would require a large amount of consumables from the fuel cells because the electrical circulation pump requires approximately 2000 watts to run. The system #1 unloader valve was replaced twice since STS-28 because of excessive leakage. The first unloader valve was a -0001 configuration; known to have leak problems. Both replacements were made with -0002 configuration unloader valves. OV-102/STS-32 had -0002 valves installed on systems #1 and #2; system #3 still had the -0001 configuration valves. The -0002 valve incorporates a filter on the accumulator outlet to protect the pilot section of the unloader valve which is highly susceptible to contamination. To date, only two failures of the -0002 valves have been documented. The first failure was related to a workmanship problem that was found during acceptance testing; a screenable failure. The second failure was attributed to built-in contamination. Initial installations of -0002 valves did not require system flushing until after the filters were installed. Investigation of the contamination-related failure found that contamination in the system prior to installation of the -0002 valves would be trapped. Corrective action has been implemented to flush all new -0002 valves prior to installation of the filters. Relative to the two -0002 unloader valves on OV-102/STS-32, it was determined that system #1 was not flushed prior to filter installation; system #2 was flushed prior to filter installation per the revised installation instructions.

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
<u>ORBITER</u>		
9 (Continued)		Contamination was the most probable cause of the system #1 unloader valve leakage. Leak rates measured on December 14, 1989, would require circulation pump operation every 5 to 6 hr on system #1, less often on systems #2 and #3. This was considered acceptable because there were enough fuel cell consumables to run system #1 continuously. ***This risk factor was acceptable for STS-32.***
10	Suspect solder joints in Master Event Controllers (MECs). HR No. INTG-165 ***No MEC anomalies were reported on STS-32.***	MEC Serial Number (S/N) 10 was at the vendor, Autonetics, for rework. Certain integrated circuits, primarily the 24-pin circuits, were found to have a number of fractured joints. To date, 6 of the 24-pin integrated circuits in S/N 10 had been replaced. Solder joints in the MECs were suspect. The problem was isolated to workmanship. Leads were applied to the integrated circuits in a manner that resulted in a prestressed condition prior to the application of solder. This stress can cause the solder joint to fracture and lift the lead from the connection point. Visual inspection of all MEC solder joints was mandated. However, there were questions concerning the inspection record-keeping process and the adequacy of visual inspections. MECs on OV-102 were identified as S/N 1 and S/N 8. JSC reviewed records to verify that these units were inspected and cleared of suspect solder joints.

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
10 (Continued)		Rationale for STS-32 flight was: • A backup MEC board is carried on each flight; the backup board manifested on STS-32 was inspected and cleared. • The Orbiter has redundant MECs. • The MECs are internally redundant. Each MEC has 2 coils; only 1 has to fire to provide proper system operation. *This risk factor was resolved for STS-32.*

RESOLVED STS-32 SAFETY RISK FACTORS

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
<u>SSME</u>		
1	Engine #2022 overangulation HR No. ME-C3 (All Phases) ME-D3 (All Phases) ***No anomalies were reported on STS-32.***	During positioning of platforms around OV-102/STS-32 in the OPF, an interference problem was found between the platform and engine #2022. A technician was asked to use the stiffarm to gimbal the engine in order to properly position and secure the platform. The technician was inexperienced with stiffarm operation and adjusted the yaw stiffarm so that the screw mechanism only slightly engaged. During engine work performed on the subsequent shift, stiffarm or engine movement resulted in stiffarm disengagement which allowed the engine to swing freely to the left until the low-pressure fuel duct contacted the Thrust Vector Control (TVC) yaw actuator. This resulted in engine overgimbaling to a 16.2° angle. The specification limit for gimbaling is 11°. Extensive inspection and analysis cleared all engine hardware for flight, except the fuel bleed articulating duct that was replaced. Rationale for flight was based on inspection and structural analysis indicating an adequate Factor of Safety (FOS) for the engine hardware involved in the overgimbaling (except for the fuel bleed duct that was replaced). Additionally, engine #2022 harness checkout was successfully performed during flight readiness testing and avionics checkouts. ***This risk factor was resolved for STS-32.***
2	Crack found on fuel preburner diffuser. HR No. ME-B2 (All Phases) ***No anomalies related to the fuel preburner were reported on STS-32.***	A crack is known to exist on the lip of certain fuel preburner diffusers. There have been 7 instances of similar cracking found during the life of the program. Investigation found that 6 of the 7 previous instances of cracks were attributed to diffusers or housings with dimensions that exceeded drawing specifications and had excessive interference fits. Interstage seal wear was also typical on units with cracked diffusers. Additional background on this issue may be found in the STS-33 MSE Report.

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
SSME		
2 (Continued)		The rationale for STS-32 flight was: • Diffuser cracks are acceptable for continued flight usage, and there have been no reports of cracks in the STS-32 fuel preburner diffusers. • Prior flight experience with cracked diffusers resulted in benign conditions and no detrimental effects. There are 7 known cracked units. A total test time of 49,344 sec during 137 tests has been logged with cracked diffusers. The fleet leader of these 7 had undergone 64 tests, for a total operating time of 28,699 sec. ***This risk factor was resolved for STS-32.***
3	Engine #2024 Main Combustion Chamber (MCC) hot wall depressed area. HR No. ME-B5S ***No anomalies related to engine #2024 were reported on STS-32.***	Engine #2024, MCC Unit Number (U/N) 2013, had a depressed area (lack of cleanup) on the hot wall at the end that increases the nozzle coolant tube protrusion. Lack of cleanup is a result of insufficient material during final machining caused by weld distortion and an undersized liner. This resulted in an increase in tube protrusion of approximately 0.045". This condition may have influenced bulge formation in the crown on nozzle U/N 4014 during its acceptance test series. The resulting tube protrusion with this combination was a 0.093" effective protrusion. Rationale for STS-32 flight was: • Nozzle U/N 4014 was replaced with U/N 4006 that had no bulges. • Engine #2024 had a maximum protrusion of 0.050".

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
<u>SSME</u>		
3 (Continued)		• Eight engines with equal or greater protrusions had demonstrated 37 starts and 12,250 sec of hot-fire time with no bulges. • The 2 instances of bulges showed stability under hot fire. ***This risk factor was resolved for STS-32.***
4	High-Pressure Oxidizer Turbopump (HPOTP) exceeds 50% fleet leader. HR No. ME-C1 (All Phases) ***No HPOTP anomalies were reported on STS-32.***	The intermediate seal heat shield of HPOTP #2305R1, installed on STS-32 engine #2022, exceeded 50% of the fleet leader experience. The heat shield had accumulated 32 starts and 8752 sec of operating time; 68% of the number of starts and 57% of the operating time experienced by the fleet leader. The heat shield was used on HPOTP #2305 due to a housing match set requirement. It functions as a thermal shield and conducts helium from the main housing to the intermediate seal assembly. The shield is visually inspected at every complete disassembly. Rationale for STS-32 flight with HPOTP #2305 was: • Worst-case failure effects would allow internal helium leakage due to piece part failure. Intermediate seal pressure redline protects against loss of helium barrier. • The stationary part had a high FOS (1.6 yield, 4.3 ultimate). – Primary loading is from compressive force of the bolts. – Infinite fatigue life is predicted.

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
<u>SSME</u>		
4 (Continued)		• No failures had been experienced in the program. • Intermediate seal assembly leak checks and green run data were normal. The part was acceptable for flight. All of the other SSME components had less than 50% of the fleet leader experience. ***This risk factor was resolved for STS-32.***
5	Engine #2029 heat shield debris. HR No. ME-B1 (All Phases) ME-C2 (All Phases) ***No engine heat shield anomalies were reported on STS-32.***	The main injector heat shield reinforcement ring was found delaminated on OV-104 engine #2029 after STS-34 flight. A section was missing outboard of posts 61-65, row 13. Two of the 3 pieces spanning the section were recovered in the HPOTP; 1 piece fell free, 1 was in the turbine. A segment approximately 0.65" long by 0.35" wide by 0.35" thick (weighing approximately 0.96 grams) was not found. It may possibly have located between Liquid Oxygen (LOX) posts. HPOTP inspection and a successful green run were performed at Stennis Space Center (SSC). The main injector outer row, Heat Exchanger (HEX), and High-Pressure Fuel Turbopump (HPFTP) were borescoped. The engine was rotated twice on the handler; 12 times in each direction. It has been recommended that, if the segment of the heat shield reinforcement ring is not found, the main injector should be overhauled. Engine #2029 was replaced by engine #2027 on STS-36/OV-104.

RESOLVED STS-32 SAFETY RISK FACTORS

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
<u>SSME</u>		
5 (Continued)		Rationale for STS-32 flight was: • All engines were inspected before flight. • Hot-fire tests verified heat shield integrity. • Heat shield failure during flight is not a hazard. Broken pieces remain at the main injector due to the flow. No flow blockage hazards exist. • STS-32 engines had new-configuration heat shields. They were not subject to breakage, and the heat shield was contained. ***This risk factor was resolved for STS-32.***
6	Main injector LO_2 post hazard FOS. HR No. ME-B4C ME-B4M ***No anomalies associated with the LO_2 posts were reported on STS-32.***	Hazard Reports (HRs) ME-B4C, Main Injector Burnthrough, Rupture, Explosion (Cutoff) (currently an accepted risk for other reasons), and ME-B4M, Main Injector Burnthrough, Rupture, Explosion (Main Stage), were reviewed. Change Requests (CRs) to Level II were prepared to reclassify these HRs to the Accepted Risk category due to the calculated High-Cycle Fatigue (HCF) FOS of 3.5. This violated the 4.0 FOS Configuration End Item (CEI) requirement. The focus of this concern was with the calculated FOS for LO_2 posts 6 and 7, row 13, engine #2022, and for high-cycle Return To Launch Site (RTLS) missions. LO_2 post cracks may propagate and lead to failure of the LO_2 post and combining of LO_2 and LH_2. LO_2 post failure can be caused by excessive cumulative HCF damage in the inertia weld area at the base of the LO_2 post. HCF can be accelerated by the combination of stub height, offset between the injector post and the stud, and a residual electrical discharge machining recast layer on the post inner-diameter surface.

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
SSME		
6 (Continued)		Structural analysis, referenced in Deviation Approval Request (DAR) 1620R4, utilized a material test program that established the fatigue properties of parts with electrical discharge machining recasts in critical inertia weld joint regions. This refined analysis indicated that an FOS of 3.5 remained at the end of an RTLS abort scenario, potentially the longest run time, for engine #2022 posts 6 and 7 in row 13. The System Safety Review Panel (SSRP) reviewed the proposed changes on January 4, 1990, and recommended that the HRs not be changed for this single component deficiency condition. Rather, the FOS requirement should be waived. Engine #2022 had 12 starts at this time, with a total operation time of 3610 sec. In comparison, engine #0211 had been tested with 69 starts and 28505 sec of operation and reached a damage fraction greater than 1.0 on the LO_2 post with the electrical discharge machining recast defect. No LO_2 post failures had been reported to date. Additionally, engine #2010 was tested to 66 starts and 19807 sec of operation. The injector was sectioned for inspection, with no cracks or HCF damage identified. Rationale for STS-32 flight with engine #2022 was based on: • Comparison with engines having much greater operating times and starts. • Calculated high-cycle FOS of 3.5 for an RTLS, and an FOS of 4.0 for a low-cycle (nominal) mission. ***This risk factor was acceptable for STS-32.***

RESOLVED STS-32 SAFETY RISK FACTORS

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
SSME		
7	Potential for residual recast in critical zone of injector LO_2 post No. 8, row 13, engine #2022. HR No. ME-B4 (All Phases) ***No associated anomalies were reported on STS-32.***	The potential for residual recast existed in the critical zone of engine #2022 LO_2 injector post 8, row 13. Projected LO_2 post damage fraction exceeded 0.25; calculated damage fraction for post 8, row 13 of engine #2022 was 0.46 after a worst-case RTLS abort. The injector on engine #2022 was fabricated prior to the implementation of RL00860, injector post inspection requirements for surface finish and defects. During an inspection of the post, an offset of 0.0045" was found at the inertia weld. Light recast was also found in the 0.183" and 0.156" diameter areas of the post. Subsequent borescope inspection of the post inner diameter was performed to determine the actual recast location. No unacceptable recast was found to be present which would inhibit safe flight. ***This risk factor was resolved for STS-32.***

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
<u>SRB</u>		
1	Integrated Electronic Assembly (IEA) test failures. HR No. B-50-26 Rev. C-DCN2 ***No IEA anomalies associated with wiring bundle shorts to ground were reported on STS-32. However, during postflight disassembly the right IEA connector was found damaged (IFA No. STS-32-K-03). Two pins were bent, probably during mating of the cable to the IEA. The pins were wired spares; therefore, they were not checked out during final functional testing after final mate of cables to the IEA.***	While performing normal receiving inspection electrical tests at United Space Boosters, Inc. (USBI), the aft IEA, S/N 55, failed the power bus isolation test due to a hard short. Power bus "A" return-to-chassis read shorted; resistance to chassis should be 160,000 ohms minimum. The unit had tested "good" during the vendor's Acceptance Test Procedure (ATP). The IEA was sent back to Bendix where the cover was removed. It was determined that one bundle of 49 wires was wedged between a standoff and another wire bundle. This caused the power cable to rub against the standoff, and a short-to-ground resulted. Three wires in the bundle of 49 carry Criticality 1 functions; the other 46 have no flight-critical effect. Seven other aft IEAs were inspected, and 1 additional instance of rubbing was found. It was determined that this configuration was allowable in the applicable drawing and was not just the result of technician error. Both STS-32 aft IEAs were removed in the VAB at Kennedy Space Center (KSC). IEAs S/N 29 and 49 were inspected for adequate wire bundle clearance prior to installation in STS-32. ***This risk factor was resolved for STS-32.***
2	SRB TVC tilt channel D driver current dropout. HR No. INTG-144A B-00-17 Rev. B-DCN3 ***No anomalies were reported on STS-32.***	During power-up, the RH SRB TVC tilt channel D driver current dropped out for 13 min. During investigation into the cause of this problem, the following actions were taken: • Shook connectors between the monoball interface and aft avionics bay #6. No dropouts were observed. • Shook Ascent Thrust Vector Control (ATVC) #4 Command (CMD) connector/harness (646P123) and ATVC output connector/harness (66P121). Dropout occurred.

