MISSION SAFETY EVALUATION REPORT FOR STS-34

Postflight Edition: January 12, 1990

Safety Division

Office of Safety, Reliability, Maintainability, and Quality Assurance

National Aeronautics and Space Administration

Washington, DC 20546

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EXECUTIVE SUMMARY

The first attempt to launch *Atlantis* was made on October 17, 1989, at 12:57 p.m. Eastern Daylight Time (EDT). It was scrubbed due to rain showers seven miles from the Return To Launch Site (RTLS) runway. This was a Launch Commit Criteria (LCC) violation; the LCC requires that there be no rain within 20 miles of the RTLS at launch. STS-34 launch was rescheduled for the next day, October 18, 1989.

On October 18, the launch countdown proceeded on schedule through the final planned hold, at T–9 minutes. At T–5 minutes, the countdown was held for 3 minutes 40 seconds to update the onboard computer configuration. This update was required to reflect the change in the Transatlantic Abort Landing (TAL) site from Ben Guerir, Morocco to Zaragosa, Spain. Weather at Ben Guerir, the primary TAL site, was declared unacceptable because of rain near the runway. *Atlantis* was launched satisfactorily at 12:53:40 p.m. EDT, and the Orbiter achieved the planned orbit.

Galileo was launched on its six-year journey to Jupiter approximately 6 hours after the STS launch. Deployment of Galileo from the payload bay was flawless, and the Inertial Upper Stage (IUS) performed nominally. All other payloads and experiments operated successfully throughout the mission. Overall, STS-34 was an unqualified success.

Because of a forecast of high winds at Edwards Air Force Base (EAFB), the planned landing on orbit 82 was moved up by two orbits. *Atlantis* landed on EAFB Runway 23 (lakebed) at 12:33:11 p.m. EDT on October 23, 1989. Nosewheel steering and crosswind landing development test objectives were not performed.

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, Reliability, Maintainability, and Quality Assurance (SRM&QA) and the National Space Transportation System (NSTS) Program Manager prior to each NSTS 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 NSTS Hazard Reports. Unresolved safety risk factors impacting the STS-34 flight are also documented prior tothe STS-34 Flight Readiness Review (FRR) (FRR Edition) and prior to the STS-34 Launch Minus Two-Day (L–2) Review (L–2 Edition).. This final mission edition evaluates performance against safety risk factors identified in previous 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 NSTS flight.

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SECTION 1

INTRODUCTION

1.1 Purpose

The Mission Safety Evaluation (MSE) provides the Associate Administrator, Office of Safety, Reliability, Maintainability, and Quality Assurance (SRM&QA) and the National Space Transportation System (NSTS) Program Manager with the NASA Headquarters Safety Division position on significant 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-34 safety risk factors that represent a change from previous flights, factors from previous flights that have 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 NSTS 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 eight 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-related information.

Section 3 - Contains a list of safety risk factors/issues, considered resolved or not a safety concern prior to STS-34 launch, that were impacted or repeated by anomalies reported for the STS-34 flight.

Section 4 - Contains a list of safety risk factors that are considered resolved for STS-34.

Section 5 - Contains a list of Inflight Anomalies (IFAs) that developed during the STS-28 mission.

Section 6 - Contains a list of IFAs that developed during the STS-30 mission.

Section 7 - Contains a list of IFAs that developed during the STS-34 mission. Those STS-34 IFAs which are considered to represent safety risks will be addressed in the MSE for the next NSTS 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-34 MISSION SUMMARY

2.1 Summary Description of STS-34 Mission

The first attempt to launch *Atlantis* was made on October 17, 1989, at 12:57 p.m. Eastern Daylight Time (EDT). This attempt was scrubbed due to rain showers seven miles from the Return To Launch Site (RTLS) runway. This was a Launch Commit Criteria (LCC) violation; the LCC requires that there be no rain within 20 miles of the RTLS at launch. Launch of STS-34 was rescheduled for the next day, October 18, 1989.

On October 18, the launch countdown proceeded on schedule through the final planned hold, at T–9 minutes. At T–5 minutes, the countdown was held for 3 minutes, 40 seconds to update the onboard computer configuration. This update was required to reflect the change in the Transatlantic Abort Landing (TAL) site from Ben Guerir, Morocco to Zaragosa, Spain. Weather at Ben Guerir, the primary TAL site, was declared unacceptable because of rain near the runway. *Atlantis* was launched satisfactorily at 12:53:40 p.m. EDT, and the Orbiter achieved on the planned orbit.

Galileo was launched on its six-year journey to Jupiter approximately 6 hours after the STS launch. Deployment of Galileo from the payload bay was flawless, and the Inertial Upper Stage (IUS) performed nominally. All other payloads and experiments operated successfully throughout the mission. Overall, STS-34 was an unqualified success.

During ascent, Auxiliary Power Unit (APU) #1 experienced an anomaly that caused a shift to the high-speed mode. The crew manually selected the high-speed band to avoid APU high-speed alarms. APU #1 continued to operate satisfactorily at the high-speed position for the remainder of ascent. This anomaly caused a change in APU usage during the mission. APU #3 was used for Flight Control System (FCS) checkout instead of APU #1. APU #2 was the first APU started for reentry, 5 minutes prior to the deorbit maneuver. APU #3 was started 13 minutes prior to reentry interface. Because of the high-speed anomaly with APU #1, and its relation to limited-life concerns, APU #1 was not turned on until Mach 10, 11.5 minutes before landing. APU #1 was started in high speed and was shut down shortly after wheel stop.

The Flash Evaporator System (FES), primary "A", shut down after Main Engine Cutoff (MECO). The secondary high-load operated satisfactorily. Inflight maintenance was performed on the FES, and the system was restored to normal operation.

Prior to the second Orbital Maneuvering System (OMS) burn, an Input/Output (I/O) error occurred in the Multiplexer/Demultiplexer (MDM) Flight Aft 1 (FA-1). An I/O reset attempt failed to recover the unit. The crew successfully port-moded the MDM to a secondary port, where it continued to operate error-free. The impact of this anomaly was loss of the redundant data path to MDM FA-1.

At approximately 5 hours Mission Elapsed Time (MET), APU Gas Generator/Fuel Pump (GG/FP) system "A" heaters were turned on. APU #1 and #3 responded nominally; however, no temperature response was noted for APU #2 heaters. APU #2, system "B" heaters were selected and operated properly on all three APUs. During the crew post-sleep period on Flight Day 2 (FD-2), APU #2 GG/FP heater was switched to system "A" to determine if the total heater system "A" had failed or if only the gas generator bend heater had failed. During the 3 1/2 hours of heater system "A" operation, the GG/FP system heaters did not cycle, indicating that the entire heater system "A" was anomalous.

When the crew attempted to close Cryogenic Oxygen Manifold Valve #2, during the crew pre-sleep period on FD-2, there was no indication that the valve had closed. Since the anomaly occurred so close to the sleep period, the cryo tank was placed in a safe configuration until the beginning of the next flight day. On FD-3, the switch controlling the cryo valve was actuated and the valve closed as commanded by the crew. To protect against the valve failing open, the valve was left closed for the remainder of the mission. The impact of this anomaly was a potential inability to maintain nominal cryogenic oxygen quantity balancing.

Approximately 58 hours into the mission, APU #2 GG/FP system "B" heaters started cycling erratically and, during the crew sleep period on FD-4, the APU #2 fuel pump bypass line temperature sensor violated the upper Fault Detection Annunciator (FDA) 180°F limit. The crew was awakened to switch to the system "A" heaters and to monitor associated temperatures. Acceptable APU fuel pump temperatures were maintained by manual heater cycling during the day and by selected Orbiter thermal control attitudes during crew sleep periods. On FD-5, the crew switched back to the system "B" heaters, which again operated erratically. Temperatures, however, were maintained within specified limits for the remainder of the mission.

Because of a high winds forecast at Edwards Air Force Base (EAFB), the planned landing on orbit 82 was moved up by two orbits. *Atlantis* landed on EAFB Runway 23 (lakebed) at 12:33:11 p.m. EDT on October 23, 1989. Nosewheel steering and crosswind landing development test objectives were not performed.

2.2 Flight/Vehicle Data

- Launch Period: October 12, 1989 to November 21, 1989
- Launch Date: October 18, 1989
- Lauch Time: 12:53:40 p.m. EDT
- Launch Site: KSC Pad 39B
- RTLS: Kennedy Space Center, Runway 33
- TAL Site: Zaragosa, Spain (Changed from Ben Guerir, Morocco due to rain at the Ben Guerir runway.)
- Alternate TAL Site: Moron, Spain
- Landing Site: Edwards AFB, CA, Lakebed
- Landing Date: October 23, 1989
- Landing Time: 12:33:11 p.m. EDT
- Mission Duration: 4 Days, 23 Hours, 40 minutes (80 Orbits)
- Crew Size: 5
- Inclination: 34.3 Degrees
- Altitude: 160 Nautical Miles/Direct Insertion
- Orbiter: OV-104 (5) *Atlantis*
- SSMEs: (1) #2027, (2) #2030, (3) #2029
- ET: ET-027
- SRBs: BI-033
- SRMs: RSRM Flight Set #6

2.3 Payload Data

Payload Bay:

- Galileo Spacecraft/Inertial Upper Stage (IUS)
- Shuttle Solar Backscatter Ultraviolet (SSBUV)

Middeck:

- Air Force Maui Optical Site (AMOS) Calibration Test
- Growth Hormone Concentration Distribution (GHCD) in Plants
- Polymer Morphology (PM) Experiment
- IMAX Camera System
- Mesoscale Lightning Experiment (MLE)
- Sensor Technology Experiment (STEX)
- Zero Gravity Growth of Ice Crystals from Supercooled Water with Relation to Temperature (Project SE82-15)

SECTION 3

SAFETY RISK FACTORS/ISSUES IMPACTED BY STS-34 ANOMALIES

This section contains a list of the safety risk factors/issues, considered resolved or not a safety concern for STS-34 prior to launch (see Sections 4, 5, 6, and 7), that were impacted or repeated by anomalies reported for the STS-34 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		
SRB 5	Aft skirt Factor of Safety (FOS) waiver.	During STS-34 launch, the holddown stud at Holddown Post (HDP) #2 (Right-Hand (RH) tension post) hung-up at liftoff. This resulted in broaching of the right SRB aft skirt and thread impressions at the HDP bore. Stud hangups were recorded on five previous missions (STS-2, STS-4, STS-51I, STS-51J, and STS-61A). MSFC continues to investigate the stud hangup anomaly. (IFA No. STS-34-M-01)
SRM 3	Putty found on outer igniter gasket on STS-33 RH Solid Rocket Motor (SRM) (preflight).	During STS-34/SRM postflight inspection, putty was found up to the aft face of the outer primary gasket and into the seal void/gland area between 234° and 0° of the right SRM igniter. This indicates that vertical igniter installation does not necessarily resolve the igniter putty problem. The putty did not go past the primary seal, and no blowholes were found. (IFA No. STS-34-M-03)
Section 5: STS-28 Inflight Anomalies		
Orbiter 14	Excessive body flap deflection during ascent.	STS-34/OV-104 ascent film review found some evidence of body flap deflection; however, it was not considered as great as seen on STS-28/OV-102. No damage to tile or body flap mechanisms was reported during postflight inspection. (Not an IFA on STS-34)

ITEM		COMMENT
Section 5: STS-28 Inflight Anomalies		
SRB 1	Loose bolts on the left Solid Rocket Booster (SRB) External Tank Attachment (ETA).	Postflight STS-34 SRB inspection found that certain fasteners and connectors were either not torqued or not properly safety wired. Effort is underway at Kennedy Space Center (KSC) to emphasize the importance of good workmanship and proper installation of fasteners and connectors. (IFA No. STS-34-K-03).
Section 6: STS-30 Inflight Anomalies		
SRM 1	Factory joint weather seal aft edge unbonding.	Three forward edge factory joint weather seal unbonds were noted on the left-hand STS-34 SRB. Corrosion was present on the outside diameter of the outer clevis leg on both joints. Adhesive failure implies that the cause of the unbond is case surface contamination. No sooting or heat effects were found under the weather seal, indicating that the unbonds occurred at splashdown. (IFA No. STS-34-M-02)

SECTION 4

RESOLVED STS-34 SAFETY RISK FACTORS

This section contains a list of the safety risk factors that are considered resolved for STS-34. These items have been 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

INTEGRATION

ORBITER

SECTION 4 INDEX - (Cont.)

SECTION 4 INDEX - (Cont.)

RESOLVED STS-34 SAFETY RISK FACTORS

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
INTEGRATION		
1	External Tank (ET)/Orbiter Separation Assembly Cartridge failure to generate sufficient pressure to separate the separation bolt. HR No. INTG-052B ***No separation bolt anomalies were reported. There was a bent stop bolt found on the STS-34/OV-104 separation assembly centering ring (IFA No. STS-34-21); however, this was attributed to the ET/Orbiter mating process.***	During acceptance testing, one of the ET/Orbiter Separation Assembly cartridges (forward end) failed. The calculated pressure of 4810 pounds per square inch (psi) did not meet the specified 4950-6800 psi range. There are two cartridges (dual redundancy) per assembly. The requirement is that separation occur if only one cartridge fires. However, it should be noted that, if one cartridge detonates, proximity will cause sympathetic detonation of the second cartridge and additional pressure generation. If both fail to operate, the ET and Orbiter will not separate causing a catastrophic failure. These cartridges are unique to this application; therefore, they do not impact other National Space Transportation System (NSTS) elements. The NASA Standard Initiators (NSIs) were not considered to be a problem. Initially, it was believed that the failure indication was due to the test setup. However, the test setup was "corrected", and additional tests were performed. Pressure values calculated by the vendor indicated that the tested cartridges still did not meet specifications on the low end. Acceptance test standards require that 10 units from each lot fire without failure, or the whole lot must be rejected. These cartridges were originally part of the HSS lot, but were then separated into 2 lots, HRA and HSW, when new NSIs were installed. Acceptance test failures were noted on only 1 of the lots, HRA, with the new NSIs. However, the cartridges currently on STS-34 were from the HSW lot and were suspect. A detailed review by the Propulsion and Power Division, Engineering Directorate, Johnson Space Center (JSC) into the vendor's methodology for evaluating acceptance test results found some incorrect interpretations of the test data. The vendor concurred with the JSC findings. When correct test data was used,

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
INTEGRATION		
1 (Continued)		calculation of the pressure generated showed that the cartridges passed the test. JSC Engineering is working on new procedures to standardize evaluation of acceptance test results for the cartridges. *This risk factor was not a concern for STS-34.*
2	Rosemont braze/weld deficiencies. HR No. ORBI-286 ***No anomalies were attributed to braze or weld deficiencies on STS-34.***	A determination was made that material procured from Rosemont had deficient brazing and welding. Additionally, quality control of these deficiencies by Rosemont was not satisfactory. Review by all Program elements was undertaken to identify all Rosemont-manufactured parts in the system and to determine their flight worthiness. Following is a summary of the findings. Orbiter: During rebuild of an improved spare fuel cell at IFC (vendor), x-ray of the fuel cell Oxygen (O_2) flowmeter braze joint showed voids exceeding specifications. Each fuel cell contains one Hydrogen (H_2) and one O_2 flowmeter. The O_2 system operating pressure is 1050 pounds per square inch absolute (psia) maximum; H_2 system operating pressure is 335 psia maximum. Leak rate (4×10^{-6} cubic centimeters per second (ccs)) met Rockwell specification requirements but failed tighter supplier (IFC) requirements (no indicated leakage allowed). X-rays showed braze void areas exceeding 15% allowable, with connecting voids providing a leak path. MIL-B-7783 specification requires braze coverage of 85% or greater and no voids greater than 15% of the joint length. Review with the flowmeter manufacturer (Rosemont) determined that the original x-rays of this and other flowmeter braze joints failed to meet the 15% maximum void area requirement.

RESOLVED STS-34 SAFETY RISK FACTORS

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
<u>INTEGRATION</u>		
2 (Continued)		OV-104 fuel flowmeter braze joint x-rays were reviewed. Of the 33 braze joints involved: 13 met standards, 17 did not meet standards, and 3 x-rays were not located. Of the 17 that did not meet standards, the worst case contained 15-20% braze coverage. Joints for which x-rays were missing are in OV-104 fuel cell #2 H_2 flowmeter. OV-104 joints were not accessible for inspection at the pad. Structural analysis of the braze areas indicated that all braze joints were stronger than the tube itself. (Worst-case braze coverage results in a braze joint Factor of Safety (FOS) of 1.27.) All braze joints passed a minimum 2x maximum operating pressure proof test: • O_2 proof 2100 psia (factor of 2) • H_2 proof 2100 psia (factor of 6) All OV-104 flowmeters passed numerous leak checks, including pressure decay checks conducted during each OV-104 turnaround. All OV-104 flowmeters have flown two flights without problems and were otherwise undisturbed. Based upon the history of these fuel cell flowmeters, including proof, leak, and flight experience, and the fact that only 1 extremely small O_2 leak has developed during their entire history, OV-104 flowmeters are acceptable for continued service. <u>SRM/SRB/SSME/ET</u>: No Space Shuttle Main Engine (SSME) related failures were found. Marshall Space Flight Center (MSFC) has discontinued procurement from Rosemont.