RESOLVED STS-32 SAFETY RISK FACTORS

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
<u>SRB</u>		
2 (Continued)		• Further testing of the output connector/harness produced 2 more dropouts. Output connector 66P121 was demated/inspected/replaced, and the 2 suspect sockets on the harness plug were reconnected. (The malfunction laboratory uncovered no probable cause in the connector.) Instrumentation connector 66P124 was demated, and the suspect sockets were reconnected. A break-through box was installed to monitor open path signal characteristics seen during the dropouts; these signal characteristics were reproduced. The assembly was remated to flight configuration. Retest was performed as part of the SRB Hydraulic Power Unit (HPU) hot fire. Orbiter circulation pumps were brought up to retest the Space Shuttle Main Engine (SSME) TVC signals. SRB HPU hot fire with gimbaling retested the SRB paths. ATVC #4 was powered up periodically and monitored for dropouts. Retest performance was satisfactory. The dropouts were probably due to an open signal path at the output connector. ***This risk factor was resolved for STS-32.***
3	TVC fuel filter bowl drain cap hazard upgrade. HR No. A-20-24 B-20-04 ***No anomalies were reported on STS-32.***	A CR was submitted to Level II to reclassify HR A-20-24, Hydrazine Leakage, and B-20-04, Hydrazine Source in the Presence of an Ignition Source, from Controlled to Accepted Risk. This classification change related to the hazard of hydrazine leakage past the HPU/Auxiliary Power Unit (APU) fuel pump filter bowl drain Quick Disconnect (QD) and its cap that form a bore seal on the QD. The cap is the secondary seal in this case. There were no requirements for torquing, lockwire, thread engagement verification, or other securing provisions for the QD cap. These HRs were not submitted for approval for STS-32; however, updates were prepared and submitted for consideration with other HRs to update the hazard baseline for STS-36.

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
SRB		
3 (Continued)		The SSRP reviewed this HR on January 4, 1990, and concluded that the drain cap may not be qualified for full flight pressure and that leak tests do not independently check both seals. The SSRP recommended that the drain caps be visually verified during a window of opportunity on January 4, 1990, but decided not to consider this to be a constraint if the inspection could not be performed. It was decided not to perform the inspection due to serious schedule impact on launch. A document/photo review of the configuration was performed instead. The closeout photos showed that the caps were installed. Rationale for acceptance of this additional risk for STS-32 was: • The QD primary seal was designed with an FOS 2 times that necessary to meet the operating pressure of 1500 psi. • The QD primary seal was leak checked at the vendor. It was checked by USBI during processing via sniff checks for hydrazine leakage. • There was no previous record of leaks or QD failures in this area of the HPU/APU fuel system. There was also no experience of caps backing off during flight. • Both HPUs were hot-fired on the pad without QD leakage. ***This risk factor was acceptable for STS-32.***

RESOLVED STS-32 SAFETY RISK FACTORS

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
SRB		
4	Fuel Isolation Valve (FIV) isolation mount washer. HR No. A-20-26 Rev. C ***No FIV anomalies were reported on STS-32.***	Postflight inspection of STS-34 hardware revealed a loose isolation mount fastener (backed out 3/16") on FIV S/N 0060. The flight configuration specified an MS-35338-139 lock washer with each fastener. Both isolation mount fasteners on FIV S/N 0060 had NAS-1587-4C flat washers. Inspection of 42 flight units revealed 1 additional FIV isolation mount with a flat washer. Failure of this isolation mount during ascent could result in a Criticality 1 failure (fuel system leakage). The 2 improperly configured mount assemblies had off-nominal processing steps; however, the installation point of the flat washers could not be determined. To verify that proper lock washers were installed on STS-32 hardware, a visual inspection was performed on the pad. It was found that proper lock washers were installed on all FIV bolts. ***This risk factor was resolved for STS-32.***

RESOLVED STS-32 SAFETY RISK FACTORS

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
SRM		
1	Colocated fretting of SRM tang and clevis at the RH forward field joint on STS-32. HR No. BC-01 Rev. B BC-08 ***No associated anomalies were reported on STS-32.***	The SRM Project Office identified that 2 segments mated on STS-26 (360L001) at the forward RH field joint became fretted and were mated in the same location on the STS-32 (360L008) stack. There was concern relative to the deleterious effects of mating 2 segments with facing frets. To date, mated segments had only one side of the field joint identified as being fretted, as was the case on STS-33. Rationale for STS-32 flight was: • Analysis showed that facing frets would not affect gap deflection (or sealing) at the primary and secondary O-rings because the fretted areas are localized. • The localized fret blends did not provide a complete gas path through the tang/clevis metal-to-metal interference region, so thermal erosion is not an issue. • For additional confidence, thermal erosion was only a consideration if the J-seal insulation and the capture feature O-ring fail. To date, hot gas had never penetrated through the J-seal insulation except when intentionally flawed during the Redesigned Solid Rocket Motor (RSRM) testing program. ***This risk factor was resolved for STS-32.***

RESOLVED STS-32 SAFETY RISK FACTORS

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
SRM		
2	Intermittent paint flaking on LH center aft SRM segment on STS-32. HR No. INTG-037B ***No associated anomalies were reported on STS-32.***	During processing of the STS-32 SRMs at KSC, paint flaking was observed intermittently around the full circumference of the segment near the aft tang end. There was a concern that bond strength was inadequate and the potential for debris existed. Laboratory tests of the flaked paint identified HD-2 grease contamination. Since this finding, process inspections were instituted to ensure proper surface preparation and absence of contamination prior to painting. However, this inspection could not be performed on mated STS-32 segments. For the STS-32 LH center aft segment, tape pull tests were performed to identify areas where paint adherence was questionable; these areas were cleaned and repainted. In addition, Porta-Pull tests were conducted to verify acceptable cork bonding. ***This risk factor was resolved for STS-32.***
3	Left SRM aft joint heater experienced high voltage readings. HR No. FI-01 Rev. B ***No further SRM heater anomalies were reported on STS-32.***	The left SRM aft joint heater experienced high voltage readings following heater power-up. The voltage readings returned to normal following igniter joint heater deactivation and remained normal throughout the remainder of the countdown. Rationale for STS-32 flight was: • Ground Fault Interrupt (GFI) circuitry with a response time of less than 500 milliseconds (msec) had been incorporated in all SRM joint and igniter heater circuits on the Mobile Launch Platforms (MLPs). This would protect against damage to the SRM case. • The system passed the Dielectric Withstanding Voltage (DWV) test. ***This risk factor was resolved for STS-32.***

RESOLVED STS-32 SAFETY RISK FACTORS

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
SRM		
4	Voids in SRM forward dome insulation. HR No. BC-09 BC-10 ***No associated anomalies were reported on STS-32.***	STS-32 RH SRM forward dome insulation had 2 voids between 4.7" and 6.4" outboard of the igniter opening. The voids were evaluated to determine if there was adequate thermal and erosion protection remaining. A similar problem existed on STS-34 (360L006) and STS-33 (360L007). Rationale for STS-32 flight was: • Using the minimum insulation thickness measured and subtracting the voids provided the following data: (see table below) • Based on review of the above information, it was determined that the insulation in the void areas was adequate to protect the SRM case. ***This risk factor was resolved for STS-32.***

Void Number	Thickness Measurement	Erosion Safety Factor (based on an M + 3 sigma decomposition depth)
1	0.560" (measured 10" from igniter port opening)	1.75 (1.5 required)
2	0.656" (measured in void area)	1.72 (1.5 required)

RESOLVED STS-32 SAFETY RISK FACTORS

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
<u>SRM</u>		
5	Nozzle throat erosion. HR No. BN-04 Rev. B BN-07 Rev. B ***No associated anomalies were reported on STS-32.***	During STS-33 postflight assessment, localized erosion areas were discovered in the nozzle throat ring. Two small 0.2" wide by 2-3" long localized areas of erosion (wash) were found in the aft end of STS-33B carbon cloth phenolic throat ring. • 0.18" deep at 200° location. • 0.17" deep at 300° location. Causes of localized erosion areas include: • Density variation. • Localized disturbances in supersonic flow at the throat exit that creates heat transfer coefficient differences. • Materials and process variations that result in density differences. Erosion wash areas were seen previously in this location on STS-26A (0.25" deep), STS-29A (0.1" deep), STS-30B (0.12" deep), and STS-34A (0.15") deep. Erosion wash areas and pockets are allowed per CEI specification, provided the performance margin of safety requirements are met. The erosion wash areas on this motor showed positive FOSs (2.14 at 200° location and 2.23 at 300° location). Review of the raw material, processing, and part acceptance data showed no nonconformances.

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
<u>SRM</u>		
5 (Continued)		Rationale for STS-32 flight was: • Review of raw materials, processing, and part acceptance data showed STS-32 throat rings were acceptable. Lot 2032, used on STS-32B, was previously used on STS-33A and showed nominal performance. • Erosion wash areas were expected for tape-wrapped parts. ***This risk factor was resolved for STS-32.***

RESOLVED STS-32 SAFETY RISK FACTORS

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
<u>GFE</u>		
1	Remote Manipulator System (RMS) fails to stop. HR No. RMSX0028026 RMSX0041028 ***No associated anomalies were reported on STS-32.***	The RMS arm is supposed to stop and apply the brakes on all joints when the command words are lost. The Manipulator Controller Interface Unit (MCIU) is the data interface between the RMS Display and Control (D&C) panel, the Orbiter General Purpose Computer (GPC), and the arm. Each 42 msec, the MCIU sends 12 16-bit serial command words to the arm. A frame sync pulse latches the commands into the joints, and the MCIU receives 30 16-bit serial return words from the arm. An MCIU Built-In-Test Equipment (BITE) routine compares the 12 command words with 12 return words and automatically safes the arm if a mismatch is detected. If the frame sync pulse does not occur, the arm will continue to drive based on the last good data that was latched into each joint. HR and Failure Modes and Effects Analysis (FMEA) review found a new failure mode, with a payload captured that causes the consistency check to be reset during the frame in which the consistency check is needed to detect loss of frame sync. This condition causes the arm to continue to drive in the direction in which it was last commanded to move. Alarms are sounded but the arm is not automatically stopped. The crew must recognize the anomalous condition and manually stop the arm before it causes damage. ***This risk factor was acceptable for STS-32 based on crew backup being a satisfactory control to preclude damage.***
2	Concern for flammability of off-the-shelf camcorder case. NSRS Report No. 270 HR No. ORBI-259A ***No anomalies were reported on STS-32.***	STS-32 flew a commercial, off-the-shelf camcorder. A NASA Safety Reporting System (NSRS) report was received which indicated that the case was made of ABS plastic, which is very easily ignitable, burns intensely, and gives off toxic fumes while burning. It did not meet flammability and toxicity requirements for use in the Shuttle crew cabin. An arc from a 6-volt source (same as the battery for the camcorder) is sufficient to ignite the case.

RESOLVED STS-32 SAFETY RISK FACTORS

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
GFE		
2 (Continued)		Discussions with the JSC TAG member via telecon indicated that the issue was thoroughly reviewed by the JSC technical community. They agreed with the NSRS report with regard to flammability. Several factors were weighed for risk acceptability. • Amount of plastic is small and discrete. • Main ignition source, the battery, was fused at the negative terminal to protect against arcing in the camcorder. • Camcorder is stowed, unpowered, during ascent and descent in an isolated stowage locker. Rationale for flying the camcorder on STS-32 was: • Crew members were aware of the flammability potential of the ABS plastic used in the camcorder and would use caution while the camcorder was not stowed and in use. • Crew members would inspect the camcorder for any obvious defects prior to applying power. • The NSTS Program normally will allow use of small, discrete packages, such as the camcorder (e.g., cassette recorders), which can easily be controlled. ***Although NSRS Report No. 270 was not formally closed prior to launch, this risk factor was not considered a constraint to STS-32 flight.***

RESOLVED STS-32 SAFETY RISK FACTORS

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
<u>KSC</u>		
1	Crew emergency escape breathing device, known as "SCRAM", generates nearly pure oxygen about the heads of the crew. NSRS Report No. 269 ***There were no fires, and no SCRAM-associated anomalies were reported on STS-32.***	NSRS Report No. 269 indicates that the crew emergency breathing devices, called SCRAM, are unsuitable for use in emergencies involving fires. Prior to entering the Orbiter, crew members require emergency escape breathing devices for use without their suit helmet and personal breathing equipment. KSC was requested to purchase SCRAMs and pre-position them in the white room to meet this requirement. The SCRAMs produce nearly pure oxygen into a hood placed around the head. In a fire, the oxygen could support vigorous combustion of human hair and oils on and under the skin. This would likely be fatal. The NSRS Report recommends switching to emergency breathing devices that provide an air mixture. The NSRS Report was evaluated by KSC and JSC. This issue was included in the MSE for information because the NSRS Report was unresolved. ***This issue was not considered a constraint to STS-32 launch.***

SECTION 5

STS-33 INFLIGHT ANOMALIES

This section contains a list of Inflight Anomalies (IFAs) arising from the OV-103/STS-33 mission. Each anomaly is briefly described, and risk acceptance information and rationale are provided.