RESOLVED STS-34 SAFETY RISK FACTORS

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
INTEGRATION		
2 (Continued)		Kennedy Space Center (KSC)/Ground Support Equipment (GSE): KSC discontinued procurement from Rosemont 3 years ago due to weld problems encountered. No GSE currently has Rosemont parts installed. ***This risk factor was resolved for STS-34.***
3	Rice fastener alert. ***No anomalies were attributed to Rice fasteners on STS-34.***	On August 16, 1989, Rice Aircraft, Incorporated was indicted for fraud. Rice is an aerospace fastener distributor, representing Hi-Shear, Cherry, Voi-Shan, Deutsch, and other major aerospace fastener companies. The indictment included allegations that Rice stripped original plating material from used and rejected fasteners and replated or relubricated these fasteners prior to sale under the original fastener manufacturers' trademark. Rice did not follow process and testing requirements to avoid or detect hydrogen embrittlement of the fasteners. Additionally, it was alleged that Rice forged manufacturer test reports for replated and relubricated fasteners. The fasteners in question were distributed from 1977 to 1988. Investigation reports from the NSTS Projects found that Rice fasteners are used in certain systems. Project procurement records show that all fasteners procured from Rice were subjected to receipt inspection and/or acceptance testing. Inspection/test results indicated that all Rice fasteners exceeded specified requirements. There is no concern relative to the various uses of Rice fasteners in the NSTS Program. ***This risk factor was resolved for STS-34.***

RESOLVED STS-34 SAFETY RISK FACTORS

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
1	Hydraulic system noise. HR No. ORBI-050 ORBI-180 ***No hydraulic system anomalies were reported on STS-34.***	Noise was detected on OV-104/STS-34 during brake system checkout and persisted when the pedals were released. This was a different vibration phenomenon than the one documented on OV-102. The noise pitch was much higher and occurred continuously, not just when the brakes were applied. The estimated frequency was approximately 800 Hertz (Hz) versus the 55 Hz witnessed on OV-102. Analysis isolated the problem to the hydraulic system #2 regulator; it was removed and replaced. The hydraulic system was satisfactorily retested in accordance with Operational Maintenance Requirements and Specifications Document (OMRSD) requirements; the noise/vibration was eliminated. ***This risk factor was resolved for STS-34.***
2	Reaction Control System (RCS) left helium valve "A" failed. HR No. ORBI-129A ***No helium valve anomalies were reported on STS-34.***	The RCS left helium oxidizer valve "A" went closed when the "B" valve was opened during the STS-28 regulator reconfiguration. The failure was attributed to shock induced by the pressure surge following "B" valve opening. When the valve is opened, high pressure upstream causes helium to surge into the low-pressure area between the valve and the regulator. This surge, and the shock that occurs with the high delta pressure across the valve, may cause the valve in the parallel circuit (in this case the "A" valve) to close. These valves are held open magnetically and close by spring tension. The surge and the mechanical shock may cause the valve to close by combining with the spring to overpower the magnetic latch. Only 1 of the 6 helium valves demonstrated this anomaly on STS-28.

RESOLVED STS-34 SAFETY RISK FACTORS

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
2 (Continued)		The Flight Rules were changed for STS-34 to require the crew to place the "A" valve in the manual "open" position prior to opening the "B" valves. This change will prevent the "A" valve from closing due to shock from the pressure surge caused by the "B" valves opening. ***This risk factor was resolved for STS-34.***
3	Contamination found in RCS propellant tank. HR No. ORBI-166 ***No RCS propellant anomalies were reported on STS-34.***	A white, powdery substance was found in an RCS propellant tank during rework. Contamination in the tank could accumulate and clog propellant acquisition screens. This condition can lead to catastrophic RCS thruster failures. The contamination was analyzed. Results indicated that the substance was mostly phosphate and was soluble. Rationale for risk acceptance was: • The quantity of contamination was very small and was soluble. • Performance of the bubble-point verification test will detect propellant acquisition screen clogging. No anomalies were reported as a result of OV-104/STS-34 bubble-point testing. ***This risk factor was acceptable for STS-34.***

RESOLVED STS-34 SAFETY RISK FACTORS

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
<u>ORBITER</u>		
4	Liquid Oxygen (LO_2) umbilical actuator failure. HR No. ORBI-302A ***No actuator anomalies were reported on STS-34.***	The forward inboard ET LO_2 hydraulic actuator on OV-102 failed to extend when commanded. Testing verified that the actuator was receiving the command signal. The actuator was removed and returned to the vendor for failure analysis; no problems were found. The most probable cause was determined to be a tilted umbilical, but the failure could not be duplicated. During testing of the replaced actuator on OV-102, the replacement failed to respond to the retract command. This unit was also replaced with another actuator. Analysis revealed that the replacement actuator failed to retract and go into hydraulic lock. This was considered to be a low-impact condition, because the actuator would be in the free-float mode after retract command was removed. Failure of 1, 2, or 3 actuators in this failure mode (failure to retract and in free float) is a survivable condition. However, there is a potential for minor local damage to the interior of the ET umbilical door if the umbilical plate contacts the door during closure and locking. The actuators on OV-104 were tested and proved acceptable for flight. During performance of revised OMRSD actuator tests on OV-104, the ET/Orbiter umbilical flex hoses were extended 0.62" beyond the certified envelope limits. There was a concern that overextension of ET umbilical flex hoses could result in line failure and cryogenic leakage. Rockwell performed a Computer Aided Drawing (CAD) analysis of the overextended condition and concluded that no adverse effects would result. In addition, inspection of OV-104 umbilical electrical harnesses found no anomalies. Rationale for flight was based on favorable results of analyses and inspections performed, and satisfactory actuator operation experienced during STS-30. ***This risk factor was resolved for STS-34.***

RESOLVED STS-34 SAFETY RISK FACTORS

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
<u>ORBITER</u>		
5	Orbital Maneuvering System (OMS) oxidizer propellant inlet line leak. HR No. ORBI-212 ***No further leaks were reported on STS-34.***	A pin-hole leak was found in the OV-104 OMS oxidizer feedline. An oxidizer leak could lead to excessive loss of RCS propellant and hazardous accumulation of O_2 in the OMS Pod. The pin hole can be traced to one of several causes: material deficiency, weld defect or crack, installation damage, etc. The feedline was removed and replaced. Leak checks were performed on the new line with no anomalies reported. ***This risk factor was resolved for STS-34.***
6	Auxiliary Power Unit (APU) Quick Disconnect (QD) leak. HR No. ORBI-250 ***No further leaks were reported on STS-34.***	A leak was discovered at the QD for APU #1 when Hydrazine was loaded aboard the Orbiter. This QD is between the fill line and APU #1 fuel tank in the aft compartment. The QD was replaced on the pad, and leak checks were successfully performed. ***This risk factor was resolved for STS-34.***
7	RCS L2U Thruster combustion chamber overpressure. HR No. ORBI-119 ***No thruster anomalies were reported on STS-34.***	During Orbiter preparation, the RCS L2U Thruster combustion chamber was inadvertently overpressurized to 82 psia during OMRSD test performance. A waiver to the OMRSD pressurization limit was proposed. Safety originally did not concur with the waiver and requested inspection of wirewrap of the combustion chamber for damage resulting from the overpressure condition. This type of damage could lead to possible burnthrough of the thruster combustion chamber, resulting in a catastrophic condition. The combustion chamber and wirewrap was inspected, with no anomalous conditions noted. Safety then concurred with the waiver. ***This risk factor was resolved for STS-34.***

RESOLVED STS-34 SAFETY RISK FACTORS

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
<u>ORBITER</u>		
8	OV-104 has four Multiplexer-Demultiplexers (MDMs) that may contain Erie capacitors which are prone to failure. HR No. ORBI-038 ***No reported MDM anomalies were related to failed Erie capacitors. MDM Flight-Critical Aft (FA) #1 had a reported Input/Output (I/O) error and had to be port-moded to continue the mission. (IFA No. STS-34-05)***	In 1981, Erie capacitors were found to be prone to failure due to a low-resistance short. The Orbiter Program Office (OPO) directed that the capacitors be purged from increment III MDM builds and directed that replacement of these capacitors on other MDMs be made by attrition or when MDMs were returned to the vendor. Presentations made at the STS-28 Flight Readiness Review (FRR) Action Item Closeout Meeting indicated that OV-104 has four MDMs installed with Erie capacitors. The configuration of OV-104 MDMs is as follows: S/N 27 — PL2 — Payload MDM #2 (16 Erie Capacitors) S/N 67 — OF3 — Operational Instrumentation - Forward MDM #3 (272 Erie Capacitors) S/N 71 — OF4 — Operational Instrumentation - Forward MDM #4 (160 Erie Capacitors) S/N 74 — OA3 — Operational Instrumentation - Aft MDM #3 (256 Erie Capacitors) Failure of PL2 would result in a single path for communications and control of the Galileo Spacecraft through PL1. This MDM is one of a redundant set that would be required to operate only through payload separation from the Orbiter. There were no signs of incipient failure. OF1, OF2, and OF3 are criticality 1/1 units. Failure of OF3, coupled with a fuel cell heater relay turn-on, cannot be detected. Additionally, failure of OF3 in combination with a subsequent undetected failure in a fuel cell stack due to hydrogen/oxygen crossover could result in possible loss of crew and vehicle. Failure of OF3, therefore, results in reentry at the next Primary Landing Site (PLS), per Flight Rule 9-23.

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
8 (Continued)		Three of the 272 Erie capacitors in OF3, Serial Number (S/N) 67, are in critical locations in the MDM. They are on the I/O module card #1, channels 27, 28, and 29. These channels carry critical Cell Performance Monitor (CPM) fuel cell reactant (H_2 and O_2) crossover data.
		Automated ground monitoring of the Orbiter will not detect the failure of OF3 during operation. Nominal CPM substack delta voltage output is 0 to 150 millivolts (mV). Exceeding the 150-mV redline will trigger an alert at the Electrical Power System (EPS) console at the Mission Control Center (MCC). Failure of the capacitor will skew the output downward by a factor of approximately 2 to 20. Therefore, the 150-mV redline may be exceeded by a large amount without instrumentation triggering an alarm. The CPM outputs a 50-mV reference voltage every 7.5 minutes for a period of 2.3 seconds. This reference voltage may be manually read by the EPS console operator, but is not automatically annunciated. When operating correctly, a 50-mV reference voltage will be displayed on the console. Failure to read 50 mV may be an indication that the capacitor has failed.
		Rationale for flight was based on the low probability of occurrence and the fact that there have been no Erie capacitor flight failures to date. JSC Safety, Reliability, and Quality Assurance (SR&QA) recommended that the MCC EPS console operator be alerted to this condition and directed to pay particular attention to the CPM self-test reference voltage for MDM OF3. Additionally, it was recommended to the OPO that the OF3 MDM, S/N 67, be removed and replaced prior to the next OV-104 flight (STS-36).
		This risk factor was acceptable for STS-34.

RESOLVED STS-34 SAFETY RISK FACTORS

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
9	Main Propulsion System (MPS) Flex Hose leakage. HR No. ORBI-306 ***No further leaks were reported on STS-34.***	During performance of MPS Flex Hose Acceptance Test Procedures (ATPs), the hose failed the proof pressure test, and leakage occurred. Six flex hoses of this type are used in the OV-104 MPS. Failure of the flex hose during ascent, or during a Return to Launch Site/Transatlantic Abort Landing (RTLS/TAL) contingency, could result in a catastrophic condition (cryogenic leakage in the aft compartment and loss of helium supply pressure). Rationale for flight was: • Flex-hose failure is ATP and OMRSD screenable during pressure/operating leak tests. • All flex hoses on OV-104 successfully passed qualification and acceptance tests. • No anomalous conditions were reported as a result of OMRSD tests on STS-34. ***This risk factor was resolved for STS-34.***
10	Main and nose gear wheel assembly overinflation plug burst disk concern. HR No. ORBI-018A ***No wheel assembly anomalies were reported on STS-34.***	Failure analysis of an overinflation plug on the wheel and tire assembly that failed the cold-soak leak test at KSC indicated that the leak occurred due to corrosion pitting through the Nickel (Ni) burst disk. The analysis concluded that the most likely cause of corrosion was high concentration of residual sulfate remaining on the disk following a bubble-leak check (both the corrosion products and leak test compound have high sulfate content). In January 1989, another wheel assembly failed a leak test in the wheel and tire shop due to a leak in the overinflation plug burst disk. Inspection indicated that the leak originated from a crack-like defect at the flat-to-dome radius. Surface

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
10 (Continued)		deformation markings were also found at the radius. Additionally, the radius showed significant thinning away from the leak site. The crack was found to be a ductile-appearing fracture, with no evidence of fatigue or creep. Some minor pitting was also seen. Since January 1989, the same leak test solution was used on plug burst disks when routine leak checks were performed on each tire assembly. Six additional overinflation plugs were checked. One of the 6 was found to have a crack; the others had no crack or corrosion. The cracked wheel assembly (STS-28 S/N 024) was found using Helium mass spectroscopy; a technique not normally used. The crack was located at the flat-to-dome radius. The leak rate was within the allowable OMRSD limit. Minor pitting was also observed. As a result of these leak checks, it was suspected that corrosion potential existed on the flight wheels already processed. There was additional concern that, even though leak rates on the STS-34 tires were nominal, ascent vibrations and/or stresses due to on-orbit thermal cycling would initiate or aggravate a leak if the burst disks were corroded. Structural analyses and assessments were performed. Launch vibration on the tire/wheel assembly was very low. On-orbit thermal stress induced was also very low. Landing loads were considered inconsequential, partly because the deflation rate through an open, or burst, plug was very slow and would not deflate the tire to a deleterious degree until after rollout. The tire pressure load was the only significant loading on the overinflation plug. Rationale for flight with the current tire wheel assemblies was: • No evidence of corrosion thinning on any tire/wheel assembly. • No evidence of rapid pitting corrosion; the worst cases observed to date were several minor through pits.

RESOLVED STS-34 SAFETY RISK FACTORS

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
<u>ORBITER</u>		
10 (Continued)		• No significant fatigue stresses induced during liftoff or during flight, and no metallurgical evidence of fatigue seen to date. • Creep process is extremely slow at low temperatures, and no metallurgical evidence of creep found. If the tire/wheel assemblies are not leaking at liftoff, it is unlikely they will leak in flight. Flight-induced stresses are exceptionally low, and the corrosion process, if any, is arrested in the vacuum of space. ***This risk factor was resolved for STS-34.***
11	750-psia helium regulator failed to lock up after a "slam test." HR No. ORBI-108E ***No helium regulator anomalies were reported on STS-34.***	During testing of a 750-psia helium regulator (S/N 027), the regulator exceeded the 760-psia allowable pressure and failed to lock up after performance of a "slam test." Subsequent inspection showed inner edge damage on the vespel ring. It was noted that S/N 027 had experienced approximately 400 slams. There are some regulators in the fleet, including S/N 034 on OV-104, that have more than 300 slams. Failure of the regulator in the "open" position results in a negative margin of safety for the primary structures during ascent and descent. Tests were performed to demonstrate and verify the projected mission life of the helium regulators. These tests included a 2000 slam test and resulted in no further anomalies. The OPO concluded that the failure mode experienced on S/N 027 was an isolated case and was not a generic helium regulator problem. Prior to completion of testing, it was determined that S/N 034 had experienced approximately 380 slam starts. S/N 034 was considered a risk, because S/N 027 failed with approximately 400 slams. For this reason, S/N 034 was removed and

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
11 (Continued)		replaced with a regulator having less than 200 slams. The regulator outlet pressure is monitored during prelaunch and is unlikely to drift to a significantly higher pressure during ascent. ***This risk factor was resolved for STS-34.***
12	Fuel cell separator plate plating defects. HR No. ORBI-282A ***No anomalies were reported on STS-34.***	During teardown of fuel cells S/N 104 and S/N 115 for operational improvements, plating blisters were found in 46 separator plates (O_2-to-H_2 and H_2-to-coolant). Fuel cell operating times were approximately 1000 hours, 3 flights each (STS-9, STS-61C, and STS-26). All of the plates were from a single lot of 255 manufactured from December 1982 through December 1983. The blister failure was in the form of separation of the gold and nickel layers from the magnesium base material. No corrosion was observed through to the magnesium. The potassium hydroxide, used as an electrolyte with water, passivates the bare magnesium, and no corrosion occurs. Corrosion pits may develop if material impurities are present at the blister site. Explosive mixing of H_2 and O_2 through the separator plate could lead to a catastrophic event; indication of H_2 and O_2 mixing requires immediate fuel cell shutdown and safing. Mixing of H_2 and coolant is more benign, resulting in slow degradation in fuel cell performance. Separator plates from this suspect lot are in current flight or qualification fuel cells. An accounting of these plates follows: OV-104 (STS-34) 1 in Fuel Cell #1, H_2-to-coolant plate, with 346 hours of operation.

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
12 (Continued)		OV-103 (STS-33): 2 in Fuel Cell #1, H_2-to-O_2 plate, with 411 hours of operation. 1 in Fuel Cell #2, H_2-to-coolant plate, with 519 hours of operation. 45 in Fuel Cell #3, 2 in H_2-to-O_2 plate, 43 in H_2-to-coolant plate, with 854 hours of operation.
		OV-102 (STS-32): None.
		Qualification Unit: 4 plates with a total of 2000 hours of operation.
		Spares: 7 in Fuel Cell S/N 106, H_2-to-O_2 plate, with 482 hours of operation. 5 in Fuel Cell S/N 108, H_2-to-O_2 plate, with 496 hours of operation. 4 other spare Fuel Cells at KSC do not have any plates from this lot.
		The probability of experiencing through-pitting in the 1 Fuel Cell plate in OV-104 was remote based on the following: • Plates in the qualification unit have over 2000 hours of operation with no apparent blister problem. • Fuel Cells S/N 104 and S/N 115 operated for greater than 1000 hours prior to discovery of the problem. • Maximum operating time for Fuel Cell #1 on OV-104 was 348 hours. • The remaining 2 Fuel Cells on OV-104 did not contain suspect plates.