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STS-33 INFLIGHT ANOMALIES

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STS-33 INFLIGHT ANOMALIES

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
INTEGRATION		
1	Space Shuttle Main Engine (SSME) #2107 nozzle bluing. IFA No. STS-33-I-01 HR No. ME-B7 (All Phases) ***No Main Engine (ME) nozzle bluing was reported on STS-32.***	Postflight visual inspection of the ME #2107 nozzle revealed discoloration or "bluing" on the front face of the aft manifold. The discoloration was centered about the lower centerline (±1.5 feet (ft)), low reentry heating region. Nozzle structure is uninsulated in this region (Inconel 718). No discoloration was evident on the ME #2031 nozzle. Discoloration in this region was not observed in previous flight experience. The nozzle discoloration cannot be explained by the predicted heating environment. The time/cause of the discoloration is not yet understood. Worst-case recurrence would impact nozzle reuse. This Flight Problem Report was approved at the Level II Noon Program Requirements Control Board (PRCB) on February 8, 1990. Per Dr. Lenoir at the STS-36 Flight Readiness Review (FRR), this Inflight Anomaly (IFA) was reopened. Further data was requested from other flights using new ME nozzles. ***Not a safety concern for STS-32.***

STS-33 INFLIGHT ANOMALIES

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
1	Auxiliary Power Unit (APU) #1 lube oil output pressure was high. IFA No. STS-33-01 HR No. ORBI-036 ***A similar anomaly was observed on STS-32 (IFA No. STS-32-02). APU #3 experienced slightly high lube oil output pressure during ascent. Outlet pressure rose to 90 pounds per square inch (psi) and then decreased to a normal pressure range at L+9 minutes (min) when the APU reached full operating temperature.***	APU #1 experienced higher than normal lube oil output pressure during ascent. Pressure peaked at approximately 85 psi, 25 psi higher than normal. The pressure returned to normal just prior to Main Engine Cutoff (MECO). Two waivers, 1 for high APU gearbox delta pressure and the other for high APU gearbox blanket pressure, were approved prior to STS-33 launch. The seal cavity pressure was higher than the gearbox pressure due to a procedural error, allowing hydrazine seepage into the gearbox. A wax substance, pentaerythritoral, is formed when hydrazine is mixed with lube oil. This substance goes back into solution between 175-200°F, the nominal APU operating temperature. Kennedy Space Center (KSC) performed oil flush and drain, as well as lube oil filter changeout per Operational Maintenance Requirements and Specifications Document/Operations and Maintenance Instruction (OMRSD/OMI) V10078, prior to the next OV-103 flight. KSC was directed to double-bag the filter and send it to Rockwell International (RI)/Downey for analysis. Oil samples were taken prior to system flush. ***Not a safety concern for STS-32.***

STS-33 INFLIGHT ANOMALIES

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
2	Cabin air leak through the Waste Collection System (WCS). IFA No. STS-33-02 HR No. ORBI-077 ***No anomaly was reported on STS-32.***	Cabin pressure decreased to 14.28 pounds per square inch absolute (psia) before the leak was isolated. The crew isolated the leak to coincide with WCS usage. The leak was verified when the commode slide valve was opened and no discernable air flow was noted. Air transportation of fecal matter was also lost. The crew performed inflight maintenance to manually move the vacuum ball valve from vacuum position to FAN SEP position. Cabin pressure was restored as well as full WCS operation. Inspection of the OV-103 WCS at Dryden by Johnson Space Center (JSC)/Hamilton Standard personnel found a broken pin on the linkage between the handle and the relief valve. Further investigation determined that the wrong pin was installed. OV-102 was checked prior to STS-32 and found to be correct. OV-104 will be inspected at KSC prior to STS-36. ***Not a safety concern for STS-32.***
3	Reaction Control System (RCS) F1U pressure transducer failure. IFA No. STS-33-04A HR No. ORBI-203 ***No RCS anomalies were reported on STS-32.***	The RCS F1U chamber pressure transducer failed during Flight Control System (FCS) checkout in preparation for reentry. Indications were that the jet fired properly on ascent. For reentry, F1U was deselected due to the low chamber pressure indication and was not required for the remainder of the mission. Similar instances of low RCS thruster chamber pressure were experienced on 3 previous flights on all Orbiters. A decision was made not to repair this transducer until after STS-31, since this jet is mainly used for proximity missions only and STS-31 was not a rendezvous mission. ***Not a safety concern for STS-32.***

STS-33 INFLIGHT ANOMALIES

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
4	Commander's airspeed mach indicator out of specification. IFA No. STS-33-05 *No anomaly was reported on STS-32.*	During FCS checkout, the Commander's airspeed mach indicator read 20,500 feet per second (fps); specification is 20,000 fps. This problem was also reported on the 2 previous OV-103 missions since reflight. On STS-26, it read 22,250 fps (IFA No. STS-26-20); on STS-29, 22,050 fps. This anomaly was isolated to OV-103. *Not a safety concern for STS-32.*
5	Hydraulic systems #1 and #2 accumulator ascent pressure locked-up low. IFA No. STS-33-07 HR No. ORBI-052 ***This condition was waived for 1 flight only, STS-32, with the understanding that accumulator pressures would be closely monitored during prelaunch activities. Hydraulic Systems #1 and #2 unloader valves also exhibited anomalous operation on STS-32 during launch scrub turnaround (IFA No. STS-32-16). Prior to STS-32 flight, it was known that all 3 unloader valves were seeing out-of-specification leakage. The cause of the leakage was believed to be contamination in the unloader valve pilot area. (See Section 7, Orbiter 8 for further details.)***	During ascent, hydraulic systems #1 and #2 accumulator pressure locked-up low. This anomaly was similar to a problem on STS-26 and STS-29 (IFA No. STS-29-26) where priority valves #1 and #2 experienced low reseats at APU shutdown. The valves are required to lock up at 2600 pounds per square inch differential (psid) pressure (referenced to reservoir pressure). After STS-33 ascent, priority valve #1 locked-up at 2420 psid; valve #2 locked-up at 2340 psid. Lockups have been repeatable during the 3 OV-103 flights since reflight and showed no sign of further degradation. During special testing at KSC, 2 of the 6 lockups were below specification. There was no immediate system concern; therefore, these valves were allowed to fly as-is for STS-33. However, the valves were known to be out-of-specification. It is believed that the valves were set low during acceptance testing at the vendor or changed with time. These valves had never flown prior to STS-26. There has been no evidence of problems with the priority valves on OV-102 and OV-104 missions since reflight. The 2 valves were removed and replaced. *Not a safety concern for STS-32.*

STS-33 INFLIGHT ANOMALIES

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
6	Power Reactant Storage and Distribution (PRSD) Oxygen (O_2) tank #1 had a sticky Check Valve (CV). IFA No. STS-33-08 HR No. ORBI-094 ***No anomaly was reported on STS-32.***	PRSD O_2 tank #1 CV stuck twice during the mission. This O_2 tank was not in use when the anomalies occurred. When a 20-psid pressure difference built up across the CV, it opened and operated nominally. Nominal cracking pressure is 3-5 psid. This particular CV experienced a large 180-psid closing force after high O_2 flow associated with the pressure leak through the WCS (see Orbiter 2 above). Stopping the high O_2 flow caused Liquid Oxygen (LO_2) to be trapped in the manifold. Environmental heat converted the LO_2 to gas and pressurized the manifold until the relief valve opened. The CV operated nominally for the remainder of the mission. Sticking CVs were observed on previous flights subsequent to large closing forces. No remedial action was required. It is believed that this anomaly was caused by transient contamination, compounded by the high checking force during the pressure leak through the WCS. ***Not a safety concern for STS-32.***
7	Forward attach point system A and system B connectors found damaged. IFA No. STS-33-10 HR No. ORBI-289 ***No pyro connector anomaly was reported on STS-32.***	During Orbiter inspection at Dryden, it was found that the tangs on both system A and system B pyro connectors were clocked incorrectly. Clocking was at 30° aft instead of straight-up. One connector (20V77W11J13) had a broken strain relief; the other connector (20V77W12J12) had a loose backshell. A known interference problem existed between these connectors and the forward attach pyro bolt; it is very alignment sensitive. All connectors and harnesses in this area are replaced prior to each flight. JSC and RI engineers prepared a design change to replace these connectors with 90° backshell connectors. This change will correct the interference problem. ***Not a safety concern for STS-32.***

STS-33 INFLIGHT ANOMALIES

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
8	"Y" Star Tracker door thermal blanket detached. IFA No. STS-33-11 HR No. ORBI-011A ***The thermal blankets were removed prior to STS-32 launch, thereby precluding recurrence of this anomaly. Postflight inspection of the STS-32/OV-102 "Y" Star Tracker door found no apparent thermal effects.***	The "Y" Star Tracker door thermal blanket was found totally detached from the door and lying loose on the bottom of the Star Tracker cavity. The blanket was not damaged at the attach points. A small tear on the top of the blanket indicated that it was detached when the door closed. No fastener damage was observed. Investigation of problems during Star Tracker door cycling on OV-104, prior to rollout for STS-34, found that the thermal blankets interfered with the bright-object sensor. Redesigned thermal blankets were installed on all Orbiters. There were no reported problems with the modified blankets on STS-34. Worst-case effects of loose thermal blankets are related to jamming the Star Tracker doors open during reentry. This would allow plasma flow through the cavity resulting in damage to the Star Tracker. Recent RI thermal analysis indicated that the thermal blankets in the Star Tracker cavity were not necessary, based on redefined heating environments. A recommendation was made by RI at the STS-32 FRR to remove these blankets prior to launch. The recommendation was subsequently approved by the PRCB, and the blankets were removed. ***This anomaly was resolved for STS-32.***

STS-33 INFLIGHT ANOMALIES

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
9	Flash Evaporator System (FES) B outlet temperature oscillation. IFA No. STS-33-13 HR No. ORBI-276B ORBI-300 ***No similar anomaly was reported on STS-32. However, FES topping duct B string heater failed on day 7 of the STS-32 mission. FES topping duct heater A was selected and operated nominally for the remainder of the mission (IFA No. STS-32-14).***	During FES B deorbit preparation, when FES B was reconfigured from the "PRI B ON" to the "PRI B GPC" position, it shut down because FES B was above the temperature limits. This was due to FES B inability to bring control band temperatures within shutdown logic limitations. A similar occurrence was experienced on STS-29 (IFA No. STS-29-14). Prior to STS-33, the midpoint sensors were repacked due to a lag that existed between the midpoint temperature sensor and actual Freon Coolant Loop (FCL) temperatures. This was caused by a midpoint sensor manifold design change for OV-103 only, which should have rectified this problem. After the first occurrence of this anomaly on STS-33, FES B was recycled; this successfully brought the temperature into the control band before the shutdown logic timed out. FES B operated nominally for the remainder of the flight. This anomaly was believed to have been caused by a tolerance build-up in the lead/lag times of controller "B" and its 3 temperature sensors. ***This anomaly was resolved for STS-32.***

STS-33 INFLIGHT ANOMALIES

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
10	Erratic temperature indications from APUs #1 and #3 bypass line "A". IFA No. STS-33-16 HR No. ORBI-250 ***No APU temperature sensor anomaly was reported on STS-32.***	Bypass line "A" temperature sensors on both APU #1 and APU #3 demonstrated erratic behavior. This was indicated by erratic bypass line heater operation. The temperature sensors, or thermostats, are mounted on the APU bypass lines. It is believed that these lines experienced vibration which led to loosening of the thermostat sensor mounts. A determination was made to replace both the "A" and "B" temperature sensors on both APUs. APU #1 temperature sensors were replaced and tested satisfactorily. A decision was made to delay the replacement of APU #3 temperature sensors until after STS-31, when the entire APU will be replaced. ***This anomaly was resolved for STS-32.***
11	Hydraulic System #2 Water Spray Boiler (WSB) Gaseous Nitrogen (GN_2) leakage was out of specification. IFA No. STS-33-17 HR No. INTG-072 INTG-113 ***WSBs #2 and #3 had pressure decay rates above the allowable specification during the STS-32 prelaunch period. The probable cause was a water or GN_2 leak. Monitoring of pressure decay rates found that they approached zero by the end of the mission (IFA No. STS-32-17).***	During on-orbit operations, the WSB for hydraulic system #2 demonstrated excessive GN_2 leakage. Some decay in GN_2 tank pressure is expected. Leakage on STS-33 was at a rate of 0.36 pound per square inch/hour (psi/hr); the specification limit is 0.30 psi/hr. A similar anomaly was experienced during STS-29 on WSB #1. ***Not a safety concern for STS-32.***

STS-33 INFLIGHT ANOMALIES

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
SRB		
1	Holddown Post (HDP) anomalies. IFA No.STS-33-B-01 IFA No.STS-33-B-02 HR No. INTG-164 B-00-15 B-00-17 ***No HDP stud hangups were reported on STS-32. However, a large amount of debris (approximately 7 pounds) escaped from the HDP Debris Containment System (DCS) during STS-32 liftoff. This was directly attributed to removal of the frangible link from the DCS. (For more details on the debris escape, see the STS-36 Postflight Mission Safety Evaluation (MSE), Section 4, SRB 3.)***	Orbiter accelerometer readings at Solid Rocket Booster (SRB) ignition indicated a holddown bolt anomaly. The launch film showed the stud at HDP #3 hung-up, similar to the occurrence on STS-34. The stud extended approximately 8" and contacted the aft skirt stud hole wall. This may have caused a piece of the epon shim to pull loose and separate from the skirt foot. An area of epon shim material (approximately 34 square inches) on the bottom of the right SRB HDP #3 was observed falling off during the launch. An RI evaluation of this type of anomaly concluded that the probability of shim material ricocheting and impacting the vehicle is extremely remote as the primary forces acting on the shim particles are gravity, plume impingement, and aspiration. Postflight inspection of the Right-Hand (RH) aft skirt found that it had been broached on the aft side of the HDP #3 bolt hole. Thread impressions were also visible on the forward side of the same hole. One of the 2 pyrotechnic charges used on each frangible nut did not appear to explode properly on HDPs #3, #4, and #8. The frangible nut separation area showed a ductile separation. Nominal operation of the pyrotechnics causes splintering of the nut material at the explosion site. The cause of ductile separation seen on these nuts was inconclusive. It could indicate explosion was either less powerful than desired or late. The anomalous pyro action might have contributed to the stud hangup at HDP #3. HDP broaching occurred on several previous flights, most recently on STS-34. Rationale for STS-33 launch, the next flight after STS-34, was that a Marshall Space Flight Center (MSFC) and RI integration analysis indicated that all 8 HDP bolts could hang-up with no deleterious liftoff performance effects, provided that all frangible nuts are released. However, the potential problem experienced with the skewed firing of the frangible nut pyrotechnic charges identified the need for further