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
<u>ORBITER</u>		
12 (Continued)		The rationale for STS-34 flight was: • Only 1 suspect plate on OV-104; an H_2-to-coolant separator plate. Mixing through this plate is not catastrophic and leads to slow degradation of fuel cell performance. • Low probability of attaining this failure mode. • Turnaround tests on OV-104 were successfully completed; Nitrogen (N_2) diagnostics did not indicate any crossover, and current coolant ullage indicated that there was no coolant loss. ***This risk factor was resolved for STS-34.***
13	Star Tracker Door stalled during closure. HR No. ORBI-011A ***No Star Tracker Door anomalies were reported on STS-34.***	The Z Star Tracker Door stalled during closure as OV-104 was readied for rollout. Investigation found that 6 of 7 fasteners on the Z-door insulation blanket were located incorrectly. The wrong reference line was used to locate the fasteners, causing the insulation blanket to protrude into the door track. The Y-door was also cycled to verify that the blanket was installed correctly. It was found that the blankets on the Y-door and the Z-door interfered with the Star Tracker bright object sensor. Star Tracker door blanket interference has most likely existed for some time. Corrective actions included blanket redesign to improve fastener location and a cutout in the blanket for the bright object sensor. Blanket installations in areas of other doors and moving parts were assessed. Modifications were made to tape

RESOLVED STS-34 SAFETY RISK FACTORS

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
<u>ORBITER</u>		
13 (Continued)		cotter pins on the Payload Bay Door torque tubes to alleviate possible blanket interference. Design of blanket installations in all other areas was found to be acceptable. ***This risk factor was resolved for STS-34.***
14	Backup Flight Software (BFS) downlist anomaly. HR No. ORBI-334 ***No further BFS anomalies were reported on STS-34.***	At the end of the STS-34 Trial Countdown Test (TCDT), the BFS computer was taken to halt (subsequently to standby) and ran in accordance with existing procedures. Although the BFS display indicated that the system was correctly in OPS-0 (Operational Software Mode 0), the major mode downlist parameter indicated that the BFS was in major mode 101. This discrepancy was traced to a known BFS constraint documented in User Note B04524C, dated July 11, 1980. This user note states: • If the BFS is moded to halt without first being moded to OPS-0 and then moded back to run without performing an initial program load, the BFS software may not be properly initialized. The specific initialization failure that caused this anomaly was identified and the anomaly repeated. Operating the BFS in a manner that could result in incomplete

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
<u>ORBITER</u>		
14 (Continued)		or indeterminate initialization is unacceptable. Accordingly, KSC reviewed its RTLS site abort and G1 to G9 recycle procedures and made the following changes: • For an RTLS abort, the BFS computer will be moded to halt but will not subsequently be moded to run. • For the OPS-1 to OPS-9 recycle, OPS-0 will be entered via keyboard before the BFS computer is moded to run. ***This risk factor was resolved for STS-34.***
15	Right-Hand (RH) RCS B-leg primary helium regulator anomaly. HR No. ORBI-111 ORBI-129A ***No helium regulator anomalies were reported on STS-34.***	During RCS helium regulator flow checks, the primary B-leg fuel helium regulator undershot the minimum specified pressure of 235 psi and took 4 seconds to return the pressure to within the flow band; this should take a maximum of 2 seconds. The most probable cause of the sluggish operation was restriction of the regulator sense port, a result of exposure to monomethyl hydrazine fuel vapor. An anomaly of this type was experienced on STS-61A. A redesigned helium regulator is available that alleviates contamination induced by hydrazine. OV-104 regulators are all the old version and are susceptible to hydrazine contamination. A waiver was processed prior to the STS-34 launch. The regulator will be changed out post STS-34. Removal of the OMS pod is required. Because of fuel contamination concerns, the configuration of RCS helium regulators on-orbit was modified for STS-34 to use both A and B pressurization paths on the right RCS. This minimized the influence of hydrazine vapors on the regulators. ***This risk factor was acceptable for STS-34.***

RESOLVED STS-34 SAFETY RISK FACTORS

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
<u>ORBITER</u>		
16	RCS helium tank liner delaminations/yielding. HR No. ORBI-111 ORBI-129 *No RCS anomalies were reported on STS-34.*	Two RCS helium tanks, S/N 021 and S/N 022, were found to have delamination in the tank liners. The delamination was traced to improper Acceptance Test Program (ATP) testing. Delamination and yielding of the tank liner can lead to possible helium tank rupture. Corrective action was to test the tanks in accordance with proper ATP procedures. S/N 021, the tank found with the worst damage, will be subjected to additional pressure cycles. Additional testing for S/N 021 and S/N 022 will be required to determine if they can be used for flight units. The helium tanks on OV-104 were tested properly and are not suspect. *This risk factor was resolved for STS-34.*
17	Potential tire failure due to undetected delaminations after preroll. HR No. ORBI-021 ORBI-185 *No anomalies were reported on STS-34.*	Tires are inspected for possible delamination when new and after preroll per a new requirement. Tire preroll will be performed every 15 months. Previously-built tires have no Nondestructive Inspection (NDI) after preroll as do new tires. Preroll was determined to be benign relative to stressing the tires. Only 60,000-pound (lb) load at 5 knots is imposed on a tire during preroll. Vendor NDI of a test tire found no irregularities and no indication of delamination. These inspections included special, multiview tire x-rays. Destructive testing of an STS-34 tire will be performed after flight at the vendor. The tire will be sliced, and pull tests will be performed on the plies to test for adhesive capabilities. These tests have not yet been completed.

RESOLVED STS-34 SAFETY RISK FACTORS

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
17 (Continued)		Rationale for STS-34 included: • NDIs showed no delamination on the test tire. • No history of tire delaminations on any flight vehicles. ***This risk factor was resolved for STS-34.***
18	Pyrotechnic harnesses on OV-104 Orbiter/ET umbilical have previously flown. HR No. ORBI-289 ***No anomalies were attributed to failed pyrotechnics on STS-34.***	Four pyrotechnic harnesses used on the Orbiter/ET umbilical separation system have flown on a previous mission. Specifications call for a new harness to be installed after each flight. The harness cable assembly was refurbished to assembly specifications through the replacement of all previously damaged parts. The refurbished harnesses were fully tested to the original manufacturing requirements. No safety-of-flight deficiencies existed on these harnesses. ***This risk factor was resolved for STS-34.***
19	OMS fuel tank weld crack in communication screen. HR No. ORBI-054 ORBI-166 ***No OMS fuel system anomalies were reported on STS-34.***	Excessive leakage was observed from several weld cracks on 3 communication screen panels on an OMS fuel tank. This tank was returned to the White Sands Test Facility for failure analysis due to temperature rise experienced during probe replacement at KSC. The communication screen is part of the OMS propellant acquisition system that provides bubble-free propellants to the OMS engines. In addition to the communication screen, 2 other propellant acquisition system parts, the collector manifold and the galley assembly, remove bubbles from the propellant. These parts are downstream from the communication screen panels. Bubbles in the propellant result in reduced thrust, hard starts, and transient combustion instability. Hard

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
<u>ORBITER</u>		
19 (Continued)		starts and combustion instability can result in engine explosion leading to possible loss of crew and vehicle. The particular OMS fuel tank in question also had weld cracks in the communication panels in 1983. These cracks were found during tank acceptance testing. Cracks were due to lack of fusion in the weld. The cracks were repaired, and the tank was sent to KSC for installation in LP04 on OV-103. Only 5 communication panels were found with weld cracks: 3 on the LP04 tank, 1 on an oxidizer tank on LP04, and 1 that was scrapped. All tanks on OV-104/STS-34 passed the bubble-point test before delivery. This test induces bubbles into the tank to determine leakage through the propellant acquisition system. To date, flight data has shown no gas ingestion. The cracks found on the communication screen are 1/2 to 3/4" in length. Detailed fracture analysis by the vendor indicated that the cracks will not grow to greater than 3/4". Cracks of this size, or less, will not cause bulkhead structural failure and are insignificant if leakage occurs on-orbit. Rationale for STS-34 flight was based on: • All OV-104 OMS fuel tanks passed the ATP with no indication of cracks or repaired cracked welds on the communication screen panels. • Bubbles passing through weld cracks of 3/4" or less are not considered detrimental to OMS engine performance based on past experience. • Two additional means exist downstream of the communication screen panels for removing bubbles from the propellant. ***This risk factor was resolved for STS-34.***

RESOLVED STS-34 SAFETY RISK FACTORS

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
<u>SSME</u>		
1	Nozzle tube bulge on engine #2027. HR No. ME-B7A ME-B7C ME-B7M ME-B7S ***No anomalies related to nozzle tube bulges were reported on STS-34.***	A bulge was found during inspection of the nozzle tube on engine #2027 (STS-34 engine #1). Protrusion measurements indicated that the bulge was present for at least 2 flights. Protrusion Measurements made after STS-30 indicated that the bulge was not growing. Leak checks were performed on the engine which verified that there were no leaks. The bulges were the likely result of tube stacking during fabrication with no impact on operation or performance. Engine #2011 had similar nozzle tube bulges. Analysis concluded that, unlike engine #2027, the bulges were the result of pressure buildup between the jacket tubes as a result of a hydrogen leak. These bulges were found through leak checks. Certain tubes that had previously bulged finally cracked, providing a small leak path. Subsequent test firings found no degradation in engine performance due to the leaks and associated bulges. The rationale for STS-34 flight was: • Leak checks performed after STS-30, the last OV-104 flight with engine #2027, verified that there were no leaks. Special leak checks performed on engine #2027 confirmed the absence of leaks. The pressure applied during this special test was held for an extended period of time; no leakage was measured. • Feel checks on engines #2030 and #2029, the other 2 engines on OV-104, indicated no tube bulge anomalies. • Protrusion measurements showed dimensions present for at least 2 flights, with no change in protrusion noted; therefore, there was no concern that the bulge would grow during flight. ***This risk factor was resolved for STS-34.***

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
<u>SSME</u>		
2	Crack found on diffuser lip of High-Pressure Fuel Turbopump (HPFTP). HR No. ME-D1A (All Phases) *No HPFTP anomalies were reported on STS-34.*	A crack was found on the lip of the second stage diffuser on HPFTP #4009R1 during investigation of a speed decay anomaly. The lip controls the diffuser radial position. The speed decay anomaly was repeated in subsequent tests. Speed delay was noted at engine start, and decay was noted at cutoff. The 8.75" crack was found during disassembly. Heavy wear of the second-stage interstage seal was also noted. Seven instances of similar cracking were found during the life of the program. Typically, circumferential cracks are up to 7" long. 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. Measurement of HPFTP #4009R1 found that the housing operational and assembly pilot were within print. However, the diffuser operational pilot was found to be undersized for the full 360°, ranging from 0.0144" to 0.0188" undersize at 0.100" below the diffuser lip. The operational diametral interference was the largest documented to date; a maximum of 0.0303". Fabrication records indicated that the diffuser diameter was in accordance with the print. The rationale for STS-34 flight was: • HPFTPs on STS-34 demonstrated no speed decay or other anomalous operations. • Build records were reviewed for the STS-34 HPFTPs (#4008, #2323, and #6003), and all dimensions were found to be in accordance with print requirements. The diffuser on HPFTP #2323 was inspected after testing on prior flights, with no cracks found.

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
SSME		
2 (Continued)		• A pilot lip fragment would be contained if one became dislodged. • Prior flight experience with cracked diffusers resulted in benign conditions and no detrimental results. *This risk factor was resolved for STS-34.*
3	Main Combustion Chamber (MCC) bond line leak. HR No. ME-B5A ME-B5C ME-B5M ME-B5S *No MCC bond line leaks were reported on STS-34.*	Leak checks and borescope inspections after STS-29 found a class III leak in the aft bond line of MCC unit 4007, an engine which was hot fired at Stennis Space Center (SSC). Statistical analysis of hot-fire histories indicated that this was a random failure condition, classified as an infant mortality failure as opposed to structural fatigue. This finding was consistent with the structural analysis performed. There has been a demonstrated higher probability of defect initiating after the first hot fire, due to yielding of the Narloy-Z material during the hot fire. Subsequent hot firings are less severe on the bond line than the first one. Inspection of the fleet after STS-29 found no other debonds. The MCCs on the STS-34 engines have accumulated hot-fire time prior to ultrasonic inspections. The time for each is as follows: • Engine #2027 — 8 starts, totaling 2817 seconds • Engine #2030 — 4 starts, totaling 1342 seconds • Engine #2029 — 12 starts, totaling 3607 seconds The engines and MCCs on STS-34 successfully passed all leak checks. No fabrication discrepancies or proof test disbonds, indicative of marginal bonds, were recorded for the STS-34 engines. *This risk factor was resolved for STS-34.*

RESOLVED STS-34 SAFETY RISK FACTORS

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
SSME		
4	Main Engine (ME) #1 O-ring damage. HR No. ME-B3M ME-C3A ME-C3C ME-C3M ME-C3S ***No similar anomalies were reported on STS-34.***	Damage to the antiflood valve O-ring was discovered on OV-104 ME #1 during inspection at KSC. Material was found to be missing from the O-ring, the largest missing piece was 0.177" x 0.020" x 0.002". There was a concern that the Liquid Oxygen/Gaseous Oxygen (LOX/GOX) System in the engine was contaminated with this missing material. Additionally, there was a concern that system orifices could be blocked. The orifices of concern are downstream of the antiflood valve. Three locations which are smaller than the largest missing piece, if intact, are: Heat Exchanger Bypass Orifice 0.0813" GOX Flow Control Valve Orifice 0.077" GOX Check Valve 0.011" Ignition is possible in the heat exchanger coil at operating temperature and pressure if a particle sticks to the heat exchanger tube wall and if all heat is transferred to the tube wall. If the Bypass Orifice is restricted, high-temperature GOX would be delivered to the POGO accumulator and Orbiter tank pressurization system causing engine and vehicle hardware failure. This would result in uncontained engine damage and possible loss of the vehicle. At engine start, restriction of the GOX Flow Control Valve Orifice blockage could result in loss of the POGO accumulator, resulting in engine shutdown and mission scrub. During ME burn, blockage or restriction of this orifice would result in loss of POGO accumulator GOX flow and loss of POGO suppression capability, leading to loss of the vehicle. GOX Check Valve blockage has the same effect as the check valve not opening when commanded. At engine start, blockage of this valve would result in loss of POGO suppression capability, leading to engine shutdown and mission scrub. During ME burn, this function is not used. Blowdown of the GOX system was performed several times in an attempt to collect the total volume of missing O-ring material, with little success. Borescope inspection of the GOX System was performed; no debris was found.

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
<u>SSME</u>		
4 (Continued)		It was determined that the material used in this O-ring, Buna-N, is not LOX compatible. However, the amount of material was small and was considered very unlikely to be capable of causing a sustainable fire. ***This risk factor was acceptable for STS-34.***
5	Severity 2 software problem fix not implemented for STS-34. HR No. INTG-165 ***No SSME software anomalies were reported on STS-34.***	A severity 2 software problem was identified in the SSME Controller software. An Unsatisfactory Condition Report (UCR) was written to document a coding error in the SSME Controller software in the sample-and-hold circuit monitoring subroutine. The function of this subroutine is to determine if sample-and-hold feedback signals are within tolerance (within 2% of full-scale value of the sample-and-hold digital command). If not, a retest is performed. Retest capability allows for differentiation between channel noise and actual hardware failures. The nature of the coding error was such that retest was not performed. Instead, the first failure was reread, resulting in disqualification of all channel A actuators. The potential impact of this error was that good Channel A actuators would be disqualified if the first failure indication was a soft failure due to noise. The software response to this failure would be a launch scrub or abort before liftoff, and loss of actuator redundancy after liftoff. It was the position of Safety, Reliability, Maintainability, and Quality Assurance (SRM&QA) that all severity 2 software problems should be fixed prior to flight, if possible. A software fix for this problem was developed and successfully completed verification at the Hardware Simulation Laboratory. The SSME Project policy is that all software changes for the Main Engine Controller (MEC) be demonstrated in a hot-fire test. This software fix was not subjected to a hot-fire test. The SRM&QA community did not feel that subjecting the change to a hot-fire test would positively verify this change, because it was not in a failure path that would be exercised during an engine test. The software fix was already been

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
SSME		
5 (Continued)		incorporated into the mass memory in a spare load block; therefore, it was available for use on STS-34. The Project elected not to implement this software change prior to STS-34. Flying with the old software was acceptable for STS-34 based on the low probability of occurrence of this failure mode. No failure modes of this nature have been experienced to date. New software should be implemented for future flights. ***This risk factor was acceptable for STS-34.***
6	Engine #2029 high-pressure fuel duct alignment. HR No. ME-D3 (All Phases) ***No anomalies were reported relative to the misalignment high-pressure fuel duct on STS-34.***	During engine processing for STS-34, it was necessary to remove the HPFTPs on all 3 engines. This action was required to perform an inspection of fuel-side liner hot-gas manifold weld joints. When a high-pressure pump is removed and reinstalled, realignment of the high-pressure duct is required to prevent excessive preloading of the duct joint flanges. Measurements are required to verify that alignment criteria have been met before the joints are torqued and stretched. A nomograph is used to measure the stresses induced into the titanium to assure that they are not above specification. The nomograph is also used to measure the gap at the joint to ensure that it is adequate to apply pressure to the seal. An error was uncovered in the alignment measurements on engine #2029, STS-34 ME #3, during review of build paper. Misalignment existed at the F4 joint with the following characteristics: 0.133" gap, 0.081" offset, and an angle of 0.21°. It was determined that the wrong nomograph was used for measurements taken on engine #2029. Rocketdyne/Canoga Park evaluated the amount of misalignment and determined that the resulting preload was acceptable for flight. Engine #2030 (also on OV-104) flew with a similar condition on a previous mission. This misalignment was not present on engine #2030. Analysis determined that the structural FOS for

RESOLVED STS-34 SAFETY RISK FACTORS

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
<u>SSME</u>		
6 (Continued)		this joint on engine #2029 was greater than 2.0. The factor of protection against leakage at the seal was 1.11. A Material Review Board was held on October 6, 1989 to review the measurement discrepancy. Based on the resulting FOS, determination was made to fly STS-34 engine #2029 as is. ***This risk factor was resolved for STS-34.***
7	Lack of penetration noted in High-Pressure Oxidizer Turbopump (HPOTP) weld joint 4. ***No SSME HPOTP anomalies were reported on STS-34.***	During borescope inspection of HPOTP #2305 for contamination, weld joint 4 (inner bellows to turbine inlet faring) was noted to have a lack of penetration intermittently 360° around the joint. This weld is a class II weld; it was determined to be not critical per the Failure Modes and Effects Analysis/Critical Items List (FMEA/CIL) analysis because of the low-pressure environment in the area of the weld ($\leq$ 100 psi). The HPOTP turbine housing was built in 1984; borescope equipment used at that time did not have the capability for 100% inspection of concealed weld joints. Recent inspection of 6 additional HPOTPs found similar weld discrepancies. This is a generic problem. Inspection of the HPOTP fleet leader, with 25095 seconds of operating time and 55 starts, revealed similar weld discrepancies with no failure or leakage. A review of the weld assessment found that weld joint 4 is primarily compressively loaded. Weld joint 4 anomalies have not been reported. This information was presented to a Material Review Board on October 10, 1989, which dispositioned that the weld joint 4 should fly as is.