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
<u>SRB</u> 1 (Continued)		analysis relative to the influence and contribution of the bolt hangup at HDP #3 and liftoff performance degradation. Further analysis found the following: • Worst-case hangup was defined as the hangup of all 4 studs on 1 SRB. • Worst-case hangup has a minimal effect on post and tower clearance. • Worst-case hangup has a negligible effect on flight controllability. • Worst-case hangups could cause the limit load to be exceeded on some External Tank (ET) and/or SRB hardware based on a conservative quick look analysis (4 stud hangups could possibly reach 1.2 to 1.4 times the limit load). One, 2, or 3 stud hangups yields loads within limit loads. • The probability of a worst-case 4-stud hangup is less than 2 times 10^{-5} with removal of the plunger-to-stud frangible bolt. • RI load analysis concluded that the structure can withstand a 4-post worst-case load plus 3σ dispersed loads. Some SRB personnel believe that stud hangup can be minimized by incorporating a 0.030" bias in the alignment of the skirt to the Mobile Launch Platform (MLP) support post. The incorporation of this bias before assembly is expected to compensate for flexure of the structure due to the loading of the aft skirt during assembly. The MLP spherical bearings would then be properly aligned and allow maximum clearance between the holddown bolt and the bolt hole, thereby significantly reducing the likelihood of holddown bolt hangup. ***This anomaly was resolved for STS-32.***

STS-33 INFLIGHT ANOMALIES

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
<u>SRB</u>		
2	Left-Hand (LH) ET Attachment (ETA) ring Integrated Electronic Assembly (IEA) end cover and cable sooted. IFA No. STS-33-B-03 HR No. B-60-24 Rev. C ***Minor sooting of the ETA ring aft IEA middle cover was found on STS-32 (IFA No. STS-32-B-02). The function of the IEA was not affected. This sooting on STS-32 was attributed to installation of larger Hi-Lok fasteners, preventing proper fit of the cover.***	Upon removal of the LH IEA covers, sooting was noted on 16 cables and interior painted surfaces of the end cover. Examination of the cable jacket indicated no heating effects (no erosion, clouding of material, or degradation). It was determined that the gap in the RTV-133 sealant allowed hot gases to enter the ETA ring and the IEA cable areas through the aft side of the IEA end cover. The gases entered at the aft side of the end cover, traveled across the wire bundles, and exited through the opposite (forward) side of the end cover. This was determined by the heaviest sooting deposits on the aft side of the IEA end cover and the flow pattern. The direction of hot gas flow entering the end cover indicated that this condition occurred during reentry or descent. The RTV-133 material was missing at the area of soot entry and exit. All cables functioned properly during the mission. There was not adequate heat present to damage the cables or impair the cable function. Corrective action consisted of an engineering change (Field Engineering Change (FEC)-10266) effective for STS-32, STS-36, STS-31, and STS-35; Engineering Change Proposal (ECP)-2670 will make this revision to the closeout procedures permanent. This change clarifies the Thermal Protection System (TPS) closeout, thereby assuring proper closeout and preventing recurrence of this anomaly. ***This anomaly was resolved for STS-32.***

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
<u>KSC</u>		
1	Improper installation of cable connector assemblies. IFA No.STS-33-K-01 STS-33-K-02 STS-33-K-03 ***During postflight disassembly of STS-32, 2 bent pins were found on the right SRB IEA connector (IFA No. STS-32-K-03). This was considered to have occurred during mating of the cable to the IEA. The pins were wired spares that were not checked out during functional testing after final mate of the cables to the IEA.***	During STS-33 postflight assessment, 2 cable connectors were found incorrectly installed, and 2 ground straps were loose due to omitted washers. • The RH forward skirt Range Safety System (RSS) Ground Support Equipment (GSE) cable (Radio Frequency (RF) signal to the Integrated Receiver/Decoder (IRD)) was not fully seated on its mating connector at the forward feed-through. The connector was engaged only 3/4 of a turn; 3 1/2 turns are required for full engagement. The connector was lockwired correctly. The connector insert showed signs of moisture and contained K5NA debris. This cable is not used in flight, but is used during range safety ground checkout. • The LH upper strut separation ordnance connector was finger-loose. The connector was lockwired correctly. The jam nut was retorqued to determine the relationship of the lockwire to the properly-torqued connector. Slack in the lockwire indicated that the connector had not been properly torqued prior to lockwire installation. • Two ground straps located between the RH SRB aft IEA bracket and the SRM were loose. The ground strap fasteners bottomed out due to omitted washers. Some washers had not been installed on the fasteners on the forward end of the IEA, but those fasteners had not bottomed out and the ground straps were not loose. All 4 bolts were torqued properly (125-150 inch-pound (in-lb)). The LH brackets had washers installed. ***This anomaly was resolved subject to review of similar areas for STS-32 and determination that cable connectors and straps were properly installed.***

SECTION 6

STS-28 INFLIGHT ANOMALIES

This section contains a list of Inflight Anomalies (IFAs) arising from the STS-28 mission (previous flight of OV-102). Each anomaly is briefly described, and risk acceptance information and rationale are provided.

SECTION 6 INDEX

STS-28 INFLIGHT ANOMALIES

STS-28 INFLIGHT ANOMALIES

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
1	Pilot seat moved during ascent. IFA No. STS-28-02 HR No. ORBI-256C ORBI-340 ***No similar pilot seat movement was reported on STS-32. However, during preparation for STS-32 reentry, the pilot seat would drive up but not down (IFA STS-32-27). (See Section 7, Orbiter 16 for more details.)***	The pilot's seat slid to the full back position several times during 2-g ascent periods. The pilot had to drive the seat forward 2 to 3" with the motor several times, causing spikes on the Alternating Current (AC) bus. After the seat was repositioned, it immediately began to drift back to the stops. The crew performed inflight maintenance. There was no indication of a short in the forward/aft positioning switch, and no problems were indicated. An investigation was initiated which included examination of the clutch mechanism. Troubleshooting at Kennedy Space Center (KSC) confirmed a bad motor/brake assembly. The motor/brake assembly was removed and replaced with a part from OV-105 inventory and retested on OV-102. The failed unit was sent to the manufacturer (Western Gear) for teardown inspection. The failed motor/brake assembly was identified as a qualification test unit used for life-cycle testing in which it was subjected to 300 extend/retract cycles. This involved continuous operation for greater than 1 hour (hr) during which the motor became very hot, but it passed the test. It was installed in a mockup for approximately 2 years after completion of the qualification test. When the original motor/brake assembly for horizontal movement in OV-102 had gear noise detected after STS-9, a spare unit was not available for replacement. The qualification unit was subsequently removed from the mockup and given flight status by RHFA. The qualification test motor/brake assembly was then installed in OV-102. The unit flew 1 flight (STS-61C) before STS-28; no problems were noted. During standdown after STS-51L, the seat was removed from OV-102 and shipped to Wright Patterson Air Force Base (WPAFB) for vibration testing. It was subjected to vibration equivalent to greater than 900 flights. The seat was reinstalled in OV-102 by RHFA and passed the Acceptance Test Procedure (ATP) (1-g).

STS-28 INFLIGHT ANOMALIES

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
1 (Continued)		During brake assembly failure analysis teardown, the assembly fell out when the housing was removed. The screw used to hold the brake rotor to the shaft was loose and fell out. Failure analysis also showed evidence of significant heat damage. The brake pad-to-metal surface bond was degraded, and the pad had become separated from the base. Loctite on the brake assembly screw failed, and the screw had backed out. Heat discolorization was also found on the interior of the unit. It was determined that the qualification testing which forces the brake motor into continuous operation was a high-temperature, abnormal operating mode. Investigation determined that there were no other motor/brake assemblies in the flight vehicles that had been used as qualification test units. ***This anomaly was resolved for STS-32.***
2	Vernier thruster F5R annunciated fail leak. IFA No. STS-28-03 HR No. ORBI-056 ***No Reaction Control System (RCS) anomaly was reported on STS-32.***	Vernier thruster F5R (forward, #5, right) annunciated fail leak and was deselected by RCS jet Redundancy Management (RM). Oxygen and fuel injector temperatures decreased below the 130°F RM limit. The chamber pressure also increased during the decrease in injector temperature. A throat plug was inserted, and the manifold drain procedure was performed at Dryden prior to ferry flight. The thruster was removed and replaced during OV-102/STS-32 turnaround flow. ***This anomaly was resolved for STS-32.***

STS-28 INFLIGHT ANOMALIES

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
<u>ORBITER</u>		
3	Nose Landing Gear (NLG) Weight-On-Wheels (WOW) indication failed off. IFA No. STS-28-04 HR No. ORBI-184 ***No landing gear anomaly was reported on STS-32.***	The NLG WOW #1 proximity sensor discrete failed to the "off" condition, indicating weight on the nose gear during prelaunch activities. The NLG WOW discrete was seen toggling between "on" and "off" states before finally failing to the off/weight on nose gear discrete. The WOW "on" indication recovered on-orbit. A procedure to press the External Tank/Separation (ET/SEP) pushbutton after nose gear touchdown (nominal crew procedure) eliminated the anomaly caused by this problem. Proximity switch box troubleshooting at KSC repeated the failure indication for 6 minutes (min), but the cause could not be isolated. KSC swapped sensors, and proximity box #1 repeated the failure; box #1 was removed and replaced. Retest was completed with no problems. ***This anomaly was resolved for STS-32.***
4	Fuel Cell (FC) #1 Hydrogen (H_2) flow erratic. IFA No. STS-28-05C HR No. ORBI-094 ***No FC anomaly was reported on STS-32.***	FC #1 H_2 flow measurement began to drift high at Mission Elapsed Time (MET) 12:30 and exhibited subsequent erratic behavior with intermittent upper-limit indications. The H_2 cryogenic usage did not reflect a high flow rate. A determination was made to fly OV-102 "as is" since the required corrective maintenance would necessitate FC removal. ***This anomaly was resolved for STS-32.***
5	Abort light failure. IFA No. STS-28-06 ***No anomaly was reported on STS-32.***	During prelaunch tests, 2 of 4 abort lights on panel F6 did not illuminate. After troubleshooting, the problem was isolated to Channel 31 of Annunciator Control Assembly (ACA) #2, where a bad bulb assembly was found. The socket and bulb were removed and replaced. ***This anomaly was resolved for STS-32.***

STS-28 INFLIGHT ANOMALIES

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
<u>ORBITER</u>		
6	Forward RCS F5L heater failed on. IFA No. STS-28-07 HR No. INTG-172 ***No RCS anomaly was reported on STS-32.***	The forward RCS F5L (forward, #5, left) heater failed "on". The pod was removed to allow F5R removal and replacement; the F5L heater was also fixed at that time. Retest was performed with no problems. The vernier thruster heater operates at low wattage; it will not overheat the thruster if it remains on. ***This anomaly was resolved for STS-32.***
7	Main Bus C utility outlet #1 teleprinter short circuit (teleprinter cable anomaly). IFA No. STS-28-11 HR No. ORBI-301 ***No similar anomaly was reported on STS-32.***	The teleprinter cable plugged into Main Bus C utility outlet #1 shorted, causing a 1.5-second (sec) sustained short circuit with a 51-ampere peak. The 10-ampere circuit breaker did not trip, and the short sustained itself by arc-tracking of the Kapton wire until the wire pair opened at the connector. Preflight inspection and testing did not detect the break. This utility outlet is used during ascent/descent for plugging in crew suit fans. Because of the short, the utility outlet was not used for the remainder of the mission. The Commander, Mission Specialist #1, and Mission Specialist #2 had to plug their suit fans into the Main Bus B utility outlet. Investigation revealed that the most likely failure cause was long-term fatigue and stress cracking of the Kapton insulation due to repeated sharp bending of the wires against the metal backshell tang. A design change was approved to change to 90° backshells on the connectors interfacing with the A15 panel so that wires are not bent sharply in order to be flush with the panel. A change to clamp-type backshells to accommodate strain relief sheathing was approved. In addition, the wire insulation will be changed to teflon throughout the cable to improve cable flexibility.

STS-28 INFLIGHT ANOMALIES

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
<u>ORBITER</u>		
7 (Continued)		New cables were fabricated and subjected to 100% inspection and hipot testing. An investigation was conducted to determine if other similar cables using Kapton wire were degraded. Johnson Space Center (JSC) review resulted in teleprinter cable changes to a 90° backshell and use of teflon wire; this change was to be ready for the STS-32/OV-102 flight. Redesign is also in work to eliminate small bend radii. ***This anomaly was resolved for STS-32.***
8	Auxiliary Power Unit (APU) isolation valve talkback failure. IFA No. STS-28-12 HR No. ORBI-103 ***No similar anomaly was reported on STS-32.***	During prelaunch checkout, the talkback sensor on the APU isolation valve failed. It was determined that this anomaly was not critical, and the mission would proceed with the anomaly. The primary reason for this decision was that talkback sensor removal and replacement would require APU removal. This anomaly continued during flight. Postflight load test verified that the valve was open but talkback failed. A waiver was approved for the next flight. ***This anomaly was resolved for STS-32.***
9	Environmental Control and Life Support System (ECLSS) Freon Coolant Loop (FCL) low flow rate. IFA No. STS-28-15 HR No. ORBI-275A ***FCL operation was normal on STS-32.***	Freon flow rates in the ECLSS have degraded on OV-102 since its first flight. During STS-28, the FCL radiator panel exit temperature dropped below −60°F. Additionally, FCL #2 flow rate degraded about 100 pounds per hour (lb/hr). FCL #1 flow rate degraded about 50 lb/hr during the flight. Flow returned to normal as panels reheated. Reduced flow rates at colder temperatures have been attributed to possible water contamination in the loops. Another possible cause is coagulation of teflon suspended in the freon.

STS-28 INFLIGHT ANOMALIES

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
9 (Continued)		The FCL #2 radiator flow control assembly, flow proportioning valve, pump package, and filter were removed and replaced. Samples were taken on FCL #1 and #2; moisture content was within specification. Flow rate transducers were removed and replaced, and "brazed-in" filter replacement was completed. Flow rates were within specification (redline lower limit is 2150 lb/hr): FCL #1 – 2350 lb/hr; FCL #2 – 2450 lb/hr. Visual inspection of removed components confirmed the suspected contamination. ***This anomaly was resolved for STS-32.***
10	Right-Hand (RH) Orbital Maneuvering System (OMS) fuel quantity gage reading high. IFA No. STS-28-17 HR No. ORBI-183 ***No similar anomaly was reported on STS-32.***	The RH OMS fuel quantity gage read approximately 5.7% high compared to predicted values after deorbit burn. Evaluation indicated fuel aft probe failure. There was no indication that this is a generic failure problem that would impact subsequent flights. ***This anomaly was resolved for STS-32.***

STS-28 INFLIGHT ANOMALIES

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
<u>ORBITER</u>		
11	APU #1 test line temperature read high. IFA No. STS-28-18 HR No. ORBI-104 ***No similar anomaly was reported on STS-32.***	APU #1 test line temperature was recorded as 90-92°F, over the 90°F Fault Detection and Annunciation (FDA) limit for several cycles. When the "B" heaters were switched on in accordance with the test plan, heater temperatures were almost at the FDA limit for the entire operational period. Engineering confirmed that the heaters operated properly. Since the heater temperature sensors were relocated, a Change Request (CR) was approved to increase the FDA limit appropriately. This change was implemented for STS-36 in February 1990. ***This anomaly was resolved for STS-32.***
12	STS-28 crew experienced eye irritation. IFA No. STS-28-21 HR No. ORBI-279 ***No eye irritation was reported by the crew on STS-32.***	The crew experienced eye irritation and sneezing during STS-28 when their heads were close to windows W1 and W2 on the flight deck. The irritation was similar to that experienced during Lithium Hydroxide (LiOH) changeout. Samples were taken at windows W1 and W2 and from the Air Revitalization System (ARS). KSC dumped the LiOH canisters and sent the contents to JSC for analysis. Nothing abnormal or toxic was found from this analysis. No further analysis will be performed unless this condition recurs. ***This anomaly was resolved for STS-32.***

STS-28 INFLIGHT ANOMALIES

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
13	Hydraulic system #2 unloader valve operated out-of-specification. IFA No. STS-28-23 HR No. ORBI-052 ***Hydraulic systems #1 and #2 unloader valves experienced similar anomalous operation on STS-32 (IFA No. STS-32-16). (See Section 7, Orbiter 8 for more details.)***	During prelaunch, the unloader valve cycled when the accumulator pressure reached 2350 pounds per square inch (psi); this is higher than the 2100-psi specification limit. During the mission, accumulator pressure dropped sharply from 2500 to 2350 psi, and the unloader valve cycled. Valve leakage or striction were considered possible causes of this anomaly. The MC284-0438-0001 configuration unloader valve has a history of leakage. The Orbiter Project Office (OPO) directed replacement of -0001 valves with -0002 valves on an attrition basis. KSC removed and replaced this valve; it was returned to the vendor for failure analysis. Leak check of the replacement valve was satisfactory. ***This anomaly was resolved for STS-32.***
14	Excessive body flap deflection during ascent. IFA No. STS-28-24 HR No. ORBI-025 ***No excessive body flap deflection was reported on STS-32.***	Excessive body flap deflection was believed to be observed by the film analysis team from the E-207 tracking camera at approximately 46-sec MET during STS-28 ascent. Initial measurements taken from the film were assessed to show a deflection of up to 9 ± 4" at a natural frequency of 8 Hertz (Hz). This amplitude measurement was suspect due to dynamics of the vehicle camera, plume effects, and variable lighting; it was later revised to 6.1 ± 3.0". Additional background data may be found in the STS-33 Mission Safety Evaluation (MSE). No significant body flap tile damage has occurred on any flight that could be attributed to excessive body flap deflections. ***This anomaly was resolved for STS-32.***

STS-28 INFLIGHT ANOMALIES

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
<u>ORBITER</u>		
15	Orbiter structural heat damage. IFA No. STS-28-26 HR No. ORBI-084 ORBI-245A ***No similar anomaly was reported on STS-32.***	It was prematurely reported that the Orbiter structure in the area aft of the right ET door showed evidence of possible burnthrough. The JSC Thermal Subsystem Manager and KSC and Rockwell/Downey thermal subsystem engineers reviewed the evidence. They agreed that there was no burnthrough or overheating. Tile charring was found; this was expected due to the out-of-tolerance step and gap around the ET door. The out-of-tolerance condition was waived prior to flight. Tile removal was completed, and structural inspection was performed. No damage was noted. Tile was reinstalled. A problem closeout report was written and approved. Out-of-tolerance step and gap conditions on OV-102/STS-32, if any, were to be scrutinized relative to deleterious thermal effects. No step and gap problems were reported. ***This anomaly was resolved for STS-32.***
16	Crew reported a loud thump/thud at the first OPS-1 transition. IFA No. STS-28-27 ***No thumps or thuds were reported on STS-32.***	During postflight debriefing, the crew reported a loud thump/thud at the exact time of the first OPS-1 transition at T-20 min. The crew stated that the whole vehicle shook. At the time of the OPS-1 transition, the aerosurfaces are commanded to the null position from droop (move approximately 8°). Hydraulics are operating on circulation pumps (500 psi). Vehicle systems are quiescent at this time period. Flight Control System (FCS) sensor outputs and actuator response data were reviewed. Hydraulic circulation pump pressures were also reviewed. Other possible sources were reviewed but were not correlated with the reported thud (cabin vent

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
16 (Continued)		valves, crew access arm, payload events, pilot seat movement, launch pad microphones). Hydraulic circulation pump pressures exhibited nominal transient behavior during elevon repositioning – 500 psi to 100 psi for approximately 3 sec. Hydraulic pressure was insufficient to move rudder/speedbrake, body flap, or Space Shuttle Main Engine (SSME) Thrust Vector Control (TVC) actuators. Elevon repositioning transients were nominal (inboard elevons - 7° (gravity droop position) to 0° in 3 sec; outboard elevons - 3-1/4° (gravity droop position) to 0° in 2 sec). The elevon droop position was within flight experience. The lateral accelerometer started bit toggling between 0 and 0.003 g. The normal accelerometer showed an occasional bit toggle between 0 and 0.008 g. Consultation with previous crews found a similar experience. Orbiter access arm movement and hydraulic shock were ruled out. A review of the cockpit acceleration instrumentation found inconclusive evidence of motion. No malfunctions were reported during STS-34 trial countdown. For future flights, the decision was made to turn on the Modular Auxiliary Data Systems (MADSs) during OPS-1 transition and measure vehicle data in an attempt to record any repeat of this anomaly and isolate the cause. No thumps or thuds were reported by the crew or MADS during the STS-34 and STS-33 countdowns. MADS was again turned on prior to OPS-1 transition during the STS-32 countdown; no thumps or thuds were reported. *This anomaly was resolved for STS-32.*

STS-28 INFLIGHT ANOMALIES

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
17	Gaseous Hydrogen (GH_2) Flow Control Valve (FCV) #1 showed sluggish response. IFA No. STS-28-28 HR No. ORBI-151 ORBI-338A ***No GH_2 FCV anomalous operation was reported on STS-32. However, Gaseous Oxygen (GOX) FCV #2 opened sluggishly when first cycled at T+61 sec. (See IFA No. STS-32-06, Section 7, Orbiter 3.)***	SSME GH_2 FCV #1 experienced slow opening and closing response during the first 3 min of ascent. There was no response to 3 commands at the minimum power level during maximum Q throttling. GH_2 FCVs #2 and #3 operated normally during the entire ascent. Liquid Hydrogen (LH_2) tank ullage pressure and Net Positive Static Pressure (NPSP) requirements were satisfied. Leak checks and inspection found that FCV #1 was stuck in the "open" position. The 3 FCVs were removed, and the poppets were sent to the vendor for inspection and cleaning. Contamination and tight sleeve-seal clearance were found. The sleeve-seal clearance was modified to the design configuration of 0.0008-0.0009" versus actual of 0.0005-0.0009". The FCVs were reinstalled and successfully retested for current signature, pull-in and drop-out voltage, and external leakage. While there have been repeated instances of sluggish GOX FCV operation, none was reported on STS-30, STS-34, or STS-33. This was the first reported case of a GH_2 FCV anomaly. The GH_2 FCVs on both OV-103 and OV-104 had flown 2 missions with no reported sluggish operation. Replacement GH_2 FCVs had not demonstrated sluggish operation. ***This anomaly was resolved for STS-32.***

C-2

STS-28 INFLIGHT ANOMALIES

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
18	Early asymmetrical boundary layer encounter resulted in anomalous aerosurface movement, usage of more than a normal amount of RCS propellant, and excessive Thermal Protection System (TPS) damage. IFA No. STS-28-30 HR No. ORBI-136A ORBI-249A ***Early asymmetric boundary layer transition was not experienced on STS-32.***	Unusual low-frequency aileron movement occurred in the Mach 20 to Mach 10 range during STS-28 entry. Unusual RCS and aerosurface activity was observed during roll reversal. The boundary layer transition from laminar to turbulent flow began to occur approximately 250 sec earlier than expected. Transitions normally occur 1100 to 1200 sec following entry. Additional background on this issue may be found in the STS-33 MSE. Rationale for the STS-32 launch was based on two facts: protruding and missing gap fillers had been replaced since STS-28, and the FCS operated per design and within specification. ***This anomaly was resolved for STS-32.***
19	Umbilical foam detached from the ET LO_2 17" disconnect. IFA No. STS-28-31 HR No. ORBI-302A INTG-037A INTG-081A ***No umbilical foam was reported detached from the ET LO_2 17" disconnect on STS-32.***	A review of STS-28 ET/Orbiter separation photographs revealed a large section of foam, approximately 18" x 8" x 2", detached from the ET LO_2 umbilical. The foam was attached at the base in a hinged manner. The exposed face of the foam appeared to have the same geometry as the outer surface of the 17" disconnect. Similar problems were noted on STS-4, STS-9, and STS-61A; most flights have evidence of minor damage. Possible causes of the problems included installation anomalies, LO_2 impingement, aerodynamic effects during ascent, or a combination thereof. The failure mode is not totally understood. There were approximately 65 cryogenic ET/Orbiter separation tests conducted during the ET/Orbiter Separation Ground Test Program, with only the first test resulting in forward foam damage. A bracket was installed to protect the foam for the remaining 64 ground tests. No additional foam damage was recorded during these tests.

STS-28 INFLIGHT ANOMALIES

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
<u>ORBITER</u>		
19 (Continued)		Debris damage to the Orbiter is unlikely. Interference with the umbilical door closure from foam debris was considered remote. *This anomaly was resolved for STS-32.*

STS-28 INFLIGHT ANOMALIES

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
<u>SRB</u>		
1	Loose bolts on the left Solid Rocket Booster (SRB) External Tank Attachment (ETA) ring. IFA No. STS-28-B-02 HR No. B-30-06 Rev. C ***No similar anomaly was reported on STS-32.***	During postflight inspection of the left SRB ETA ring, 18 randomly located 3/8" fasteners were found loose on the left-hand Solid Rocket Motor (SRM) stub/ETA ring aft web joint. Six of the fasteners were located at the Integrated Electronic Assembly (IEA) position, and the remaining 12 were located randomly around the ETA ring. The loose fastener assemblies could be turned by fingers. All of the loose fasteners had acceptable running torque which indicated that the nut locking mechanisms functioned properly. No metallurgical or dimensional discrepancies were identified for the 18 fasteners, indicating that all characteristics were within specification. Deformation, with a typical depth of 0.005", was identified on the washers under the bolt heads. No other deformations were identified on the fastening components. A review of similar test articles revealed similar washer deformation. Analysis of the joint (a shear pin type application) indicated that preload in the fasteners is not essential for proper joint function. The fastener assemblies are replaced after each flight. The Factor of Safety (FOS) is 1.53 for existing design and flight loads. No corrective action was required. ***This anomaly was resolved for STS-32.***

STS-28 INFLIGHT ANOMALIES

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
<u>SRM</u>		
1	Gask-O-Seal void found during postflight inspection. IFA No. STS-28-M-01 HR No. BC-03 Rev. B ***SRM Gask-O-Seal anomalies were also reported on STS-32. During postflight inspection of the right SRM Safe and Arm (S&A) gasket, a small depression was found in the crown of the secondary seal aft face (IFA No. STS-32-M-01). Small raised areas or bulges were also found on the cushion and in the valleys of the igniter inner Gask-O-Seal (IFA No. STS-32-M-02). (See Section 7, SRM 1 and SRM 2 for more details.)***	During postflight disassembly inspection of the STS-28 right SRM igniter, a small depression was found at 210° on the inner primary seal on the aft face of the inner Gask-O-Seal (360H005B). The crown of the seal was depressed inward and measured approximately 0.100" long circumferentially by 0.025" radially; it extended across the crown width. It appeared that a possible subsurface void may have existed in the inner primary seal prior to flight. There was no evidence of a leak path in the putty (primary seal not pressurized). The joint passed preflight low- and high-pressure leak test. No blowby past the inner primary seal or pressure path to the seal was found. However, leak test may not be sufficient if an indentation exists in the seal. The joint gap is predicted to open 3.5 mils at the outer gasket, 3.0 mils at the inner gasket. Indentation, if present, may not dynamically track the gap opening on pressurization, and the leak test is not flight dynamic. Additionally, crown indentations were also discovered during disassembly of new gaskets on Demonstration Motor (DM)-9 and Qualification Motor (QM)-6. Subsurface void was found in both cases; contamination was also present on DM-9. Standard nondestructive inspection techniques, such as x-ray, cannot reliably detect subsurface voids. Current known gasket defects are detectable by visual and touch inspection at disassembly. Indentation is easily detectable after gasket removal. It should be noted that indentations have never been detected on reused gaskets. Corrective action is in process to develop an inspection technique to detect subsurface voids: design a plexiglass fixture for seal test; reinvestigate N-ray and x-ray; and investigate ultrasonics and background scatter.