RESOLVED STS-34 SAFETY RISK FACTORS

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
<u>SSME</u>		
7 (Continued)		Rationale for STS-34 flight was based on: • A worst-case leak of the weld would not be catastrophic; the result is an internal HTOTP temperature rise of 15°F. • Non-criticality of the weld. • Satisfactory performance of fleet leaders with similar flaws. ***This risk factor was resolved for STS-34.***
8	HPOTP cupwasher rotation. ***No HPOTP anomalies were reported on STS-34.***	During disassembly of HPOTP #2222R-1 from STS-29, 3 of 11 cupwashers were found to have rotated (loose). Disassembly of HPOTP #4501R-1, also from STS-29, found 2 of 11 cupwashers experienced a similar occurrence. Investigation indicated no cup cracking. This was the first time that detent have been overridden without cracking. There have been no problems of this kind since 1986. Cup cracking problems involve material and material hardness deficiencies, but the material used in these cupwashers meets requirements. Also, the staking processing was reviewed and found satisfactory. Rotation was never seen on Left-Hand (LH) threaded cup-seal applications, only on the RH threaded applications. This indicated the possibility of a force generating enough torque to back-out the cupwasher.

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
<u>SSME</u>		
8 (Continued)		Rationale for STS-34 flight included: • Screw preload is not functionally required to carry loads. The delta pressure load is in the direction of seating the retainer/silver seal against the RH vane (screws do not carry the loads). • Maximum cupwasher rotation experienced to date was 75°, resulting in a margin of 4 for 1 full rotation. A minimum of 2 rotations is required to disengage the locking feature. • No evidence of cracking was seen on a rotated cupwasher. • No evidence of heating or ignition in the fretted areas. ***This risk factor was acceptable for STS-34.***
9	Engine #2 Controller anomaly. HR NO. INTG-165 ***No further SSME Controller anomalies were reported on STS-34.***	The MEC (Unit Number (U/N) F-19) on OV-104 engine #2 failed 2 of 64 Low-Pressure Fuel Pump (LPFP) discharge pressure 80% R-Cal checks during T–27 hr sensor checkout for STS-34. During Direct Memory Access (DMA) data load, the Channel (CH)-B DMA failed to load data at least twice. Both Digital Computer Units (DCUs) verify memory parity error circuitry each major cycle. If DCU-A attempts a DMA write request to DCU-B memory during the parity checker test, DMA write is blocked, and the memory location retains the previous data. The parity checker blocks DMA write 6 out of 20,000 microseconds (major cycle). DMA write requests (1-microsecond each) occur 58 times per major cycle. The problem is limited to data input into the standby DCU only; it can occur in all phases of operation.

RESOLVED STS-34 SAFETY RISK FACTORS

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
SSME		
9 (Continued)		The concern was that DCU-B data was not updated when DCU-B takeover occurred. The data includes sensor calibration data, Oxidizer Preburner Oxidizer Valve (OPOV) command limit setting at +5.5 seconds, and HPFTP discharge temperature drift monitor mainstage lower limit. Sensor calibration is satisfactory if there are no Failure Identifications (FIDs) in the DCU-B buffer; OPOV command limit too low would result in engine shutdown upon DCU-B takeover; HPFTP drift monitor too low could delay failed sensor disqualification after DCU-B takeover. Failure investigation was performed at Honeywell. The problem was assessed to be produced either by intermittent DMA address failure or by asynchronous DCU software timing interference. No controller hardware problem has occurred to date. Asynchronous DCU software timing was the most probable cause. DCU-B parity check interference was demonstrated; DMA write was blocked 6 out of 20,000 microseconds. F-19 failure occurred after 21,000 checks. The potential software fix affects standby DCU only -- in sensor checkout, deactivate parity checker; in all other operating modes, deactivate parity checker in alternate major cycles. This assures data read into the standby DCU is never more than 20-microseconds old. The near-term recommendation was to make no changes and to continue verification sensor checkout in DCU-B and rerun the check until satisfactory if necessary. The long-term solution is to modify the software and verify no adverse results from the fix (target is for STS-35).

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
SSME		
9 (Continued)		Rationale for STS-34 flight was: • Problem was isolated to the Controller. – CH-B DMA addressing hardware. – Asynchronous DCU software timing related. • T–27 hour checks validate the Controller. – All hardware functions verified. – Sensor calibration correct. • Low probability of operation with incorrect DCU-B OPOV limit or HPFTP drift monitor. – Controller demonstrated Mean-Time-Between Failure (MTBF) = 6055 flights per failure. – Channel switchover would be required. This has never happened in the history of the flight program. – F-19 DMA failure was the only one of its type in 41,438 hours. ***This risk factor was resolved for STS-34.***

RESOLVED STS-34 SAFETY RISK FACTORS

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
<u>SSME</u>		
10	Engine #0213 MCC liner cavity diaphragm ruptured at higher than design pressure. HR No. ME-B5 (All Phases) ***No burst diaphragm anomalies were reported on STS-34.***	During test 904-052 at SSC, engine #0213 shut down prematurely at T+5.6 seconds. Shutdown was due to MCC liner cavity pressure exceeding 165 pounds per square inch gage (psig); the maximum redline pressure established for this test. Nominal redline pressure for flight is 135 psig. MCC liner cavity pressure is normally about 20 to 25 psig during acceptance tests of engines that are not leakers. Engine #0213 MCC is a known leaker, causing the burst diaphragm to rupture on 4 previous tests between 120 and 135 psig. All diaphragm geometric and material characteristics were found to be nominal, except for the thickness of Room Temperature Vulcanizate (RTV) compound applied over the diaphragm. The redline was set at 165 psig for this test to ensure that no subsequent structural chamber damage would occur. The burst diaphragm ruptured at approximately 195 psig that was a cause for concern. Investigation was initiated to determine why this burst diaphragm did not rupture until 195 psig. Indications were that this diaphragm gave way gradually instead of bursting, allowing pressure to continue to build. During a subsequent hot-fire test, the burst diaphragm ruptured at 165 psid. Hot-fire test data showed uniform pressure within the liner cavity and ambient temperature downstream of the diaphragm. Laboratory tests confirmed that rupture pressure is influenced by RTV thickness and cryogenic pressurization gas. Rupture pressure experience from 7 hot-fire samples with an MCC liner leak demonstrated the following FOS levels:

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

SSME

10 (Continued)

Liner Cavity Pressure		Factor of Safety		
Basis	Pressure psia	Mainstage 104%	Mainstage 65%	Cutoff
Max	195	2.1	1.8	1.4
90/95	213	1.9	1.6	1.2
99/95	255	1.6	1.4	1.06

Rationale for STS-34 flight was:

- Engines #2027, #2029, and #2030 have no indications of MCC leakage; engine #0213 was a known leaker. Green runs of these engines were successfully performed prior to shipment, with no premature shutdowns or MCC leakage noted.
- The cavity has a pressure containment capacity of 300 psi, considerably above even the delay rupture of the anomalous burst diaphragm. Worst-case liner cavity pressure will not buckle the MCC liner:
  - FOS is 1.8 at mainstage, 1.4 at cutoff with maximum measured pressure.
  - FOS is 1.4 at mainstage and greater than 1.0 at cutoff with 99/95 pressure based on 7 hot-fire tests of known leakers.

This risk factor was resolved for STS-34.

RESOLVED STS-34 SAFETY RISK FACTORS

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
<u>ET</u>		
1	External Tank LO_2 tank buckle/dimple (oil can). HR No. S.03 *No ET anomalies were reported on STS-34.*	During LO_2 tank-to-intertank assembly, a section of the LO_2 tank was witnessed to be buckled and/or dimpled. All welds in the affected area (4' x 3' x 1") were checked, and all weld x-rays were reviewed. It was determined that the welds were in good condition. In addition, an investigation was performed on the structural integrity of the LO_2 tank barrel section welds in the affected area. A model was used to determine and analyze all induced surface loads. Analysis results indicated that the load margin would be decreased by 2%; this still satisfies the FOS requirement. More recent failure analysis of the tank material indicated that it actually performed 6 to 8% better than the predicted FOS. MSFC reviewed the analysis results and was satisfied that the LO_2 tank exceeded the required FOS and was, therefore, safe to fly. ***This risk factor was resolved for STS-34.***
2	Probability exists for the ET debris to impact land masses. HR No. P.09 *No ET anomalies were reported on STS-34.*	An ET breakup analysis was performed to predict the ET rupture altitude for STS-34 using a generic Thermal Protection System (TPS) configuration. This would normally be acceptable. However, ET-27 had a significant amount of repairs to the TPS. ET-27 was slated for use at the Vandenburg Shuttle Launch Site and was modified for Development Test Instrumentation installation. Holes remaining after instrumentation removal were filled and covered with TPS. Because of these repairs, the breakup model required corrections; breakup analysis was performed again. The modified model predicted that ET-33 would rupture 15,600 feet (ft) higher than the generic model. This resulted in a larger footprint, extending approximately 200 miles into the land mass of Mexico. Due to the potential for impacting a land mass, the decision was made to recommend reactivation of the tumble valve system for ET-27/STS-34.

RESOLVED STS-34 SAFETY RISK FACTORS

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
<u>ET</u>		
2 (Continued)		When this recommendation was brought to the PRCB, the chairman directed that Martin Marietta perform 25 additional trajectory simulations to establish a more representative rupture altitude. Based on these simulations, a revised rupture altitude of 296,500 ft was predicted (11,200 ft higher than nominal). The resulting footprint was recalculated and was predicted not to endanger any land mass. The final footprint prediction was accepted by the PRCB and Range Safety. Based on acceptance of the final footprint prediction, the tumble valve system was not reconnected. ***This risk factor was resolved for STS-34.***
3	Large divot occurred in ET intertank acreage TPS. HR No. INTG-008 INTG-037B INTG-081A ***No ET anomalies were reported on STS-34.***	When reviewing inflight photographs of ET after separation, the STS-28 Debris Assessment Team discovered that a large divot occurred in the ET intertank acreage TPS just above the RH bipod ramp. This divot was considered to be unusual and had not been seen previously. It was conjectured that the debris from this divot may have caused two impacts on the Orbiter. The divot size was estimated to be approximately 23" x 15". Photographic enhancement showed that the divot was shallow, less than 1", indicating that this was a cohesive failure. Review of ET processing paper showed no anomalies in this area. Shallow, cohesive failures should not provide sufficient mass and velocity to cause impacts on the Orbiter TPS of sufficient energy to be a safety-of-flight problem. Attention will be paid to postflight review of ET post-separation photographs for possible recurrence. ***This risk factor was acceptable for STS-34.***

RESOLVED STS-34 SAFETY RISK FACTORS

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
<u>SRB</u>		
1	Potential criticality 1 failure mode related to Solid Rocket Beacon Tracking System (SRBTS). HR No. SRBTS-01 ***There were no anomalies or debris attributed to the SRBTS.***	Hazard analysis identified a potential criticality 1 failure mode related to the SRBTS antenna based on the following event sequence: • Material deficiency in the quartz-to-baseplate epoxy bond or deficient workmanship that results in bond failure. • The quartz becomes disengaged from the baseplate and is a debris source. In either case, the resultant debris has a high probability of impacting the Orbiter. The epoxy used (Tra-Duct 2902) is a conductive silver epoxy that contributes to antenna operation. The antenna ground plane is provided through the epoxy conductive path from the antenna baseplate to the quartz. According to the vendor (Vega), a small debond area would result in inability to properly process signals. The antenna used in the SRBTS was qualified by White Sands Missile Range to meet or exceed the severity of Solid Rocket Booster (SRB) flight environments. During qualification and production, SRBTS processing, inspections, controls, and tests remained the same. To date, no discrepancies were noted relative to debonds or quartz disengagement. The SRBTS on STS-34 passed Voltage Standing Wave Ratio (VSWR) tests without signal degradation. Additionally, the SRB Project performed a test on the bond and found that the quartz would yield (rupture) before the epoxy bond. There is no history of bond failure on any qualification or production units. ***This risk factor was acceptable for STS-34.***

RESOLVED STS-34 SAFETY RISK FACTORS

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
<u>SRB</u>		
2	Cracks found in an APU containment housing. HR No. A-20-16 Rev. C ***No SRB/APU anomalies were reported on STS-34.***	During disassembly at Sundstrand of APU, S/N 163, a crack was noted in the notch machined into the APU housing for a seawater vent. The crack was in the same location as the crack found on another APU, S/N 165, prior to STS-27. Both S/N 163 and S/N 165 were manufactured by Gentz. While APU S/N 163 had never flown, it had 8 hot starts. Failure of the APU containment housing subsequent to a catastrophic failure of the APU (coming apart and/or hot-gas impingement) could result in the loss of the Orbiter and crew. Investigation of APU S/N 163 found that the crack is 1.25" long, running radially through the containment wall; nearly the identical signature of the crack found in APU S/N 165. Helium leak decay checks were performed on S/N 163. A decay of 6.5 psi/10 minutes was recorded, greater than the specification limit of 1.5 psi/10 minutes. Examination of the fuel pump housing showed no visible signs of hot-gas impingement. The APUs on STS-34 are not from the same lot or vendor as those found with cracked housings (S/Ns 163 and 165). There was a difference in the way APUs were manufactured by the two vendors, Gentz and D'Velco. This difference was in interpretation of the requirement for a seawater vent. Gentz notched the seawater vent into the cast material; D'Velco did not. Analysis demonstrated the derived stresses equal or exceeded material capability in the notched housing, thus leading to a propensity to crack. Metallurgical results supported the stress analysis failure mode that induces an overload condition in a notched housing at the seawater vent. ***This risk factor was resolved for STS-34.***

RESOLVED STS-34 SAFETY RISK FACTORS

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
<u>SRB</u>		
3	Possible use of improperly certified flight hardware by United Space Booster, Inc. (USBI). ***No anomalies were reported which could be attributed to improper hardware on STS-34.***	A report alleged that Machine Craft, a subcontractor of USBI and Martin Marietta, supplied improperly certified flight hardware. The report alleged that raw stock plate aluminum was improperly certified through repeated use of the same certification sheet. Additionally, the supplier used uncertified shops to manufacture piece parts (gussets and clips) for the aft skirt. Other instances of improper inspection, loose or lack of control, and improper certification and operation were also cited in the allegation. SRB and ET flight hardware manufactured by the subcontractor in question includes: tunnel covers, gussets for the aft skirts, bump recorder enclosures, two metal pendant components, actuator studs and washers, bolt catchers, forward skirt heater feedthroughs, Thrust Vector Control (TVC) brackets and clamps, thermal curtain attachment segments, spider brackets, altitude sensor hardware, aft booster separation motor supports, strut covers and fairings, miscellaneous structural brackets, range safety system crossover components, ET ball fittings, exposed debris hardware, ET attachment ring splice plates, antenna mounting assemblies, and parachute deck fittings. Additionally, this subcontractor repaired the S/N 18 aft skirt. A joint investigation by the SRB and ET Project Offices, the Inspector General, Martin Marietta, and USBI was performed. Martin Marietta performed material sample tests on all groups of parts that it procured from Machine Craft, with no out-of-specification anomalies identified. An audit team reviewed records and build papers at the subcontractor and USBI for alleged discrepancies. Test and audit results found no evidence to substantiate the allegation. ***This risk factor was resolved for STS-34.***

RESOLVED STS-34 SAFETY RISK FACTORS

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
SRB		
4	SRB heater cable failed the Dielectric Withstanding Voltage (DWV) test. HR No. B-50-27 Rev. C. FC-01 ***No SRB heater anomalies were reported on STS-34.***	The SRB RH center joint primary heater cable failed the DWV test at 100 volts. The OMRSD DWV requirement is 1500 volts. Similar occurrences were experienced on other missions. The failed heater circuit was disabled at the controller circuit breaker on the Mobile Launch Platform (MLP) to prevent accidental powering of the heater through the launch processing system. A failed heater on a previous flight was inadvertently turned on, with no detrimental effects. In addition to disabling the heater, the Launch Commit Criteria (LCC) was changed, reducing the minimum redline field joint temperature from 85°F to 68°F. Acceptability of the minimum redline temperature was based on the measured amount of interference fit at this joint. This provided a +3°F differential from the minimum acceptable O-ring seal temperature of 65°F. ***This risk factor was resolved for STS-34.***
5	Aft skirt FOS waiver. HR No. A-60-17 Rev. C FC-02 INTG-158B ***There was a hangup and broaching of holddown post #2.***	A waiver was submitted to the aft skirt FOS requirement. Questions were raised relative to the process used to determine the FOS for STS-34. A decision was made at Level II to process the STS-34 aft skirt FOS waiver based on the MSFC methodology. This methodology utilized the STA-3 test data and resulted in a predicted aft skirt FOS greater than 1.28 for STS-34. Initial concern was raised relative to the aft skirt FOS during the return-to-flight process. A waiver was approved for STS-26, because it was determined that the aft skirt would not meet the program FOS requirement of 1.4. There were significant differences between STS-34 and STS-26. First, the MLP spherical bearings were biased radially inward, a favorable direction, by 0.030". This eliminated detrimental effects of radial/tangential mismatch. Therefore, loads calculated for zero mismatch are applicable in the calculation of the STS-34 FOS. Second, a