STS-28 INFLIGHT ANOMALIES

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
SRM		
1 (Continued)		For the next flight (STS-32), the left and right SRM igniter seals were inspected and replaced. All 360L008 seals were reused and had flown previous missions; one was flown 3 times. They passed thorough visual and touch inspection upon removal from the compressed state; no indentations were detected. The seals passed all certification inspection criteria and leak tests. Resiliency tests demonstrated that a minimum crown height of 0.021" will meet a 1.4 tracking factor at Launch Commit Criteria (LCC) temperatures. All STS-32 igniter gaskets met the crown height requirement of 0.021-0.031". ***This anomaly was resolved for STS-32.***

SECTION 7

STS-32 INFLIGHT ANOMALIES

This section contains a list of Inflight Anomalies (IFAs) arising from the OV-102/STS-32 mission. Each anomaly is briefly described, and risk acceptance information and rationale are provided.

SECTION 7 INDEX

STS-32 INFLIGHT ANOMALIES

SECTION 7 INDEX - CONTINUED

STS-32 INFLIGHT ANOMALIES

STS-32 INFLIGHT ANOMALIES

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
1	Auxiliary Power Unit (APU) #3 lubrication oil outlet pressure high. IFA No. STS-32-02 HR No. ORBI-036	Higher than expected lube oil outlet pressure was observed on OV-102/STS-32 APU #3. The lube oil pressure was 75 to 95 pounds per square inch absolute (psia) for the first 10 minutes (min), then returned to normal (55-60 psia) at full operating temperature. The pressure was nominal for ascent and landing. This anomaly was similar to the APU #1 anomaly on STS-33 (IFA No. STS-33-01). It was determined that the high pressure was caused by the presence of hydrazine in the gearbox. Hydrazine reacts with the lube oil to form pentaerythritol and hydrazides, which liquefy at approximately 200°F. This contamination/wax buildup collects on the lube oil filter and partially blocks the filter. Heating of the oil liquifies the contaminant and clears the filter. Continued operation disperses the contaminant throughout the gear box. It is believed that seepage of hydrazine past the seals into the gearbox is due to the postlanding gearbox pressure being below the seal cavity pressure. The worst-case criticality is 1R/2 for gross hydrazine leakage into the gearbox and loss of the APU. The Launch Commit Criteria (LCC) allows for lube oil outlet pressures up to 110 psia. The Flight Rules do not address lube oil pressure, and the temperatures were normal; therefore, this anomaly did not result in a violation of the Flight Rules. The most probable effect of wax buildup is an increase in lube oil outlet pressure for a 10-min period, which does not affect the operation of the APU. The solution to this problem is postlanding pressurization of the gearbox above the pressure of the seal cavity. Hot oil flushing techniques were developed that allow the wax to melt and the system to be flushed. A Requirements Change Notice (RCN) was issued to change the Operational Maintenance Requirements and Specifications Document (OMRSD); it includes new procedures for postlanding pressurization of the gearbox to no less than 5 psia greater than seal cavity pressure. APU #3 was removed; the system was flushed and serviced.

STS-32 INFLIGHT ANOMALIES

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
2	Right-Hand (RH) Orbital Maneuvering System (OMS) "no-back" device moved during ascent. IFA No. STS-32-04	The RH OMS yaw actuator, Serial Number (S/N) 117, drifted 0.112° during the first 50 seconds (sec) after the launch of STS-32. The "no-back" device is designed to prevent back-drive or movement of the actuator during powered operations. After the initial movement, the "no-back" device held the actuator as required for the remainder of ascent. During entry, movement of 0.048° was recorded. Failure of the "no-back" device could result in positioning the OMS engine nozzle into the air flow. The air flow dynamic pressure will cause the nozzle to deform. Review of previous flights using this yaw actuator was completed. On STS-28, there was indication of 0.082° movement. The previous mission employing S/N 117, STS-61C, recorded movement of 0.098°. Movement in each of the 3 missions reviewed occurred during ascent when the highest vibration environment is experienced. Because the occurrences of movement during ascent are relatively consistent, there was no indication of degradation. Movement similar to that witnessed on STS-32/OV-102 was not considered detrimental to actuator function since no significant problem exists until 1.5° of movement occurs during launch. If movement occurs during major modes 102 and 103 of OPS-1 (ascent software), the software will automatically power up the OMS controller primary channel if the gimballed angle reaches 0.7° and commands the actuator to the stow position. In either software mode, an alarm will sound alerting the crew to manually select the backup channel. An RCN changed the acceptable limit for actuator movement to 0.2°.

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
3	Gaseous Oxygen (GOX) Flow Control Valve (FCV) #2 opened sluggishly. IFA No. STS-32-06 HR No. INTG-150A ORBI-248A	The GOX FCV #2 exhibited sluggish operation when first cycled open at T+61 sec. This FCV took approximately 0.75 sec to open versus the nominal operation of 0.2 to 0.4 sec. Sluggish operation of this FCV was only experienced during the first open cycle; all other closed-open/open-closed cycles were nominal. Investigation of previous sluggish GOX FCV operation found contamination as the cause of the slowness. This was the first instance of a sluggish GOX FCV since STS-29. All GOX FCVs on OV-102 were replaced with new reshimmed valves during the STS-35/OV-102 turnaround process. Poppet installation was completed, leak and functional tests were completed, and signature testing was completed. FCVs are scheduled for replacement with fixed orifices in the fall of 1990.
4	Humidity separator "B" water bypass. IFA No. STS-32-07A HR No. ORBI-051 ORBI-254 ORBI-321A	During changeout of the Lithium Hydroxide (LiOH) canister, the crew discovered uncontained water. They indicated that the LiOH canister was wet, and water was coming from the humidity separator "B" exit port. At that time, humidity in the cabin was nominal, and there was no indication of a humidity separator problem. The crew switched from humidity separator "B" to "A" and initiated free fluid cleanup procedures. Approximately 2 gallons of water was collected. The separator was removed and sent to the vendor for failure analysis. Some white residue was found on the heat exchanger outlet. Note that humidity separator anomalies occurred on OV-103 (STS-26) and OV-104 (STS-27). The cause of the failures was believed to be due to high humidity and an accumulation of debris on the condensing heat exchanger. There was no recurrence of the problem on subsequent flights of OV-103 or OV-104 after the refurbishment of their humidity separators.

STS-32 INFLIGHT ANOMALIES

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
5	Humidity separator "A" water bypass. IFA No. STS-32-07B HR No. ORBI-051 ORBI-254 ORBI-321A	On Flight Day (FD) 6, the crew found approximately 8 ounces (oz) of water around humidity separator "A". Inflight maintenance procedures (towel and bag) were initiated to collect additional water that might escape from humidity separator "A". On FD 7, the crew reported more water coming from humidity separator "A". Cleanup procedures were again initiated, and approximately 2 cups of water were collected. It was postulated that this water escape resulted from the high level of crew activity. Separator "A" leakage was most likely due to carryover of water from separator "B". Water was not collected for the remainder of the flight. The humidity separator was removed and sent to the vendor for failure analysis.
6	Flash Evaporator System (FES) topping duct "B" string heater failure. IFA No. STS-32-14 HR No. ORBI-276B	After activation of the FES topping duct heater "B", the aft duct temperature did not increase at the correct rate. This occurred during inflight checkout of redundant heater strings on FD 7. FES topping duct heater "A" was selected and operated nominally for the remainder of the mission. Worst-case effects occur with loss of all 3 redundant heater strings, resulting in loss of the FES. Flight Rule 9-71B states that, if the FES topping duct cannot be maintained at 100°F or more, the FES is considered lost which results in a minimum duration mission. Troubleshooting determined that Remote Power Controller (RPC) #34 was defective. The unit was removed, replaced, and successfully retest.

STS-32 INFLIGHT ANOMALIES

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
7	Inertial Measurement Unit (IMU) #1 was deselected by Redundancy Management (RM) due to Y-axis transients. IFA No. STS-32-15 HR No. ORBI-051	IMU #1, S/N 24, was deselected by RM on FD 6 due to 7 occurrences of erratic Y-axis accelerometer transients; however, IMU #1 continued to track the redundant IMU set after deselection. The crew was able to reselect IMU #1 prior to IMU alignment. After IMU alignment, all 3 IMUs were operating nominally. IMU #1 was deselected prior to crew sleep periods to avoid waking the crew should an alarm occur. No further problems were reported with this IMU for the remainder of the mission. As a precaution, the crew continued to deselect IMU #1 prior to their sleep periods. Playback data indicated that the failure was caused by multiple Y-axis velocity transients. IMU #1 was removed and sent to Johnson Space Center (JSC) for failure analysis. No previous problems associated with this IMU had been reported. Additionally, there was no indication that this anomaly was a generic problem. The IMU system has triple redundancy.

STS-32 INFLIGHT ANOMALIES

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
8	Hydraulic systems #1 and #2 unloader valves exhibited anomalous operation. IFA No. STS-32-16 HR No. ORBI-052	Approximately 1 hour (hr) prior to circulation pump #2 deactivation during the launch scrub turnaround, there was a significant increase in unloader valve #2 cycling. Approximately 45 min after deactivation of circulation pump #2, all bootstrap fluid pressure was lost. Because of a similar anomaly on STS-28 (IFA No. STS-28-23), the decision was made to replace the hydraulic system #2 unloader valve prior to the STS-32 launch. The hydraulic system #1 unloader valve leaked excessively once the accumulator pressure fell below 2300 psia. This was an internal hydraulic leak with hydraulic fluid on the high-pressure accumulator side leaking to the low-pressure return side. Prior to this flight, it was known that all 3 OV-102 unloader valves were experiencing out-of-specification leakage (see Section 4, Orbiter 9). This condition was waived (WK 1547) for 1 flight only, STS-32, with the understanding that hydraulic accumulator pressures would be closely monitored during prelaunch activities. It is believed that contamination in the unloader valve pilot area caused the leakage. The system #1 unloader valve failed during testing and was removed, replaced, and successfully retested. Systems #2 and #3 data were acceptable.

STS-32 INFLIGHT ANOMALIES

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
9	Water Spray Boiler (WSB) systems #2 and #3 regulator pressure decaying slowly. IFA No. STS-32-17 HR No. INTG-072 INTG-117	Gaseous Nitrogen (GN_2) regulator pressure on WSB systems #2 and #3 indicated pressure decay rates of approximately 0.11 pounds per square inch per hour (psi/hr) over a 16-hr period; the allowable decay rate is 0.06 psi/hr. Monitoring of the pressure decay rate throughout the mission found that the decay rate approached zero by the end of the mission. There is a tank in which GN_2 is stored for use in pressurizing the WSB water storage tank. GN_2 is routed from this tank through a regulator and relief valve prior to entering the water storage tank. Pressure loss is measured between the regulator/relief valve and the water tank. GN_2 pressure loss was experienced previously and was attributed to GN_2 leakage overboard through an improperly reseated relief valve. The relief valve "burped" on ascent and reseated when pressure was greater than 28 pounds per square inch (psi). Other possible GN_2 leaks could occur at the pressure transducer port or at the GN_2 vent Quick Disconnect (QD); however, both failure modes are very unlikely. It is believed that the pressure decays were due to the GN_2 relief valves not being fully seated and not due to water leaks. The poppets in the relief valves were removed and replaced. GN_2 24-hr decay check on system #2 indicated no leakage; decay check on system #3 indicated leakage of 0.06 psi/hr, which was within OMRSD limits.