RESOLVED STS-34 SAFETY RISK FACTORS

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
<u>SRB</u>		
5 (Continued)		comparison of load indicator values between STA-3 test results and STS-34 load indicator values resulted in a calculated FOS greater than 1.28. Calibration of the finite element model to 128% of STA-3 loads, and use of Level II provided STS-34 loads, resulted in a predicted STS-34 aft skirt FOS of 1.31. The aft skirt FOS waiver was approved for STS-34. ***This risk factor was acceptable for STS-34.***

RESOLVED STS-34 SAFETY RISK FACTORS

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
SRM		
1	Defective Hypalon paint used on STS-34 SRM aft skirt. HR No. FC-02 INTG-158B *No further problems were reported on STS-34.*	Defective Hypalon paint was applied to K5NA on the RH aft skirt. Vendor processing error introduced incorrect ingredients (Naptha, Xylene, N-Propanol) into the paint. Testing, inspection, and analysis were performed which indicated that the affected K5NA demonstrated acceptable material properties. ***This risk factor was resolved for STS-34.***
2	Fretting on STS-34 segments. HR No. BC-02 Rev. B ***No anomalies were reported on STS-34 that have been attributed to joint fretting.***	Two case segments used on STS-34 became fretted in the aft dome-to-stiffener joint when used during QM-07 static test firing. Fretting is caused by cold welding at local metal-to-metal contact surfaces that are subjected to vibration and slip in the absence of adequate lubrication. This condition is accompanied by microstructure changes and mechanical wear. There were 2 instances of fretting on the aft dome inner clevis leg (the area between the O-ring grooves), located at 314° and 330°, with the largest fret size being 0.10" wide by 0.010" deep. Additionally, there was 1 fret on the tang surface of the stiffener segment, located at 314°, with an estimated fret size of 0.10" wide by 0.010" deep. These instances of fretting were a concern for STS-34 relative to the adequacy of sealing capability and structural integrity. The fretted stiffener segment was located in the forward stiffener segment on STS-34 and was not mated to the aft dome. Additionally, all fretted joints on STS-34 were factory joints. Factory joints are protected by internal insulation that is the primary seal. Analysis of the fretted joints on STS-34 indicated that structural integrity and sealing capability were adequate. ***This risk factor was resolved for STS-34.***

RESOLVED STS-34 SAFETY RISK FACTORS

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
<u>SRM</u>		
3	Putty found on outer igniter gasket on STS-33 RH Solid Rocket Motor (SRM). HR No. BC-02 Rev. B BC-03 Rev B ***During STS-34 postflight inspection, putty was found up to the aft face of the outer primary gasket and into the seal void/gland area, between 234° and 5° of the right SRM igniter. This indicated that vertical igniter installation does not resolve the igniter putty problem. The putty did not go past the primary seal, and no blowholes were found. This problem was subsequently traced to an excessive amount of putty used on the RH SRM igniter. (See Section 7, SRM 3, IFA No. STS-34-M-03.)***	Putty was found on the aft face of the outer igniter gasket when the igniter was removed from the STS-33 RH SRM. All SRMs igniter gaskets were inspected and replaced based on the depression found in an igniter gasket on STS-28. Putty had extruded to that location during igniter installation. Sealing capability of the gasket could be impaired by creating an overfill situation. Seal contamination could also result. Normal igniter installation is performed with the SRM in a horizontal position, supported by a crane. Putty is laid up in accordance with the installation specification. The igniter is guided by teflon guide plates during the initial stages, engaging the guide pins 7" prior to full seating. Igniter putty engages putty installed on the dome side of the interface, and the igniter is seated against the dome. The putty is not supposed to extrude above the igniter-dome interface to the inner gasket; however, it apparently did in the case of the STS-33 igniter. The primary causes of putty movement during igniter installation are either that the igniter was backed out during installation or that rocking motion was introduced when the igniter was suspended from the crane. Gravity could also have caused putty to move beyond its intended position. Because igniter gaskets on STS-34 were changed out on the pad, the igniters were installed in a vertical position. Gravitational effects in the vertical position cause the igniter to seat uniformly and help maintain the putty in its intended position. Putty would have to travel upwards along the igniter-dome interface to reach the gasket surface. Reinstallation of STS-34 igniters in the vertical position, coupled with visual inspection of the joint area until igniter seating (with no putty witnessed), provided rationale for flight. ***This risk factor was resolved for STS-34.***

RESOLVED STS-34 SAFETY RISK FACTORS

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
<u>SRM</u>		
4	SRM lightweight stiffener segment FOS. HR No. FC-02 *No stiffener segment anomalies were reported on STS-34.*	Analysis indicated that the FOS for the SRM lightweight stiffener was below the 1.4 requirement. An FOS of 1.33 was calculated for the prelaunch buckling condition. The analysis assumed a nominal segment wall thickness with minimum material properties, zero payload weight, maximum SSME thrust, and maximum wind loading conditions. The actual STS-34 lightweight stiffener segment was measured. This measurement found that the wall thickness to be above nominal, resulting in a calculated FOS of 1.42. ***This risk factor was resolved for STS-34.***
5	Insulation voids on forward dome. HR No. BC-10 Rev. B ***No anomalies were reported on STS-34.***	Insulation at station 215, approximately 50" forward of the factory joint on the STS-31 LH forward segment, was found to have a below-specification design factor: 1.43 instead of 1.50. The design factor is a margin above the case temperature of 200°F. In the insulation multi-ply layup, variations in ply thickness can result in an out-of-tolerance condition after cure. The dome was x-rayed to determine if any anomalies existed. Six voids were found by this x-ray technique. The segment was washed out, and the dome area was dissected to evaluate the voids. Additional voids at the insulation-to-case interface, not detected by x-ray, were found during visual inspection. The voids were all in the thickest area of the insulation. All voids were considered acceptable based on the insulation thickness in that area. Insulation thickness was greater than the thickness required to meet thermal/erosion criteria. Voids in the forward dome were most probably due to forces experienced during autoclave cure and flow of the rubber. Voids are repeatable and will occur only in the thick boot area. It was found that the manufacturing process was changed prior to preparation of STS-7 SRMs. It was very likely that voids were present in this forward dome area since that process change. The manufacturing process, however,

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
<u>SRM</u>		
5 (Continued)		assures that insulation thickness exceeds the minimum drawing requirement by 0.3 to 0.4". Based on past experience, there were insulation voids in the STS-34 forward dome. However, the occurrence of these voids was determined not to reduce the design safety factor below the required value of 1.43. *This risk factor was acceptable for STS-34.*
6	Forward dome thin insulation FOS. HR No. BC-10 Rev. B ***There was blistering of the Carbon Fiber-Filled (CFF) Ethylene Propylene Diene Monomer (EPDM) (STS-34-M-05; however, there was no erosion through to the Nitrite Butadiene Rubber (NBR) insulation.***	During investigation of the insulation voids in the forward dome of the STS-31 LH SRM, existence of thin-insulation areas was identified. Thin-insulation areas are induced by the forward dome insulation process. Layers of calendered asbestos-filled NBR are layed-up against the forward dome surface. Thickness is controlled by the number and shape of the NBR pieces used; minimum layup thickness is 0.530". The contour (radius) regions are formed by extruded strips of NBR. Patterning cloth is installed on the insulation surface to form a textured surface that enhances liner bonding. Bleeder cloth is installed to ensure a vacuum is drawn over the entire insulation surface. The entire internal segment is vacuum bagged with a one-piece bag, and vacuum is then applied. The insulation is autoclave cured at 100 psi and 290°F (7 hours of cure time and 4 hours cooldown). Tooling and fabrication were modified beginning with the STS-8 SRM flight set and have not changed. The 57 motors processed using this method were either flown or used in static tests. The thinned insulation in the forward dome was determined to be derived from tooling problems. Two causes were identified which lead to thin insulation. First, excess rubber in the igniter boss region was forced outboard by the floating mold ring. Second, the pressure transfer ring bridged and created higher-pressure pinch points towards the edges of the ring and a resulting lower-pressure zone toward the

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
<u>SRM</u>		
6 (Continued)		center of the ring. In addition to creating folds, voids, and bulges, this condition created thin-insulation areas outboard of the transition region. The problems induced by the insulation process are generic. Six SRM forward domes were examined; all have similar voids, folds, bulges, and areas of thin insulation. The forward dome insulation was designed to meet two conditions, whichever is greater: • Median + 3σ erosion times a 1.5 design margin factor. • Median + 3σ erosion plus thermal protection thickness to maintain the case/insulation bond line at less than 200°F. The forward dome insulation is exposed to motor chamber gasses for 100 seconds. Assuming specification insulation thickness at motor start and nominal erosion, 0.335" of insulation would remain after motor burn (by design). Insulation thickness of 0.335" provides 190 seconds of additional exposure time beyond the 100-second exposure to motor chamber gasses. Assuming increased erosion of median + 3σ, 0.186" of insulation would remain after motor burn (by design). At 0.186" of insulation, the dome could withstand an additional 58 seconds of exposure time. The STS-28 RH motor had 0.323" of insulation remaining in the thinned area of the dome after motor burn. The motor could have withstood an additional 81 seconds of exposure time, an insulation erosion safety factor of 1.81, and a case structural safety factor of 4.20. Local intermittent thin spots are formed around the circumference in a band approximately 5 to 6" from the igniter boss opening. These are caused by the higher pressure toward the outer edge of the pressure transfer ring. On the STS-31 RH forward segment, the minimum local condition found was 0.396" versus 0.503" required by the design drawing. With 0.503" of insulation, the nominal insulation

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
<u>SRM</u> 6 (Continued)		erosion safety factor is 1.59, and the case structural safety factor is 4.20. Based on the worst-case thinning of 0.396" found on the 6 segments examined, the median + 3σ insulation erosion safety factor was calculated to be 1.29, with a case structural safety factor of 4.15. This lower insulation erosion safety factor results in a case/insulation interface temperature of 157°F, 37°F above the 120°F ambient. Analysis also determined the effect of a thin-insulation condition worse than the worst case seen to date (0.396"). Results of this analysis found that an insulation thickness of 0.350" would result in a case/insulation interface temperature of 200°F, the design limit, by the end of motor burn. The resulting insulation erosion safety factor is 1.20, an additional 19 seconds of exposure time, and a case structural safety factor of 4.10. Thiokol Corporation claimed that the case structural integrity was maintained at temperatures up to 1050°F. Their analysis indicated a case/insulation interface temperature of 600°F at the end of motor burn even if the initial insulation thickness is 0.265". This results in an insulation erosion safety factor of 1.00, no additional exposure time, and a case structural safety factor of 4.10. Information pertaining to the risk associated with thinned insulation, described above, was presented to NSTS Program Management and was accepted. Safety now understands the meaning of various "safety factors" and concurs that appropriate safety margin exists. ***This risk factor was resolved for STS-34.***

RESOLVED STS-34 SAFETY RISK FACTORS

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
KSC		
1	Inadvertent actuation of console keys could lead to critical conditions. *No anomalies were reported on STS-34.*	During the STS-28 launch sequence, the Liquid Hydrogen (LH_2) console operator decided to close the LH_2 chilldown valve during system safing. The operator inadvertently hit the stop key with his notebook. A second procedural error occurred when he neglected to announce the closing of the chilldown valve over the communications network. Although there were no deleterious effects on the LH_2 loading process, these 2 occurrences highlight the problems with operator-induced errors during launch. An investigation was initiated to determine possible results of inadvertent pressing of console buttons and keys. Until a more permanent fix is implemented, operators are being given additional awareness training. ***This risk factor was acceptable for STS-34 countdown.***

RESOLVED STS-34 SAFETY RISK FACTORS

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
<u>PAYLOAD</u>		
1	Inertial Upper Stage (IUS) Aft Frame Tilt Actuator (AFTA) overspeed failure mode. HR No. ICHR-018 ***No anomalies were reported on STS-34.***	The IUS Failure Modes and Effects Analysis identified single-failure points which could result in an AFTA runaway. The 2 single-point failures identified were: • Low tachometer feedback from the AFTA to the AFTA controller. • Controller transistor or operational amplifier failure. Mechanical stops were added as an interim fix for STS-26, STS-29, and STS-30. The long-term fix, which was a redesign of the Power Control Unit to provide adequate redundancy, was in place for STS-34 and all subsequent IUS flights. ***This risk factor was resolved for STS-34.***
2	IUS Explosive Train Assembly (ETA) B-nut concern. ***No anomalies were reported on STS-34.***	Annual lot recertification firing test of IUS/SRM Shielded Mild Detonating Cord (SMDC) and Through-Bulkhead Initiator (TBI) resulted in stripped threads of the B-nut connecting the SMDC to the TBI. Although performance was not affected, a concern was raised over possible impact with the second-stage exit nozzle or other surrounding hardware. Unlike the test article, flight hardware is lockwired and covered with Multilayer Insulation (MLI). Tests of B-nuts with 1.5 threads removed demonstrated that the MLI did not satisfactorily retain the SMDC/B-nut assembly; but the addition of a Kevlar restraint proved successful. A Kevlar shield (diaper) was installed over the IUS/SRM-1 dome motor to contain the SMDC/B-nut assembly. ***This risk factor was resolved for STS-34.***

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
PAYLOAD		
3	IUS TBI leakage. *No anomalies were reported on STS-34.*	During routine annual lot recertification testing, 1 of 4 TBIs failed a helium leak test that verifies integrity of the environmental seal that protects the charge from moisture. Additional testing of the units on hand revealed that approximately 10% did not meet the leak test criteria. Analysis indicated that the most likely leak path was not into the charge, but behind the swaged washer arrangement used to retain the seal. Additionally, examination of test data showed that TBI propellant is not moisture sensitive, and a large historical performance database over several programs demonstrated the reliability of TBIs without concern for moisture. *This risk factor was resolved for STS-34.*
4	IUS Converter Regulator Unit (CRU) transistor short. HR No. ICHR-003 *No anomalies were reported on STS-34.*	During electrical test following a modification to the CRU sense wire and counter, transistor Q403 was found to have a base-to-emitter short. The cause of failure was determined to be a small crack in the oxide beneath the metalization. Over time, metal migrated across the crack to form the short-circuit path. The rationale for flight was that the transistor failure was believed to be random in nature; there was no indication of a generic condition. There is a redundant transistor in this circuit. If both transistors fail, batteries would power the IUS. There would be no mission impact from this 2-transistor failure. *This risk factor was resolved for STS-34.*

RESOLVED STS-34 SAFETY RISK FACTORS

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
PAYLOAD		
5	Radioisotope Thermoelectric Generator (RTG) cooling line blockage. HR No. ORBI-275A ICHR-012 *No anomalies were reported on STS-34.*	A low flow rate of 0.48 gallon per minute (gpm) was experienced during RTG cooling system flow testing on the spacecraft side of the RTG cooling loop. The low flow rate was determined to be caused by blockage. Blockage was isolated to the line leading from the drain QD. The line section was blown through with Gaseous Nitrogen (GN_2), resulting in blowing a foam plug from the line. The plug may have been left in the line after a dynatube polishing operation. The type of plug in question is used to protect the line from metal shaving contamination. After the blockage was removed, the flow rate increased to 1.58 gpm. Flow testing and coolant checks performed after RTG installation on October 7, 1989, found an additional piece of foam in the coolant line. Parallel flow paths through RTG bypass cooling circuits masked the possibility of additional restrictions within the bypass circuits. Flow pressures were monitored while closing each side of the RTG bypass circuits to compare pressures. This demonstrated resistance in each path to be equal. The line was borescoped for additional blockage, with none found. Coolant pressure and temperature indications were within specified limits. ***This risk factor was resolved for STS-34.***
6	IUS Safe and Arm (S&A) device contamination. HR No. ICHR-018 ***No anomalies were reported on STS-34.***	The failure to arm 1 of the 2 S&A devices on the STS-26/Tracking and Data Relay Satellite (TDRS)-C/IUS Upper Stage resulted in an investigation that revealed extensive contamination as the probable cause for the failure. Because of this concern, it was decided to fly STS-34/Galileo IUS with 1 each old- and new-build S&A in each IUS stage. New build S&A production had begun but testing was not complete. Production of the new build is to be performed under more stringent cleanliness conditions to eliminate contamination as a failure mode. However, during acceptance testing of the new-build S&As, IUS S&A device, S/N 1211, from the new production lot failed in the "arm" position on the 33rd cycle. Subsequently, this device was mechanically rotated and cycled again. At this point, the device failed all electrical tests. MSFC conducted an x-ray inspection of this IUS device.

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
PAYLOAD		
6 (Continued)		Another new build S&A, S/N 1212, failed resistance test during acceptance due to a hard short. This failure was found to be caused by a small piece of metal contamination. A decision was made to use 4 old S&A devices that were previously screened for contamination, instead of using 2 old and 2 new S&A devices. Old-build screened devices have successfully flown and operated on TDRS-D, Magellan, and Titan-IV missions. ***This risk factor was resolved for STS-34/Galileo.***
7	Orbiter Environmental Control System (ECS) overtemperature anomaly. ***No anomalies were reported on STS-34.***	During safing procedures in preparation for possible rollback due to hurricane Hugo, out-of-step sequencing caused the Orbiter ECS to deliver high-temperature air to the Payload Bay, exceeding the 52 ±2°F limit. Interface cables that route temperature monitoring data for the Payload Bay were disconnected prior to disabling the ECS purge. The control system on the ECS purge interpreted the disconnected sensor as a "cold" condition and delivered hot, dry air (approximately 180°F) for about 30 minutes. Payload Bay temperature was calculated to have reached 90°F prior to purge line disconnect. Review by the Jet Propulsion Laboratory (JPL)/Galileo Project determined that no detrimental effects to the IUS resulted. ***This risk factor was resolved for STS-34.***
8	Vertical Processing Facility (VPF) payload ECS failure. ***No anomalies were reported on STS-34.***	The VPF payload ECS provides filtered, temperature and humidity controlled air flow directly to the payload purge duct. This system is independent of the facility Heating, Ventilating, and Air Conditioning (HVAC) system. It has many redundant features except one: the compressor is a single-point failure. The compressor shut down twice on August 15, 1989, resulting in exposure of the IUS to warm, moist air

RESOLVED STS-34 SAFETY RISK FACTORS

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
PAYLOAD		
8 (Continued)		flow. Cooling temperature went from 65°F to 130°F, and the relative humidity went from 43% to 85%. The first failure occurred when the setscrew in the #4 condenser fan pulley loosened, causing the fan and belt to come off. The ECS compressor shut down because of the high head pressure. The second failure occurred during recovery from the first failure. While attempting to adjust the temperature to dry purge the IUS, the compressor shut down due to low suction pressure. Troubleshooting resulted in removing and replacing several electrical components and adjusting the oil temperature safety switch. Twenty-four hours of dry air purge was performed prior to IUS power-up. Two shifts of retesting were accomplished after the purge. Successful electrical tests demonstrated that the IUS was not affected. Visual inspection showed that no IUS contamination resulted from these failures. ***This risk factor was resolved for STS-34.***
9	IUS AFTA test problem. ***No anomalies were reported on STS-34.***	During IUS AFTA testing, the secondary AFTA was inadvertently configured for testing instead of the primary. When the "raise" command was issued from the payload control panel, the primary AFTA slip ring, that should have been disconnected, was driven to the engaged position. The AFTA extended until the slip ring lockpin engaged and interrupted power, preventing IUS movement. The system was examined, reset, and reconfigured for retest. Successful retest was performed during end-to-end testing.

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
PAYLOAD		
9 (Continued)		The rationale for flight was based on interlocks preventing the AFTA from stalling. The time to engage the slip ring lockpin was nominal. In addition, the AFTA performed nominally during retest. ***This risk factor was resolved for STS-34.***
10	IUS computer A single-bit errors. ***No anomalies were reported on STS-34.***	During IUS computer testing at the pad, computer A, S/N 041, exhibited 3 single-bit errors. Six hours later, computer A exhibited the same anomaly. The IUS computers are redundant. A single IUS computer can accept up to 25 single-bit errors before declaring a computer failure and switching control to the alternate computer. Both computers operate in parallel, with 1 in control at all times. Previous problems of this type led to a computer modification which is now undergoing verification testing. This testing was not complete. For this reason, a decision was made to replace IUS computer A with a modified IUS computer, S/N 014, that was in spares at KSC. The replacement was made on October 3 and 4, 1989, and testing was completed on October 5, 1989. Further investigation into IUS computer anomalies found that IUS computer, S/N 014, recently installed on IUS-19, had an open problem package (02347). This open problem package was deferred by the IUS Program Office at MSFC. The associated problem concerned single-bit errors, similar to those experienced on STS-34 that caused removal and replacement of the computer. Two Circuit Card Assemblies (CCAs) were replaced, retests were performed, and no further anomalies were experienced. The CCAs were returned to the vendor (Delco) for failure analysis. Delco determined that the failure was caused by a bad memory chip. They further stated that this was a random failure mode, the first failure of this type in more than 540 memory chips that were used. MSFC agreed with the

RESOLVED STS-34 SAFETY RISK FACTORS

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
PAYLOAD		
10 (Continued)		Delco findings relative to a possible generic memory chip problem. An MSFC review of all records associated with IUS computers on IUS-19, S/N 014 and S/N 015, cleared all questions and concerns. IUS computer, S/N 014, was modified to alleviate concern with the single-bit error. MSFC stated that single-bit errors in the modified computer would not propagate to double-bit errors based on the modification. The other IUS computer on IUS-19, S/N 015, was not modified; however, it did not exhibit single-bit errors. Boeing ran additional confidence tests at the System Integration Laboratory to determine if problems would arise when operating with a modified and unmodified IUS computer. No anomalies were recorded. Rationale for flight focused on over 100 hours of operational testing of unmodified and modified IUS computer pairs at Boeing, with no anomalies experienced. ***This risk factor was resolved for STS-34.***
11	Galileo/IUS separation switch anomaly. ***No anomalies were reported on STS-34.***	While performing the Galileo/IUS separation switch test, Galileo did not receive 1 of 2 switch indications from the IUS. Troubleshooting revealed that the separation switches were cross-connected. Investigation found that the IUS vehicle connector bracket had the reference designators reversed. The connection drawing was also incorrect. Cable connections for the separation switch were routed to the proper configuration. Retest of the separation switch was successfully performed. It was also determined that the cross-routing in this case would have caused no flight safety impact. ***This risk factor was resolved for STS-34/Galileo.***

RESOLVED STS-34 SAFETY RISK FACTORS

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
PAYLOAD		
12	Galileo Pressure Relief Device (PRD) attachment bolt anomaly. *No anomalies were reported on STS-34.*	Attachment bolts (4 each) used to secure the PRD to the RTGs were found to have bottomed out upon installation. Two additional washers were inserted with each bolt to shorten the effective bolt length. Subsequent evaluation found that the third thread on the bolts was defective, causing the locking mechanism to engage. After installation of the 2 washers and reinstallation of the bolts, it was determined that there is at least 1 thread engaged in the locking mechanism of each bolt. Engineering evaluations using a spare RTG and PRD were performed at the JPL and General Electric to determine the structural integrity of this modified attachment scheme. Determination was made that the bolt lock mechanism engagement of at least 1 thread per bolt is sufficient to survive mission loads. ***This risk factor was resolved for STS-34/Galileo.***

SECTION 5

STS-28 INFLIGHT ANOMALIES

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

SECTION 5 INDEX

ORBITER

1	Pilot seat moved during ascent.
2	Vernier thruster F5R annunciated fail leak.
3	Nose Landing Gear Weight-On-Wheels indication failed off.
4	Fuel Cell #1 Hydrogen flow erratic.
5	Abort light failure.
6	Forward Reaction Control System F5L heater failed "on".
7	Main Bus C utility outlet #1 teleprinter short circuit. (Teleprinter cable anomaly)
8	Auxiliary Power Unit isolation valve talkback failure.
9	Low Freon flow.
10	Right-hand Orbital Maneuvering System fuel quantity gage high.
11	Auxiliary Power Unit #1 test line temperature high.
12	Crew experienced sneezing.
13	Hydraulic System #2 unloader valve operated out of specification.
14	Body flap deflection excessive during ascent.
15	Orbiter structure heat damage.
16	Crew reported a loud thump/thud at first OPS-1 transition.
17	SSME #1 Gaseous Hydrogen Flow Control Valve showed sluggish response.
18	Early boundary layer transition.
19	Loose foam on the External Tank Liquid Oxygen Umbilical.

SRB

1	Loose bolts on the left Solid Rocket Booster External Tank Attachment Ring.

SRM

1	Gask-O-Seal void found during postflight inspection.

KSC

1	Mobile Launch Platform recorders were accidently turned off.

STS-28 INFLIGHT ANOMALIES

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
<u>ORBITER</u>		
1	Pilot seat moved during ascent. IFA No. STS-28-02 HR No. ORBI-256C ORBI-340 ***No crew seat anomalies were experienced on STS-34.***	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, 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 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 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. The qualification test motor/brake was then installed in OV-102. The unit flew 1 flight before STS-28 (STS-61C); 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 underwent vibration equivalent to greater than 900 flights. The seat was reinstalled in OV-102 and passed the Acceptance Test Procedure (ATP) (1-g).

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
1 (Continued)		During brake assembly failure analysis teardown, the assembly fell out when removed from the housing. 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 bond of brake pad to metal surface was degraded, and the pad became separated from the base. Loctite on the brake assembly screw failed, and the screw backed out. Heat discolorization was also found on the unit interior. It was determined that the qualification testing which forces the brake motor into continuous operation is considered a high-temperature, abnormal operating mode. Investigation determined that there are no other motor/brake assemblies in the flight vehicles that were used as qualification test units. OV-104 seats have flown twice; no anomalies were noted. ***This anomaly was resolved for STS-34.***
2	Vernier thruster F5R annunciated fail leak. IFA No. STS-28-03 HR No. ORBI-056 ***No thruster anomalies were reported on STS-34.***	Vernier thruster F5R annunciated fail leak and was deselected by Reaction Control System (RCS) jet Redundancy Management (RM). Oxygen and fuel injector temperatures decreased below the 130°F RM limit. Chamber pressure also increased during the decline 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. ***Not a safety concern for STS-34.***

STS-28 INFLIGHT ANOMALIES

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
3	Nose Landing Gear (NLG) Weight-On-Wheels (WOW) indication failed off. IFA No. STS-28-04 HR No. ORBI-184 ***No WOW indicator anomalies were reported on STS-34.***	The NLG WOW #1 proximity sensor discrete failed to the "off" condition indicating weight on the nose gear during prelaunch. The NLG WOW discrete was seen toggling between "on" and "off" states before finally failing to the "off/Weight-On-Nose Gear (WONG)" discrete. The WOW "on" indication recovered on-orbit. A procedure to press the External Tank-Separation (ET-SEP) pushbutton after nose gear touchdown, a nominal crew procedure, eliminated the anomaly. Proximity switch box troubleshooting at KSC repeated the failure indication for 6 minutes, 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. ***Not a safety concern for STS-34.***
4	Fuel Cell #1 Hydrogen (H_2) flow erratic. IFA No. STS-28-05C ***No anomalies were reported on STS-34.***	Fuel Cell #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. Determination was made to fly OV-102 as is since the required corrective maintenance would necessitate removal of the fuel cell. ***Not a safety concern for STS-34.***
5	Abort light failure. IFA No. STS-28-06 ***No anomalies were reported on STS-34.***	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. ***Not a safety concern for STS-34.***

STS-28 INFLIGHT ANOMALIES

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
6	Forward RCS F5L heater failed "on". IFA No. STS-28-07 HR No. INTG-172 ***No thruster anomalies were reported on STS-34.***	The forward RCS F5L 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 would not overheat the thruster if it remains on. ***Not a safety concern for STS-34.***
7	Main Bus C utility outlet #1 teleprinter short circuit. (Teleprinter cable anomaly) IFA No. STS-28-11 HR No. ORBI-301 ***No cable shorts were reported on STS-34.***	The teleprinter cable plugged into Main Bus C utility outlet #1 shorted, causing a 1.5-second 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 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 pluged their suit fans into 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 do not have to be bent sharply 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 were 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 is to be ready for the next OV-102 flight. Redesign is also in work to eliminate small bend radii. ***Not a safety concern for STS-34.***
8	Auxiliary Power Unit (APU) isolation valve talkback failure. IFA No. STS-28-12 HR No. ORBI-103 ***No APU isolation valve anomalies were reported on STS-34.***	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 removal and replacement of the talkback sensor 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. ***Not a safety concern for STS-34.***

STS-28 INFLIGHT ANOMALIES

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
9	Low Freon flow. IFA No. STS-28-15 HR No. ORBI-275A *No ECLSS anomalies were reported on STS-34.*	Freon flow rates in the Environmental Control and Life Support System (ECLSS) have degraded on OV-102 since its first flight. During STS-28, the Freon Coolant Loop (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 were attributed to possible water contamination in the loops. Another possible cause was coagulation of teflon suspended in the freon. The FCL #2 pump package and filter were removed and replaced. FCL #1 and #2 samples were taken; moisture content was found to be within specification. Flow rate transducers were removed and replaced, and "brazed-in" filter replacement was completed. Flow rates were then within specification. ***This anomaly is unique to OV-102 and was not a safety concern for STS-34.***
10	Right-Hand (RH) Orbital Maneuvering System (OMS) fuel quantity gage high. IFA No. STS-28-17 HR No. ORBI-183 *No fuel gage anomalies were reported on STS-34.*	The RH OMS fuel quantity gage read approximately 5.7% high after deorbit burn as compared to predicted values. Evaluation indicated fuel aft probe failure. There was no indication that this is a generic failure problem that would impact subsequent flights. *Not a safety concern for STS-34.*

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 anomalies were reported on STS-34.*	APU #1 test line temperature was recorded from 90-92°F, over the Fault Detection and Annunciator (FDA) limit of 90°F for several cycles. When the "B" heaters were switched on per 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 is in work to increase the FDA limit appropriately. *Not a safety concern for STS-34.*
12	Crew experienced sneezing. IFA No. STS-28-21 HR No. ORBI-279 *No sneezing or eye irritation was reported on STS-34.*	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. *Not a safety concern for STS-34.*
13	Hydraulic System #2 unloader valve operated out of specification. IFA No. STS-28-23 HR No. ORBI-052 *No hydraulic system anomalies were reported on STS-34.*	During prelaunch, the unloader valve cycled when the accumulator pressure reached 2350 pounds per square inch (psi), 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 was 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; leak check of the replacement valve was satisfactory. *Not a safety concern for STS-34.*

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
14	Body flap deflection excessive during ascent. IFA No. STS-28-24 HR No. ORBI-025 ***STS-34/OV-104 ascent film review found some evidence of body flap deflection; however, it was not considered as great as that seen on STS-28/OV-102. No damage to tile or body flap mechanisms was reported during STS-34/OV-104 postflight inspection.***	Excessive body flap deflection was believed to be observed by the film analysis team from the E-207 tracking camera at approximately 46-seconds MET during ascent of STS-28. On STS-28, the camera was turned on at T-0 versus T+50 seconds on prior flights. Body flap deflection was witnessed on the film at Max Q for about 10 seconds. 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". Camera photographs from previous flights did not provide the view angle needed to observe flap movement. Deflection of approximately 2" was witnessed during qualification testing prior to STS-1. Acoustical qualification testing resulted in deflections at a natural frequency of 12.4 Hz. Also during acoustical testing, similar deflections to those recorded on STS-28 were seen in the rotary actuator attachment area; however, investigation found that a bearing in the rotary actuator was walling out. The OPO developed and implemented a plan for OV-102 (STS-28) testing in the Orbiter Processing Facility using a shaker to verify the natural frequency of the body flap and inspection of the inner body flap and the actuator mechanisms. Modal vibration tests were conducted on OV-102 and OV-103 body flaps. Static deflection tests were also conducted on each of the body flaps to determine free play; the free play was within the allowable range for all three vehicles. The body flap on OV-102 was removed, and the fittings, attachment points, etc. were inspected and measured; no significant problem was detected. The internal flap cavities were borescoped. Some evidence of heating (discoloration) and metal filings indicative of wear were seen, but no significant problems were found. One actuator was returned to Sundstrand for evaluation; that actuator tested 3% less efficient than when new, which is an excellent result for an actuator with an equivalent amount of service

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
14 (Continued)		time. Since no significant problems were found during all of the OV-102 body flap testing and inspection, the flap was reinstalled. Three new actuators and the retested actuator were installed. The body flap test and inspection results for OV-104 were satisfactory. Review of Configuration Verification Accounting System (CVAS) documentation verified that the OV-102 hardware was installed per design requirements; there are insignificant differences from vehicle to vehicle. OV-102 actuator attachments are within design requirements, and the actuators passed the ATP. However, additional analysis was subsequently assigned as an action item at the STS-34 FRR to determine the following: • Calculate estimates of potential visual amplification and distortion associated with views through Space Shuttle Main Engine (SSME) plume gases. Estimate bounds of measurement accuracy, including end-to-end photo/video system performance capabilities. • For each of the following peak-to-peak body flap deflections (4", 6", 9", 13"), determine the area and type of predicted damage, and if no predicted damage, the margin. Results of the STS-34 FRR Action Item: Estimates of potential visual amplification and distortion associated with camera views through the SSME plume were determined to have little or no effect (approximately ±0.2"). Readability errors were calculated to be ±2.2" based on comparison with other, non-moving areas on the Orbiter. The summary of more recent analysis of STS-28 film, considering the effects of plume and readability

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
<u>ORBITER</u>		
14 (Continued)		errors, led to the conclusion that there was body flap motion of 6.1 ±3.0" peak-to-peak on STS-28, as compared to 9 ±4" originally measured. Analysis of predicted structural/component damage resulting from various peak-to-peak deflections found that no damage would result with deflections up to 6" peak-to-peak. Tile damage would begin to occur around 6.5". Structural damage would occur at higher deflection levels, beginning with a bearing failure of the actuator rib upper lug at 7.5" peak-to-peak, and a tension failure of the actuator rib upper lug at 8.7" peak-to-peak. It was reported during the STS-34 Safety, Reliability, Maintainability, and Quality Assurance (SRM&QA) Prelaunch Assessment Review (PAR) on October 10, 1989, that no significant body flap tile damage has occurred on any flight which could be attributed to excessive body flap deflections. Modal vibration tests and static tests were conducted on OV-103. OV-103 remained constant at 8.23 Hz with a constant effective stiffness. The OV-102 body flap exhibited a loud thumping noise during testing; OV-103 was much quieter. Only the port, outboard actuator on OV-103 thumped. Free play tests performed on OV-103 resulted in exceeding the test criteria. This result was deemed inconclusive because it was later determined that the free play test setup on OV-103 was not correct. Rerun of the OV-103 free play tests was not possible because the vehicle was not available; however, tests and analyses performed on other Orbiters indicate that a body flap deflection problem does not exist on any vehicle. ***This anomaly was resolved for STS-34.***

STS-28 INFLIGHT ANOMALIES

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
15	Orbiter structure heat damage. IFA No. STS-28-26 HR No. ORBI-084 ORBI-245A ***No heat damage was reported on STS-34.***	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. Overheating 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. The tile was reinstalled. A problem closeout report was written and approved. ***Not a safety concern for STS-34.***
16	Crew reported a loud thump/thud at first OPS-1 transition. IFA No. STS-28-27 ***No noise was reported by the STS-34 crew or recorded on MADS.***	During postflight debriefing, the crew reported a loud thump/thud at the exact time of the first OPS-1 transition at T−20 minutes. 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 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 seconds. Hydraulic pressure was insufficient to move rudder/speedbrake, body flap, or SSME Thrust Vector Control (TVC) actuators. Elevon repositioning transients

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
16 (Continued)		were nominal (inboard elevons −7° (gravity droop position) to 0° in 3 seconds; outboard elevons −3-1/4° (gravity droop position) to 0° in 2 seconds). The elevon droop position was within flight experience. Lateral accelerometer started bit toggling between 0 and 0.003 g. 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 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 (MADS) during OPS-1 transition and measure vehicle data in an attempt to record any repeat of this anomaly and isolate the cause. ***Not a safety concern for STS-34.***
17	SSME #1 Gaseous Hydrogen (GH_2) Flow Control Valve (FCV) showed sluggish response. IFA No. STS-28-28 HR No. ORBI-151 ORBI-338A ***No GH_2 problems were reported on STS-34.***	SSME #1 GH_2 FCV indicated sluggish response during the first 3 minutes of ascent. Indications were that the FCV would not fully stroke and would not respond when commanded during thrust bucket. 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 three FCVs were removed and replaced. The poppets were sent to the vendor for inspection and cleaning. Tolerances on OV-102 GH_2 FCV were found to be tighter than specification; 0.007" versus 0.009 to 0.013" specification tolerance.