STS-32 INFLIGHT ANOMALIES

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
10	Avionics bay #3A smoke detector transient alarm and associated lights. IFA No.STS-32-19 HR No. ORBI-259A	On FD 8, the crew reported a smoke alarm with siren from avionics bay #3A, sensor 3A. The alarm cleared itself in approximately 6 sec. Playback data indicated that there was no increase in the smoke concentration readings. A successful fire/smoke detection test was subsequently performed indicating that there was no problem with the detection system. It was concluded that an intermittent fault in the smoke detection electronics most likely caused the alarm. Sensor 3A operated nominally for the remainder of the day after the initial alarm. There were several previous instances of smoke detection failures where the cause could not be found. Sensor 3A annunciated several additional times during the crew sleep period on FDs 9 and 10. Each time the crew checked for increased smoke concentrations, no increase was noted. A decision was made to pull the sensor circuit breaker to avoid nuisance alarms during the crew sleep period. Continued nuisance alarms prompted a decision to open the circuit breaker during reentry. This resulted in the loss of smoke detection redundancy in avionics bays #1 and #3. Safety concurred with this plan based on the fire/smoke detection/suppression test for avionics bays #1, #2, and #3 and after evaluating the risk of loss of redundancy against possible crew distraction during reentry and landing. Sensor 3A was removed and replaced. The defective unit was sent to the vendor for failure analysis. The replacement unit was successfully tested.

STS-32 INFLIGHT ANOMALIES

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
11	Waste water dump line/nozzle blockage. IFA No. STS-32-21 HR No. ORBI-254	During free fluid disposal on FD 10, the crew did not get any suction through the collection wand. A later attempt at dumping the waste tank was also unsuccessful. Troubleshooting and visual inspection of the dump nozzles using the Remote Manipulator System (RMS) determined that there was no icing in the dump nozzles. It was suspected that a restriction formed in the waste dump line. Inspection at Dryden found charred material around the urine dump nozzle face. This had been experienced previously; however, there was more than usual. A sample of the material was taken for analysis. A sample taken from the orifice indicated that some potassium was among the charred material; everything else was normal. "Mucky junk" was flushed from the dump line. Troubleshooting confirmed that the dump line was clogged. The line was removed, and the replacement line/nozzle installation was completed. Leak checks and heater/insulation installation were completed satisfactorily.
12	Backup Flight Computer (BFC) General Purpose Computer (GPC) errors – Input/Output (I/O) terminal B. IFA No. STS-32-22 HR No. ORBI-066 ORBI-334	GPC #5, where the Backup Flight System (BFS) software was resident, registered numerous GPC error code 41s (illegal engage/I/O term B). Real-time data analysis indicated that the GPC #5 "Term-B" discrete was toggling. If the GPC #5 discrete is toggling or fails hard "0", the backup BFS/GPC cannot gain control of the 8 flight buses. The error was the result of the BFS detecting no I/O terminate B discrete when the engage discretes are not present. The error was logged approximately 43 times before the GPC was halted. As a result, the BFS was moved from GPC #5 to GPC #2 and reinitialized. This left STS-32 with 3 primary and 1 backup GPC for entry and reduced fault tolerance to a single failure. The BFS software is normally loaded into GPC #4 in the event that GPC #5 is determined bad. Because of the preflight concern with Kemet capacitors in the GPC #4 Input-Output Processor (IOP), it was decided before launch to use GPC #2 as the alternate BFC.

STS-32 INFLIGHT ANOMALIES

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
12 (Continued)		KSC was able to recreate the problem; however, when the breakout boxes were installed, the problem did not recur. BFC connector J4 and IOP connector J5 were inspected. Power was cycled to the GPC. The GPC output switch was moved, wires were wiggled, and the problem would not repeat. Additional troubleshooting proved to be nonproductive. BFC #2 and IOP #5 were removed and replaced. A confidence test was completed on IOP #5 input receiver (DI 13). If this anomaly occurred prior to launch, the launch would have been held up until the cause of the problem was determined; or the launch would have been scrubbed if it was determined that the BFC/GPC was bad. To date, there have been several IOP circuitry failures; however, there were no failures involving erroneous I/O terminate discretes. None of the IOP circuitry failures were determined to be generic in nature. There were 2 BFC transmit circuitry failures identified involving I/O terminate discretes. Both failures occurred during acceptance testing, and both are still under investigation.
13	WSB #3 controller "A" overcooling. IFA No. STS-32-23 HR No. ORBI-170	WSB #3 went into the heat exchanger mode early and dumped excessive water while operating on controller "A". The crew switched to controller "B", and operation continued nominally. There were no previous WSB failures of this type. Troubleshooting confirmed the failure of controller "A". The defective controller was removed, replaced, and successfully retested. A redundant controller is also available. In addition, redundant hydraulic systems are available if both controllers in one system malfunction.

STS-32 INFLIGHT ANOMALIES

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
14	Main Propulsion System (MPS) Liquid Hydrogen (LH_2) outboard fill and drain relief valve leak. IFA No. STS-32-25 HR No. ORBI-306	The MPS outboard fill and drain valve PV11 was found with a blowing leak during OV-102/STS-32 postflight inspection. The leak was heard and felt at the 6:30-o'clock valve position. Helium tank decrease confirmed the leak. Investigation indicated some contamination in the system. The PV11 valve is redundant, and a second failure (PV12 or PV13) would be required to cause a hazardous condition during main stage. PV11 was removed and replaced.
15	RH stop bolt was found slightly deformed on the STS-32 centering ring of the forward External Tank (ET) attach/separation assembly. IFA No. STS-32-26 HR No. INTG-051A	Postflight inspection of STS-32/OV-102 found the RH stop bolt slightly deformed (not a bent condition) on the centering ring of the forward ET attach/separation assembly. This anomaly was similar to, but not nearly as bad as, that seen previously on STS-34. Deformations or flat spots, similar to that seen on STS-32, were found on other flight and qualification bolts. A bent stop bolt was first found on STS-34/OV-104. STS-34 postflight inspection at Dryden found the RH stop bolt to be bent, forward and inboard. This bolt, located on the centering ring of the forward ET attach/separation assembly, was found compressed into the centering mechanism. It is used to restrict side motion between the ET and Orbiter at the attach/separation assembly and is not considered a structural bolt. Indications were that the assembly sustained a side load. The moment required to bend this bolt is in excess of 10,000 inch-pounds (in-lb). The force required to obtain this moment is 900 pounds (lb). A side load of this magnitude could lead to early uncontrolled separation of the Orbiter from the ET. There was no indication that a side load occurred on either STS-34 or STS-32 flights.

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
15 (Continued)		The most probable cause of the STS-34 anomaly was determined to be improper sequencing of the ET/Orbiter mating procedure resulting in a yaw moment that could bend the bolt. Sequencing employs Ground Support Equipment (GSE) (H72-0590) that could produce the required loads. Improper sequencing would not lead to early, uncontrolled separation of the ET and Orbiter. However, a bent bolt extended into the airstream could result in excessive localized heating during reentry. An additional cause could be the use of the Orbiter transporter that moves the Orbiter from the Orbiter Processing Facility (OPF) to the Vehicle Assembly Building (VAB). Since the transporter was first used on STS-32, it is possible that the bolt was deformed at the Orbiter-to-transporter mate. There were no anomalies recorded during STS-32 ET/Orbiter mating. A bent stop bolt is a criticality 3 failure. Analysis indicated that a moment of 430-2100 in-lb could locally deform the bolt end. This moment could be generated by either side-to-side movement during normal handling or by the small, pyro-initiated rocking motion at separation. The rocking motion was first seen during review of pyro qualification test film. The bolts used in the qualification tests also exhibited similar local flat spots. (Note that the rocking motion was not sufficient to cause the bolt bending experienced on STS-34.) New mating procedures were developed to alleviate this problem. These procedures were formalized and will also be used for Orbiter-to-transporter mate. The STS-32/OV-102 ET attach/separation assembly was removed at Dryden and sent to RI/Downey for failure analysis.

STS-32 INFLIGHT ANOMALIES

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
16	Pilot seat down drive motor did not operate. IFA No. STS-32-27 HR No. ORBI-256C ORBI-340	During preparation for descent, the pilot attempted to make seat adjustments. The seat would drive up, but not in the down direction. Repeated attempts to lower the seat failed. The forward and back drive was not used or tested. The most probable cause of this failure was a defective down limit switch. Ground test showed that the seat was operating nominally. Analysis of the removed limit switch was to be performed. The flight effect was crew inconvenience if seat height cannot be adjusted.

STS-32 INFLIGHT ANOMALIES

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
<u>SSME</u>		
1	Main Combustion Chamber (MCC) aft end debond found on engine #2022. IFA No. STS-32-ME-01 HR No. ME-B5 (All Phases)	Postflight ultrasonic inspection found a 5/64" diameter MCC debond on engine #2022. It was located 1/2" from the edge and in line with nozzle tube #664. An aft region internal fuel leak is a criticality 1 failure and is assumed to be rapid and extensive, resulting in High-Pressure Fuel Turbopump (HPFTP) cavitation and Liquid Oxygen (LOX) rich operation. The test history of this engine included 16 starts and 4650 sec. The debond was limited to an area between adjacent feed slots in line with nozzle tube #664 (2 affected channels). Postflight leak checks verified no leak at the bond line. There was no fabrication or assembly history found that was indicative of a problem. The failure was consistent with previous bond line failure assessment. The debond initiated at the aft end of the feed slots, resulting most likely from an undetectable flaw or marginal bond in this region. The defect could then propagate as a result of start/shutdown transients (highest strain to bond line). A proof test screens gross bond deficiencies. Post-proof ultrasonic inspection also detects debonds. Current data on this type of condition indicates that the propagation rate is slow and stable; there is a low probability of a massive bond line failure. The MCC was returned to Canoga for rebuild/repair prior to reuse. Engine #2022 was replaced by engine #2012. (The same type failure was experienced on engine #2031, post STS-29 flight. See STS-30 Postflight MSE, Section 5 – STS-29 Inflight Anomalies, SSME 1 for additional related information.)

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
SSME		
2	Gouges found in the MCC throat area of engines #2024 and #2028. IFA No. STS-32-ME-02 STS-32-ME-03 HR No. ME-B5 (All Phases)	Gouges were found in the throat area of the MCC on engines #2024 and #2028. It was thought that these gouges were introduced when the leak check throat plug was installed prior to flight. These gouges should have been found and polished-out prior to flight. Imperfections of this type in the MCC throat area could cause localized hot spots, leading to burnthrough. The gouge found on engine #2028 measured approximately 2" long by 0.080" wide by 0.009" deep, with some raised metal. The gouge was caused by the engine horizontal installer during removal/installation after STS-28. The engine #2028 MCC liner was repaired using a cell plating process to deposit copper in the gouge area. A NASA/contractor team was formed to revise procedures or modify equipment to eliminate or minimize engine handling damage. In addition, the launch and landing site personnel were counseled on the importance of hardware inspections. The MCC gouge on engine #2024 was noted 6" out from the throat area at the 6-o'clock position. The gouge measured approximately 0.25" long by 0.24" wide by 0.10" deep. The gouge was caused by a "B" nut which is tethered to the upper throat plug. The "B" nut is used to cap the upper throat plug bleed valve. Investigation using an MCC proof-load test article and an upper throat plug found that the "B" nut swinging on its tether could inflict gouges of the dimensions noted. The engine #2024 MCC liner was repaired by reducing the stress concentration in the area of the gouge.

STS-32 INFLIGHT ANOMALIES

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
SRB		
1	Upper strut Ethylene Propylene Diene Monomer (EPDM) cover partially missing. IFA No. STS-32-B-01 HR No. B-30-06 Rev. C C-60-03 Rev. B	During postflight inspection at Kennedy Space Center (KSC), both left and right SRBs were missing some EPDM and Room-Temperature Vulcanizate (RTV) Q3-6077 materials from the upper strut location. The upper strut EPDM was partially missing, and the unprotected areas showed heat effects. A 5" section of EPDM cover was missing on the RH side, and a 4" section of EPDM cover was missing on the Left-Hand (LH) aft sides of the upper struts. The Q3-6077 high-temperature silicone that covers and protects the PR-855 foam from heat damage was missing below the lost EPDM rubber on both the RH and LH struts. The PR-855 foam showed heat effects on both the LH and RH struts. Specific heat effects on the RH SRB included: 2 cables (A-bus power and upper strut firing line) had heat discoloration on the outer YR-364 tape; 5 sealant caps were eroded. Thermal analysis indicated that the YR-364 tape should protect the cables. It is possible that damage was caused by aeroheating during descent. The previous worst-case damage was a 3" tear in the EPDM cover on STS-27 and a small piece (1/2" x 1/2") missing on STS-28. No previous heat effects were found on the cables. The edges of the EPDM covers are typically charred and frayed. The areas under investigation include: evaluation of the EPDM bond line, evaluation of the Q3-6077 failure mode, analysis of the heat damage to the PR-855, evaluation of the extent of the heating effects on the cables, and design evaluation of the upper strut closeout.

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
SRB		
2	External Tank Attachment (ETA) ring aft Instrument and Electronics Assembly (IEA) cover sooted. IFA No. STS-32-B-02 HR No. B-60-24 Rev. C	The ETA ring aft IEA middle cover was sooted on the aft inside surface. The function of the IEA was not affected. Minor sooting was confined to a small area on the cover. The problem was attributed to the installation of "larger" Hi-Lok fasteners, preventing proper fit of the cover. As a result of an inspection of this same ETA ring following STS-29, several oversized holes were drilled to accommodate 5/16" Hi-Lok fasteners in place of the normally used 1/4" size. Since the length of the larger fasteners was longer, the fasteners protruded and held the cover up approximately 0.1", thus allowing a hot-gas path into this area. Build paper on all ETA rings was checked to verify proper installation. This condition is peculiar to this one STS-32 ETA ring. The ring will be returned to proper configuration prior to reuse.
3	Broken fastener found on STS-32 LH SRB upper strut fairing. IFA No. STS-32-B-03 STS-32-K-04 HR No. INTG-081A INTG-134A	During postflight disassembly of the STS-32 SRBs, a broken fastener was found in the LH upper strut fairing or "milk-can". The broken fastener is 1 of 4 fasteners used to install the SRB end of the upper strut fairing. Proper fastener material properties and heat treatment were confirmed by analysis of the failed fastener. Material analysis also concluded that the failure was due to torsional overload. This conclusion has led to the determination that the overtorquing occurred prior to launch, based on the fact that there are no torsional forces exerted on this fastener during flight. Water impact shear loading have resulted in broken fasteners. The following corrective actions were implemented: • Review OMI procedure for the installation of the upper strut fairings for clarification. • Evaluate the development of a modified torque wrench that would enhance torque capabilities.