STS-28 INFLIGHT ANOMALIES

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
17 (Continued)		While there have been repeated instances of sluggish LO_2 FCV operations, none were reported on STS-30, the last OV-104 mission. This was the first reported case of a GH_2 FCV anomaly. The GH_2 FCVs on both OV-103 and OV-104 have flown two missions with no reported sluggish operation. ***This anomaly was an acceptable risk for STS-34.***
18	Early boundary layer transition. IFA No. STS-28-30 HR No. ORBI-136A ORBI-249A ***STS-34 reentry performance was as predicted with no anomalies.***	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. Unusual low-frequency aileron movement occurred in the Mach 20 to Mach 10 range during STS-28 reentry. Unusual RCS and aerosurface activity was observed during roll reversal. Boundary layer transition from laminar to turbulent flow began to occur approximately 250 seconds earlier than expected. Transitions normally occur 1100 to 1200 seconds following entry. External disturbances caused the early transition. The FCS began to compensate for these external forces by using the aerosurfaces and RCS jets. The ailerons executed a single-cycle sinusoidal 0.5° amplitude motion in elevon trim over a 5-minute period; trim limit on the elevons is 3°. Similar aileron activity was observed during early transition on STS-1. During this same interval, 2 RCS jets also fired in phase with the aileron for a coordinated response; the RCS limit is 4 jets for this operation. At no time was there a "force fight" between the ailerons and the RCS jets as previously reported. Total RCS propellant usage was 840 pound (lb). A nominal mission uses approximately 600 lb. The OPO presented a prediction of an additional 162 lb of RCS propellent usage at the STS-28 Launch-Minus-Two Day (L-2) Review. Previous high-inclination orbit missions without Program Test Inputs (PTIs) also

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
18 (Continued)		have a history of higher than usual usage (STS-51B, 680 lb; STS-61B, 610 lb; and STS-27, 700 lb). The limit on RCS jet activity is approximately 1300 lb of propellent usage. Postflight analysis and simulation tests showed that 170 lb were required to compensate for air density shears. The FCS operated appropriately to compensate for the external force. Adequate controls and consumable margins were maintained for the required aerosurface movements and jet firings. Postflight analysis of surface temperature measurements indicated transition from laminar to turbulent flow occurred at Mach 18. Prior to this mission, the earliest transition was at Mach 14 for STS-1. The earlier-than-normal transition caused an extended period of aeroheating at elevated temperatures. Peak temperatures on the vehicle surface and structure were within ranges experienced previously; however, the extended time period resulted in a higher structural temperature rise ($T_{rise} = T_{landing} - T_{entry\ interface}$). Structural temperatures experienced were all within the 350°F design limit. There was a concern that the high heating on STS-28, if combined with tile damage like that experienced on STS-27, could result in burnthroughs and vehicle instability, possibly leading to loss of crew and vehicle. There was extensive TPS damage as a direct result of the extended high heating. A total of 339 charred filler bars were found. Of these, 226 were Category 1, 92 were Category 2, and 21 were Category 3 (Category 1: shiny redness on the Room Temperature Vulcanizate (RTV) surface; Category 2: gray/black discoloration with flaking of the RTV; Category 3: black scorching of the filler bar, RTV flaking, and slumping of the tile, tile replacement is mandatory). A total of 668 gap fillers were damaged or missing, requiring replacement. Approximately 20 slumped tiles were

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

ORBITER

18 (Continued)

found. A total of over 1000 gap and filler bars were damaged; nominal is around 600. The elevon cove area seal was found to be charred. Inspection of OV-102 was completed, with no known structural damage found.

As a comparison to previous flights, the following table illustrates the extensive filler bar damage on STS-28:

	Cat 1	Cat 2	Cat 3
STS-28	226	92	21
STS-29	126	130	4
STS-30	440	207	1

Three protruding gap fillers were found on the forward area of the STS-28 Orbiter. Two of the 3 were installed at Palmdale in 1985 during the OV-102 modification period. Review of build paper indicated that all installation procedures were completed correctly. During postlanding inspection, 15 to 20 gap fillers were found on the runway, which was not unexpected after experiencing the high heating environment. Protruding and lost gap fillers were experienced on previous flights.

Investigation of the cause of the early boundary layer flow transition produced theories that protruding gap fillers in the left forward area of the OV-102 most likely caused an asymmetric transition beginning on the left side.

This risk factor was resolved for STS-34/OV-104.

STS-28 INFLIGHT ANOMALIES

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
19	Loose foam on ET LO_2 umbilical. IFA No. STS-28-31 HR No. ORBI-302A INTG-037A INTG-081A ***No anomalies were reported on STS-34.***	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 is 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. The foam was from that portion of the umbilical what is Government Furnished Equipment (GSE) to the ET project. Similar problems have been noted on STS-4, STS-9, and STS-61A; most flights have shown evidence of minor damage. Possible causes of the problems include installation anomalies, LO_2 impingement, aerodynamic effects during ascent, or a combination thereof. The failure mode is not totally understood. Approximately 65 cryogenic ET/Orbiter separation tests were 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. Debris damage to the Orbiter is unlikely. Interference with umbilical door closure from foam debris was considered remote. ***This anomaly was resolved for STS-34.***

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 ***Certain fasteners and connectors were found either not torqued or not properly safety wired (IFA No. STS-34-K-03). Effort is underway to emphasize the importance of good workmanship and proper installation of fasteners and connectors.***	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/ET Attachment 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 on the fastening components were identified. 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. ***Not a safety concern for STS-34.***

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
SRM		
1	Gask-O-Seal void found during postflight inspection. IFA No. STS-28-M-01 HR No. BC-03 Rev. B ***No Gask-O-Seal anomalies were reported on STS-34 SRMs.***	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 was 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 on new gaskets on DM-9 and QM-6. Subsurface voids were found in both cases; contamination was also present on DM-9. Standard nondestructive inspection techniques, such as X-ray, cannot reliably detect subsurface voids. 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 actions are to develop an inspection technique to detect subsurface voids: design a plexiglass fixture for seal test; reinvestigate N-Ray and X-ray; and investigate of ultrasonics and background scatter.

STS-28 INFLIGHT ANOMALIES

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
<u>SRM</u>		
1 (Continued)		For the next flight (STS-34), the left and right SRB igniter seals were inspected and replaced. All 360L006 seals were reused and have 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-34 gaskets met the crown height requirement of 0.021-0.031". ***This anomaly was resolved for STS-34.***

STS-28 INFLIGHT ANOMALIES

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
<u>KSC</u>		
1	Mobile Launch Platform (MLP) recorders were accidentally turned off. IFA No. STS-28-K-01 ***No operator anomalies were reported on STS-34.***	At T−15 seconds, the MLP fans were turned off. At this time, the MLP recorders were also inadvertently turned off by the console operator. Approximately 200 launch measurements were lost from T−5 seconds through T+15 minutes. Critical strain gage measurements were lost, including holddown stud, holddown post, and ET tanking measurements. While this particular incident of operator error was not a safety issue, operator errors of a similar nature on other consoles have been occurring. ***This anomaly was resolved for STS-34.***

C-2

SECTION 6

STS-30 INFLIGHT ANOMALIES

This section contains a list of Inflight Anomalies (IFAs) arising from the STS-30 mission. Each anomaly is briefly described, and risk acceptance information and rationale are provided.

SECTION 6 INDEX

ORBITER

1 Cabin pressure transducer failed.
2 The #2 Gaseous Hydrogen pressure system temperature indicator failed.
3 Center engine Liquid Hydrogen inlet pressure transducer failed.
4 Fuel Cell #2 Hydrogen flow meter failed.
5 Left engine Liquid Hydrogen inlet pressure transducer biased low.
6 Reaction Control System Jet R1U failed off, post External Tank separation.
7 Auxiliary Power Unit #2 Gas Generator fuel pump "A" heaters inoperative.
8 Right Orbital Maneuvering System fuel total quantity gage failed.
9 Right Reaction Control System A-leg oxidizer helium isolation valve failed open.
10 Water Spray Boiler #2 Gaseous Nitrogen pressure decay.
11 General Purpose Computer #4 failed to sync.
12 Engine helium fill Check Valve failures.
13 The right Orbital Maneuvering System Gaseous Nitrogen pressure regulator regulated low.
14 Main landing gear fluid leak.
15 Nose wheel steering enable late.
16 Ding on forward window #6.
17 The Altitude/Vertical Velocity Indicator reading was high during Flight Control System checkout.
18 Bulkhead blanket damage.

SRM

1 Factory joint weather seal aft edge unbonding.
2 Cut in the secondary seal of the outer gasket.
3 Solid Rocket Motor nozzle snubber ring displacement.

SRB

1 Left-Hand Solid Rocket Booster main parachute failure.
2 Debris lost from multiple Debris Containment Systems.
3 Left-Hand Solid Rocket Booster External Tank Attachment cover sheared fasteners.
4 Left-Hand Solid Rocket Booster External Tank Attachment Ring cap and web separation.

STS-30 INFLIGHT ANOMALIES

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
1	Cabin pressure transducer failed. IFA No. STS-30-01 HR No. ORB-071 ***No anomaly was reported on STS-34.***	During prelaunch, the cabin pressure transducer failed to register cabin pressurization properly. Inspection after scrub on the first attempt revealed that the dust cap was still on the transducer port. Kennedy Space Center (KSC) has revised cabin closeout inspection procedures to eliminate this problem. ***Not a safety concern for STS-34.***
2	The #2 Gaseous Hydrogen (GH_2) pressure system temperature indicator failed. IFA No. STS-30-02D ***No anomaly was reported on STS-34.***	Prior to flight, a Space Shuttle Main Engine (SSME) GH_2 pressure system indicator failed high. KSC traced the problem to a bad transducer. The transducer was removed and replaced. ***Not a safety concern for STS-34.***
3	Center engine Liquid Hydrogen (LH_2) inlet pressure transducer failed. IFA NO. STS-30-02E ***No anomaly was reported on STS-34.***	The center engine LH_2 inlet pressure transducer failed at approximately 1 to 2 pounds per square inch (psi) during ascent. The problem was traced to a bad transducer that was removed and replaced. ***Not a safety concern for STS-34.***

STS-30 INFLIGHT ANOMALIES

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
4	Fuel Cell (FC) #2 Hydrogen (H_2) flow meter failed. IFA NO. STS-30-02F HR No. ORBI-283 ***No anomaly was reported on STS-34.***	During flight, the FC #2 H_2 flow transducer shifted high by 0.2 to 0.3 pound/hour. Toward the end of the mission, the transducer started working properly. ***Not a safety concern for STS-34.***
5	Left engine LH_2 inlet pressure transducer biased low. IFA No. STS-30-02H ***No anomaly was reported on STS-34.***	The left engine LH_2 inlet pressure transducer was reading about 10 psi lower than actual pressure from Relative Velocity (VREL) = 4500 feet per second (fps) to touchdown. KSC evaluation showed that engine #2 typically read 10 psi lower than the other 2 engines. Johnson Space Center (JSC)/KSC/Rockwell International (RI) Downey review indicated that this is nominal behavior. ***Not a safety concern for STS-34.***

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
6	Reaction Control System (RCS) Jet R1U failed off, post External Tank (ET) separation. IFA No. STS-30-05 HR No. ORBI-203 ***No anomaly was reported on STS-34.***	RCS jet R1U failed in the "off" position after ET separation due to low chamber pressure. The oxidizer valve failed closed. This is the same jet that failed on OV-103. The pilot stage was found to be slow during a signature test. Analysis isolated the oxidizer valve that failed to open. The valve was sent to the vendor and cut apart revealing nitrate contamination on the main stage seat and pilot stage and corroded flexures. Stickiness prevented the valve from opening. These jets did not fail on first use; they failed each time on the second use. The R1U jet is positioned such that water may have leaked into the jet during adverse weather conditions and contributed to the nitrate contamination (e.g., on Ferry flight). The rationale for flight was based on no failures in previous first flights, test and inspection performed, and functional redundancy of other RCS jets. Also, OV-104, Pod RP01 was removed and replaced with Pod RP03 (an OV-103 Pod) prior to STS-34. ***This risk factor was acceptable for STS-34.***
7	Auxiliary Power Unit (APU) #2 Gas Generator (GG) fuel pump "A" heaters inoperative. IFA No. STS-30-06 HR No. ORBI-250 ***This anomaly was reported on STS-34/OV-104 (IFA No. STS-34-06).***	APU #2 GG fuel pump "A" heaters did not respond when the switch operated. The crew switched to the "B" heaters which operated properly. KSC was unsuccessful in recreating the problem. A similar failure occurred on STS-27. ***Because of redundancy in the heaters, this risk factor was acceptable for STS-34.***

STS-30 INFLIGHT ANOMALIES

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
8	Right Orbital Maneuvering System (OMS) fuel total quantity gage failed. IFA No. STS-30-08 ***No anomaly was reported on STS-34.***	During the OMS-2 burn, the right OMS fuel total quantity gage stopped decreasing at 49.8%. It was expected to decrease to 31.4%. The gage was sent in for failure analysis. Flight data and failure history indicated failure of the forward fuel probe (propellant intrusion suspected). ***Not a safety concern for STS-34.***
9	Right RCS A-leg oxidizer helium isolation valve failed open. IFA No. STS-30-09 HR No. ORBI-111 ***No anomaly was reported on STS-34.***	The right RCS A-leg oxidizer helium isolation valve failed open when commanded to close. The valve was verified open during postflight inspection. The valve worked properly when the pod was removed from vehicle. The OV-104 pod was repaired. Metal clips were found in the P29 connector. During connector vacuuming, some pins were bent. STS-34 valves were functionally verified during processing. ***This risk factor was resolved for STS-34.***
10	Water Spray Boiler (WSB) #2 Gaseous Nitrogen (GN_2) pressure decay. IFA NO.STS-30-10 HR No. INTG-072 INTG-113 ***No anomaly was reported on STS-34.***	There appeared to be a leak downstream of the GN_2 supply valve in WSB #2 as evidenced by 5 psi drop in the WSB regulator pressure during the first 24 hours of flight. Normal changeout was performed by KSC per Operational Maintenance Requirements and Specifications Document (OMRSD) requirements. A Requirements Change Notice (RCN) was prepared by RI/Downey to raise the leak rate limit. ***Not a safety concern for STS-34.***

STS-30 INFLIGHT ANOMALIES

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
<u>ORBITER</u>		
11	General Purpose Computer (GPC) #4 failed to sync. IFA No. STS-30-11 HR No. ORBI-066 ORBI-194 ***No anomaly was reported on STS-34.***	The system management GPC #4 experienced a "failed to sync." GPCs #1 and #2 voted against GPC #4. GPC #4 was removed and replaced with the spare GPC per Flight Rule 7-13. The replacement GPC worked properly. Redundancy allows loss of 3 GPCs with function still retained. ***Not a safety concern for STS-34.***
12	Engine helium fill Check Valve (CV) failures. IFA No. STS-30-12 HR No. INTG-019 ***No anomaly was reported on STS-34.***	During processing of STS-30/OV-104, all CVs in the Main Propulsion System (MPS) were inspected and tested for function. A number of CVs were found to be defective and were removed and replaced. When the STS-30 MPS Helium system was configured for entry, MPS #3 regulator outlet "B" CV (CV45) had a reverse leak. Leak checks were performed. One of the MPS CV failure modes was cocked poppet and jamming in the spring guide. Rationale for flight was that all of the CVs were tested, replaced if required, and retested for satisfactory performance. ***This risk factor was resolved for STS-34.***

STS-30 INFLIGHT ANOMALIES

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
<u>ORBITER</u>		
13	The right OMS GN_2 pressure regulator regulated low. IFA No. STS-30-14 HR No. ORBI-111 ORBI-165 ***No anomaly was reported on STS-34.***	The right OMS GN_2 pressure regulator regulated 5 pounds per square inch absolute (psia) below specification during post-OMS burn purges and during postlanding GN_2 tank venting. This unit was changed out by an Operations and Maintenance Instruction (OMI). STS-30 flight and postflight data showed a trend toward lower outlet pressure from the regulator. This was first noticed on STS-27. ***Not a safety concern for STS-34.***
14	Main landing gear fluid leak. IFA NO. STS-30-15A & B HR No. ORBI-188 ***No anomaly was reported on STS-34.***	Fluid was found in both main landing gear wheel wells postlanding (4-8 ounces in the right, some in the left). Laboratory analysis was unable to determine the type of fluid, possibly MEQ fluid coming from the struts. The struts were diapered to attempt to catch any additional leakage. ***Not a safety concern for STS-34.***
15	Nose wheel steering enable late. IFA No. STS-30-16 HR No. ORBI-184 ***No anomaly was reported on STS-34.***	The crew reported lateral acceleration following nose gear touchdown. Data confirmed 1/4-g lateral acceleration and about 4-second delay from nose gear touchdown to nose wheel steering enable. Investigation found that the rate at which the Nose Landing Gear (NLG) was lowered during rollout caused the 2 Weight-On-Nose Gear (WONG) transducers to make an excessive toggling internal to software limits. This caused the computer to ignore the inputs and required the crew to manually activate nose wheel steering. KSC troubleshooting found the Right-Hand (RH) NLG sensor out of adjustment and corrected the situation.