STS-32 INFLIGHT ANOMALIES

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
SRM		
1	Right Solid Rocket Motor (SRM) Safe and Arm (S&A) gasket depression on secondary seal. IFA No. STS-32-M-01 HR No. BC-03 Rev. B BI-02 Rev.B	During postflight inspection of the right SRM S&A gasket, a small depression was found in the crown of the secondary seal aft face. The crown of the right SRM S&A gasket secondary seal was depressed inward at the 0° location. The depression measured approximately 0.050" circumferentially by 0.026" radially by 0.0025" deep. This gasket had previously flown on STS-26R (RSRM-1); however, no anomaly was detected during STS-26 postflight inspection since the gasket was not inspected within 1/2 hr after removal from the joint. The gasket was later inspected in accordance with the old gasket inspection requirements for reuse on the STS-32 mission. An additional inspection of this seal was performed when an igniter seal void was discovered for the STS-28 mission. This supplemental gasket inspection required a 3-hr compression test in a Plexiglas fixture, with a post-compression touch inspection within 1/2 hr after removal from the fixture. No defects were found. This procedure was documented in the latest release of STW7-2790 (Rev D) for gaskets to be reused, which meets the definition of a "used" gasket. This gasket did not meet the criteria of a used gasket since it was not touch inspected for approximately 20 hr after STS-26 disassembly. The following corrective actions were implemented: • Review pedigrees of all gaskets installed on flight and test motors. • Replace gaskets having no touch inspection performed within 1/2 hr after undergoing 3 days of compression with gaskets that have been touch-inspected properly.

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
SRM		
1 (Continued)		• Create new S&A gasket dash numbers to preclude use of gaskets already accepted per the old requirements. • Change the reuse inspection specification to require every gasket to have a documented 3-day compression with a touch test within 1/2 hr prior to each reuse.
2	Raised areas found on the igniter inner Gask-O-Seal. IFA No. STS-32-M-02 HR No. BC-03 Rev. B	During the postflight assessment of the right SRM igniter inner gasket, raised areas of rubber were found along both sides of the gasket on the outer primary seals. This condition was limited to the void and cushion areas (nonsealing surfaces) intermittently around the circumference of the outer primary seals. The largest area found measured approximately 0.20" circumferentially. This condition was possibly caused by air trapped between the rubber and retainer during the molding process. The seal footprint was not affected by this anomaly. A new baseline was implemented which controls the molding process and the adhesive application. The process requires mold bumping to reduce the possibility of trapping air. Vents in the mold also have been added.

STS-32 INFLIGHT ANOMALIES

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
<u>ET</u>		
1	Review of the ET separation photos from STS-32 showed 4 Spray-On Foam Insulation (SOFI) divots in the bipod area. IFA No. STS-32-T-01 HR No. INTG-008 INTG-037B INTG-081A	Postflight review of STS-32 ET separation photos found 4 SOFI divots just forward and underneath the bipod area. These divots were similar to those seen in STS-28 ET separation photos. On STS-28, divots were seen above the RH bipod spindle. Divots seen on STS-32/ET-32 were into the Isochem layer. Additionally, these divots have the same appearance as those noted on flights before the implementation of intertank Thermal Protection System (TPS) vent hole modification. No Orbiter damage is attributed to the existence of these divots. Vent holes are drilled through the TPS in the intertank. It is thought that, due to tolerance stack up of the TPS (i.e., thicker areas of TPS), vent holes were not drilled to the proper depth. Additionally, a review found that the vent holes may not have been drilled at the proper angle.

STS-32 INFLIGHT ANOMALIES

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
KSC		
1	RH aft Integrated Electronic Assembly (IEA) bent pins. IFA No. STS-32-K-03 HR No. B-00-17 Rev. B	During postflight assessment, a connector in the RH aft IEA was found to have 2 bent pins. Pin #64, that was wired as a spare, was bent 90° flat and was nearly touching pin #58. Pin #66, that was a wired shield, was bent 180° into a hook shape. Since these pin are wired spares, they are not checked out during final functional testing after final mating of the cables to the IEA. The pins were bent during mating of the cable to the IEA. Adjacent pins in the connector control vital Thrust Vector Control (TVC) functions. However, the signal paths are redundant, and by design, redundant functions cannot be routed through the same connector. Also, Operational Maintenance Requirements Specification (OMRS) system check verifies every functional path within all circuits.

STS-32 INFLIGHT ANOMALIES

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
MCC		
1	State vector uplink incident. IFA No. STS-32-MOD-01 HR No. ORBI-066	An off-nominal maneuver was observed in all 3 axes during the crew sleep period on FD 9. The vehicle began to roll nose-to-tail following a state vector update that was later determined to be erroneous. The vehicle roll rates were arrested by manual intervention by the crew. A new state vector was uplinked later to allow the crew to reselect the auto-track mode. An investigation team was established to determine the cause of this incident and to make recommendations for corrective action to prevent future occurrences. The findings indicated that the state vector uplink incident was caused by an operator error. The erroneous operator procedural response was clearly outside the "trained to" and commonly expected procedures for this scenario. The basic system design and procedures associated with every aspect of this incident are mature and sound. The ground system and onboard system hardware and software worked as designed. Based on the investigation team findings, the following was to be implemented for subsequent missions in order to preclude recurrence: • The Integrated Communications Officer (INCO) console handbook will be updated to add cautionary notes prohibiting the use of manual execute (override) in the presence of an indicated data reject message. • Handshakes between uplink owners and the INCO console will be required where passing direction cosine matrix numbers. • Handshakes between the INCO console and the INCO backroom console will be required for all critical commands and command troubleshooting. • The command load owner and flight director will be notified of all manual loads or line-by-line corrections.

SECTION 8

BACKGROUND INFORMATION

This section contains pertinent background information on the safety risk factors and anomalies addressed in Sections 3 through 7. It is intended as a supplement to provide more detailed data if required. This section is available upon request.

APPENDIX A

LIST OF ACRONYMS

a.m.	Before Noon (Ante Meridiem)
AC	Alternating Current
ACA	Annunciator Control Assembly
AFB	Air Force Base
AFE	American Flight Echocardiograph
AMOS	Air Force Maui Optical Sighting
AOS	Acquisition of Signal
APU	Auxiliary Power Unit
ARS	Air Revitalization System
ATP	Acceptance Test Procedure
ATVC	Ascent Thrust Vector Control
BFC	Backup Flight Computer
BFS	Backup Flight System
BITE	Built-In-Test Equipment
CA	California
CAR	Corrective Action Request
CD	Countdown
CEI	Configuration End Item
CMD	Command
CNCR	Characterization of Neurospora Circadian Rhythms
CR	Change Request
CV	Check Valve
D&C	Display and Control
DAP	Digital Autopilot
DAR	Deviation Approval Request
DCS	Debris Containment System
DM	Demonstration Motor
	Development Motor
DoD	Department of Defense
DR	Discrepancy Report
DWV	Dielectric Withstanding Voltage

APPENDIX A

LIST OF ACRONYMS (CONT.)

EAFB	Edwards Air Force Base
ECLSS	Environmental Control and Life Support System
ECP	Engineering Change Proposal
EMI	Electromagnetic Interference
EPDM	Ethylene Propylene Diene Monomer
EST	Eastern Standard Time
ET	External Tank
ET/SEP	External Tank/Separation
ETA	External Tank Attachment
F	Fahrenheit
FAR	Federal Aviation Regulation
FASCOS	Flight Acceleration Safety Cutoff System
FC	Fuel Cell
FCL	Freon Coolant Loop
FCS	Flight Control System
FCV	Flow Control Valve
FD	Flight Day
FDA	Fault Detection and Annunciation
FEA	Fluids Experiment Assembly
FEC	Field Engineering Change
FES	Flash Evaporator System
FIV	Fuel Isolation Valve
FM	Frequency Modulation
FMEA	Failure Modes and Effects Analysis
FMEA/CIL	Failure Modes and Effects Analysis/Critical Items List
FOS	Factor of Safety
fps	Feet Per Second
FRCS	Forward Reaction Control System
FRR	Flight Readiness Review
ft	Feet
g	Gravitational Acceleration
GFI	Ground Fault Interrupt
GH_2	Gaseous Hydrogen
GIDEP	Government, Industry Data Exchange Program
GN_2	Gaseous Nitrogen
GOX	Gaseous Oxygen
GPC	General Purpose Computer
GSE	Ground Support Equipment

APPENDIX A

LIST OF ACRONYMS (CONT.)

H_2	Hydrogen
HCF	High-Cycle Fatigue
HDP	Holddown Post
HEX	Heat Exchanger
HPFTP	High-Pressure Fuel Turbopump
HPOTP	High-Pressure Oxidizer Turbopump
HPU	Hydraulic Power Unit
HR	Hazard Report
hr	Hour
Hz	Hertz
I/O	Input/Output
IBM	International Business Machines
IEA	Instrument and Electronics Assembly
	Integrated Electronic Assembly
IFA	Inflight Anomaly
IFM	Inflight Maintenance
IMU	Inertial Measurement Unit
in-lb	Inch-Pound
INCO	Integrated Communications Officer
INTG	Integration
IOCM	Interim Operational Contamination Monitor
IOM	Input/Output Module
IOP	Input-Output Processor
IPL	Initial Program Load
IRD	Integrated Receiver/Decoder
JSC	Johnson Space Center
KSC	Kennedy Space Center
L-2	Launch Minus 2 Days (Review)
L3	Latitude Longitude Locator
lb	Pound
lb/hr	Pounds Per Hour
LCC	Launch Commit Criteria
LDEF	Long Duration Exposure Facility
LH	Left Hand
LH_2	Liquid Hydrogen
LiOH	Lithium Hydroxide
LO_2	Liquid Oxygen
LOX	Liquid Oxygen

APPENDIX A

LIST OF ACRONYMS (CONT.)

LPFTP	Low-Pressure Fuel Turbopump
LPOTP	Low-Pressure Oxidizer Turbopump
LSFR	Launch Site Flow Review
M&P	Materials and Processes
MADS	Modular Auxiliary Data System
MCC	Main Combustion Chamber
	Mission Control Center
MCIU	Manipulator Controller Interface Unit
MDM	Multiplexer-Demultiplexer
MDSSC	McDonnell Douglas Space Systems Company
ME	Main Engine
MEC	Main Engine Controller, Master Event Controller
MECO	Main Engine Cutoff
MET	Mission Elapsed Time
min	Minute
MLE	Mesoscale Lightning Experiment
MLG	Main Landing Gear
MLP	Mobile Launch Platform
MMMSS	Martin Marietta Manned Space Systems
MMU	Mass Memory Unit
MPS	Main Propulsion System
MRB	Material Review Board
MSD	Mission Support Directorate
MSE	Mission Safety Evaluation
msec	Millisecond
MSFC	Marshall Space Flight Center
NASA	National Aeronautics and Space Administration
NDE	Non-Destructive Evaluation
NDI	Nondestructive Inspection
NLG	Nose Landing Gear
NPSP	Net Positive Static Pressure
NSRS	NASA Safety Reporting System
O_2	Oxygen
OMI	Operations and Maintenance Instruction
OMRS	Operational Maintenance Requirements Specification
OMRSD	Operational Maintenance Requirements and Specifications Document
OMS	Orbital Maneuvering System
OPF	Orbiter Processing Facility

APPENDIX A

LIST OF ACRONYMS (CONT.)

OPO	Orbiter Project Office
ORBI	Orbiter
OSMQ	Office of Safety and Mission Quality
OV	Orbiter Vehicle
oz	Ounce
PCG	Protein Crystal Growth
PLS	Primary Landing Site
POWG	Payload Operations Working Group
ppm	Parts Per Million
PR	Problem Reports
PRACA	Problem Reporting and Corrective Action
PRCB	Program Requirements Control Board
PRSD	Power Reactant Storage and Distribution
psi	Pounds Per Square Inch
psi/hr	Pounds Per Square Inch Per Hour
psia	Pounds Per Square Inch Absolute
psid	Pounds Per Square Inch Differential
Q	Dynamic Pressure
QD	Quick Disconnect
QM	Qualification Motor
RCN	Requirements Change Notice
RCS	Reaction Control System
RF	Radio Frequency
RH	Right Hand
RI	Rockwell International
RM	Redundancy Management
RMS	Remote Manipulator System
RPC	Remote Power Controller
RSRM	Redesigned Solid Rocket Motor
RSS	Range Safety System
RTLS	Return to Launch Site
RTV	Room-Temperature Vulcanizate
S/N	Serial Number
S&A	Safe and Arm
sec	Seconds
SIP	Strain Isolator Pad
SOFI	Spray-On Foam Insulation
SPF	Software Production Facility

APPENDIX A

LIST OF ACRONYMS (CONT.)

SRB	Solid Rocket Booster
SRM	Solid Rocket Motor
SSC	Stennis Space Center
SSME	Space Shuttle Main Engine
SSRP	System Safety Review Panel
SYNCOM	Synchronous Communication Satellite
TAL	Transatlantic Abort Landing
TDRSS	Tracking and Data Relay Satellite System
TPS	Thermal Protection System
TVC	Thrust Vector Control
U/N	Unit Number
USBI	United Space Boosters, Inc.
VAB	Vehicle Assembly Building
WCS	Waste Collection System
WOW	Weight-On-Wheels
WPAFB	Wright Patterson Air Force Base
WSB	Water Spray Boiler