STS-30 INFLIGHT ANOMALIES

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
<u>ORBITER</u>		
15 (Continued)		Software changes were made to open up the window to accommodate these delays between the 2 sensors. The first software change lengthened the time for comparing sensor inputs prior to setting the WONG dilemma condition (from 0.4 second to 3 seconds). The second software change initialized the directional factor to start at measured nose wheel position instead of zero position. ***This risk factor was resolved for STS-34.***
16	Ding on forward window #6. IFA No. STS-30-17 HR No. ORBI-009 ***No anomaly was reported on STS-34.***	The ding was larger than allowable specifications. Pitting was 11.5 mils deep. The ding was believed to be micrometeoroid in origin. KSC replaced the window. ***Not a safety concern for STS-34.***
17	The Altitude/Vertical Velocity Indicator (AVVI) reading was high during Flight Control System (FCS) checkout. IFA No. STS-30-19 HR No. ORBI-211 ***No anomaly was reported on STS-34.***	During FCS checkout, the Commander's AVVI showed 20,600 feet per second (ft/sec). The pilot's showed 20,100 ft/sec; both should have been 20,000 ft/sec. Tolerances are being reexamined. ***Not a safety concern for STS-34.***

STS-30 INFLIGHT ANOMALIES

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
<u>ORBITER</u>		
18	Bulkhead blanket damage. IFA No. STS-30-20 HR No. ORBI-249A ***No anomaly was reported on STS-34.***	Some 1307 bulkhead blankets, adjacent to those recently modified, sustained cover damage. In addition, nine snaps were found unsnapped. The blankets were replaced with modified blankets. ***Not a safety concern for STS-34.***

STS-30 INFLIGHT ANOMALIES

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
<u>SRM</u>		
1	Factory joint weather seal aft edge unbonding. IFA No. STS-30-M-01 HR No. BC-02 BC-10 Rev. B ***STS-34 Left-Hand (LH) SRM had similar weather seal unbonds. These unbonds were attributed to splashdown loads.***	Postflight inspection of the STS-30 left SRM identified several aft edge unbonds of the factory joint weather seals. The aft edge unbonds included the forward center segment factory joint and the aft segment (stiffener-to-stiffener factory joint and stiffener-to-aft dome factory joint). All unbonds were adhesive failures between the Chemlok 205 primer and the motor case. Contamination during processing and assembly, and higher than normal splashdown loads, were possible causes under investigation. Bonding surface contamination was determined not to be the cause of the unbonds. However, case surface smoothness was found to reduce the weather seal bond strength. A change allowing the entire bonding surface to be grit blasted was initiated. Minimum Conscan requirements for these surfaces are currently in place. The LH booster experienced parachute failure; this resulted in an increase of water entry velocity by 20 fps to 90-95 fps. This is believed to be the cause of the unbonds. ***Not a safety concern for STS-34.***

STS-30 INFLIGHT ANOMALIES

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
<u>SRM</u>		
2	Cut in the secondary seal of the outer gasket. IFA No. STS-30-02 HR No. BI-02 Rev. B ***No anomaly was reported on STS-34.***	Postflight inspection of the left SRM igniter gasket revealed a cut at 285° on the secondary seal of the outer gasket. The cut exists on approximately 50% of the crown and extends radially (at a diagonal) inboard. Dimensions are approximately 0.010" long by 0.010" wide by 0.030" deep. The cut was on the gasket forward face and was not visible in the void area. It appears to have been caused by a sharp raised metal edge or sliver, but the exact cause of the damage was unclear. All gaskets in stores were reinspected for similar damage, with no anomalies found. Igniter gaskets for STS-34 have successfully passed leak checks. The gaskets were packaged in containers to preclude handling damage and underwent thorough inspection. ***Not a safety concern for STS-34.***
3	Solid Rocket Motor (SRM) nozzle snubber ring displacement. IFA No. STS-30-M-03 HR No. BN-08 Rev. B ***No anomaly was reported on STS-34.***	The left SRM nozzle snubber ring was displaced slightly forward and wedged into the aft end ring. The nozzle was wedged out of the null position. All bolts connecting the snubber support ring to the forward exit cone were sheared. The support ring was displaced 10" forward at 248° and was in its normal position at 68°. Snubber support ring and snubber segments were wedged between the forward exit cone and the bearing end rings causing the flex bearing to be stretched forward approximately 3/4". The nozzle hardware damage and "snubbed" condition were attributed to high splashdown loads associated with the left Solid Rocket Booster (SRB) parachute anomaly/failure. Ripstops will be used to prevent this parachute failure in the future. ***Not a safety concern for STS-34.***

STS-30 INFLIGHT ANOMALIES

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
SRB		
1	LH SRB main parachute failure. IFA No. STS-30-B-01 *No anomaly was reported on STS-34.*	The LH SRB main parachute #2 collapsed shortly after initial inflation. There were 315 broken ribbons. Gore 93 failed from the skirt band through the vent band and across the vent cap. The most probable cause appeared to be associated with the parachute canting at an angle greater than 20°. Consequently, the parachute was forced against the Main Parachute Support Structure (MPSS) (Isogrid) during deployment from the parachute bags (at a velocity of 300 fps) resulting in distressed ribbons. Ripstop (additional bands sewn around the parachute) probably would have prevented this parachute failure. Change is being effected to place 6 variably spaced ripstop ribbons around the circumference of the parachute near the vent, the region which experienced deployment damage. If a divergent tear starts, the tear will stop when it hits a ripstop ribbon. This will prevent catastrophic failure of the parachute. For STS-33 and the following 5 flights, ripstop will be implemented on 1 main parachute per SRB. Ripstop is currently scheduled for implementation on all main parachutes for STS-38 and subsequent flights. *Not a safety concern for STS-34.*
2	Debris lost from multiple Debris Containment Systems (DCSs). IFA No. STS-30-B-02 HR No. B-60-12 Rev. B *No anomaly was reported on STS-34.*	The Holddown Post (HDP) DCS did not function properly at locations #2, #3, #5, and #7 to retain all potential debris generated by frangible nut separation. Four nut fragments from HDP #5, which weighed a total of 4.4 ounces, were found on top of the holddown stud at the Mobile Launch Platform (MLP). The DCS failed to fully contain HDP debris on 9 HDPs (32 total) through the first 4 flights (STS-26,4; STS-29,1; and STS-30,4). A Class I hardware modification was initiated to enhance the DCS. Changes included addition of a silicone rubber shock isolator between the stud attach and plug tip, and material/configuration changes on the stud attach. The experience base with the present design provided an acceptable risk. *This risk factor was acceptable for STS-34.*

STS-30 INFLIGHT ANOMALIES

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
<u>SRB</u>		
3	LH SRB ET Attachment (ETA) cover sheared fasteners. IFA No. STS-30-B-03 HR No. B-30-06 Rev. B ***No anomaly was reported on STS-34.***	Four of the ETA Ring cover fasteners were sheared off near the in-harbor tow bracket of the left SRB. Physical evidence on the fasteners and cover holes indicated that the fasteners failed during buckling of the ring segment. The ring segment is not reusable. This was not a constraint to flight due to occurrence following initial water impact. ***Not a safety concern for STS-34 or subsequent flights.***
4	LH SRB ET Attachment Ring cap and web separation. IFA No. STS-30-B-04 HR No. B-30-06 Rev. B ***No anomaly was reported on STS-34.***	Separation occurred for a length of approximately 100" on ring segment 283. Maximum gap was approximately 1/4". The damage was attributed to a combination of cavity collapse loads and negative internal pressure within the motor case. Higher than normal water impact loads resulted from loss of one main parachute. ***Not a safety concern for STS-34.***

STS-30 INFLIGHT ANOMALIES

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
<u>ET</u>		
1	Leak in 4" LH_2 recirculation line. IFA No. STS-30-ET-01 HR No. S.06 *No anomaly was reported on STS-34.*	Following the scrub of STS-30 and approximately 15 minutes after shutdown of the hydrogen recirculation pumps, gaseous flow was observed in the area of the LH_2 recirculation line burst disc. The replacement line functioned normally during launch. The line was removed and replaced while the Orbiter and ET were on the pad. The removed recirculation line was flown to the vendor and Marshall Space Flight Center (MSFC) for test and checkout. It was determined that the burst disc was intact and no leaks were found. Spray-on foam insulation and Super Light Ablator (SLA) were intact and undamaged. However, a void in the GX6300 SLA adhesive in the area of the burst disc resulted in cryogenic pumping of liquid air, thus creating the illusion of a burst disc failure. Although inspection identified a possible need for GX6300 application on ablator applied to the bellows shield, this recirculation line could have flown on STS-30 with no detrimental effects. To prevent another occurrence, Room Temperature Vulcanizate (RTV) is being applied to the exposed ablator on the bellows cover to prevent air intrusion and venting. Modifications to the recirculation line Thermal Protection System (TPS) will preclude cryo pumping on future flights. *Not a safety concern for STS-34.*

SECTION 7

STS-34 INFLIGHT ANOMALIES

This section contains a list of Inflight Anomalies (IFAs) arising from the STS-34 mission. Each anomaly is briefly described, and risk acceptance information and rationale are provided.

SECTION 7 INDEX

ORBITER

1	Engine Interface Unit #3 momentary 60-kilobit data stream loss.
2	Auxiliary Power Unit #1 fault to high speed.
3	Multiplexer-Demultiplexer Flight-Critical Aft #1 Input/Output Errors.
4	Auxiliary Power Unit #2 Gas Generator/Fuel Pump heater "A" inoperative.
5	Flash Evaporator System Hi-load inboard duct temperature low.
6	Auxiliary Power Unit #3 seal leak into drain bottle.
7	Right Orbital Maneuvering System engine cover heater system "B" failed off.
8	Auxiliary Power Unit #2 fuel pump heater "B" cycling high.
9	Cryogenic Oxygen manifold #2 isolation valve did not close.
10	Right vent door #3 motor #1 operating on 2 phases.
11	External Tank/Orbiter Liquid Oxygen aft separation hole plugger failed.
12	Right-hand stop bolt was bent on centering ring of forward External Tank attach separation assembly.

SRB

1	Right Solid Rocket Booster Holddown Post #2 broached and shoe lifted from Mobile Launch Platform during liftoff.
2	Right Solid Rocket Booster forward segment missing Thermal Protection System from forward section of systems tunnel cover.

SRM

1	Left Solid Rocket Motor rock actuator bracket damage.
2	Left Solid Rocket Motor factory joint weather seal forward edge unbonds.
3	Putty on right Solid Rocket Motor igniter outer gasket and left Solid Rocket Motor igniter gasket retainer.
4	Left Solid Rocket Motor center field joint aft side unbond of K5NA closeout.
5	Left and right Solid Rocket Motor aft dome Ethylene Propylene Diene Monomer blisters.

STS-34 INFLIGHT ANOMALIES

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
1	Engine Interface Unit (EIU) #3 momentary 60-kilobit (kbit) data stream loss. IFA No. STS-34-02 HR No. INTG-021A INTG-065 INTG-072 INTG-165	EIU #3 Built-In Test Equipment (BITE) bit #13 set and the 60-Kbit data stream was lost, both momentarily. Recurrence would have resulted in loss of 60-Kbit data. The problem did not recur during this mission. Redundancy exists in the EIU for critical command and data paths; however, the BITE is not flight critical. The worst-case effect is loss of Space Shuttle Main Engine (SSME) performance data to the Operational Instrumentation (OI) recorder; the data is not mission essential. The 60-Kbit data is used to confirm critical Launch Commit Criteria (LCC) for Liquid Oxygen (LO_2) dome temperature and ice detection. The most probable cause is BITE circuitry failure. All 3 EIUs have been scheduled to be replaced with modified EIUs during the STS-36 flow.
2	Auxiliary Power Unit (APU) #1 fault to high speed. IFA No. STS-34-04 HR No. ORBI-031	APU #1 experienced an uncommanded speed shift to the high-speed band at L+2.5 minutes during ascent. This speed shift was intermittent over a 4- to 5-second period and was permanent thereafter. The crew commanded the APU to high speed 15 seconds after the uncommanded shift to avoid alarms. The APU operated satisfactorily at high speed for the remainder of ascent. Troubleshooting found that the speed shift was due to the pulse control valve failing open. This valve varies the fuel flow to the APU to regulate speed. After failure of the pulse control valve, the shut-off valve was used to control APU speed. APU #1 was not turned on until Mach 10 and was turned off at postlanding wheel stop. APU #1 Gas Generator Valve Module (GGVM) was sniffed checked, and insulation connectors were visually inspected; there was no indication of propellant leakage and no obvious external GGVM deformity.

STS-34 INFLIGHT ANOMALIES

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
2 (Continued)		The APU controller was sent to Sundstrand for troubleshooting. During testing in an ambient temperature environment of 110°F, Sundstrand was able to duplicate this anomaly twice. The controller was left at ambient room temperature overnight and then returned to a temperature of 110°F. At the higher temperature, Sundstrand test conductors repeated the anomalous condition 5 additional times. The pulse code card in this controller was found to be susceptible to high thermal environments. The problem was isolated to an intermittent open 2N2222 transistor by Raytheon Lot Date Code (LDC) 8131 in the pulse control circuit within APU Controller Serial Number (S/N) 311. This was the first Orbiter use of this Controller. The Line Replaceable Unit (LRU) criticality is 1R2. Analysis of the failed transistor indicated circuit failure to open was caused by depletion (thinning) of the gold wire at the transistor base junction due to "purple plague". Cross-sectional analysis showed extensive voiding between the bond wire and the pad. Five transistors on the same circuit board, with the same part number and LDC as the failed part, passed electrical tests and were subsequently destructively analyzed. All passed nondestructive bond pull tests; 2 parts were destructively pull tested with good results. Two transistors were cross-sectioned and showed excellent bond-to-pad junctions. Analysis of 4 additional transistors from the Solid Rocket Booster (SRB) program, with the same part number and LDC as the failed part, resulted in all findings being normal. The rationale for flight was based on the fact that an affected APU can operate in high speed while the other APUs operate normally. The increased risk due to APU overspeed was acceptable. There was no evidence to indicate that this was a generic failure problem.

STS-34 INFLIGHT ANOMALIES

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
3	Multiplexer-Demultiplexer (MDM) Flight-Critical Aft (FA) #1 Input/Output (I/O) Errors. IFA No. STS-34-05 HR No. ORBI-038	At L+35 minutes, MDM FA #1 failure was detected by both the Primary Avionics Software System (PASS) and Backup Flight System (BFS) just prior to Orbital Maneuvering System (OMS) #2 burn. There was no response from the MDM primary port for 2 consecutive return word commands. I/O reset alone did not restore communications with MDM FA #1. Power cycling and I/O reset temporarily restored communications. The problem recurred and was restored by cycling power a few times. The crew was able to recover FA #1 operation for the remainder of the mission by moding to the backup port. Loss of the MDM FA primary port was acceptable during flight due to redundancy. Postflight troubleshooting at Dryden prior to MDM powerdown confirmed that port #1 was not communicating. The MDM was removed and replaced at Kennedy Space Center (KSC). While there have been 33 instances of loss of 1 MDM port, MDMs have 2 ports and re-porting can be accomplished. Both ports must fail in order to lose an MDM. Loss of 1 port prior to launch is acceptable. Certain critical MDMs are themselves redundant; therefore, loss of an MDM FA results in a minimum duration flight. Loss of a flight-critical MDM is an exception to the single-fault tolerant rule, because loss of a single MDM reduces redundancy in multiple systems. This increases the risk that a single lowest-replaceable-unit failure in any 1 of several systems could put the Orbiter at a zero-fault tolerance level. Loss of 2 FA MDMs results in a next Primary Landing Site (PLS) mission termination.

STS-34 INFLIGHT ANOMALIES

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
<u>ORBITER</u>		
4	APU #2 Gas Generator (GG)/Fuel Pump (FP) heater "A" inoperative. IFA No. STS-34-06 HR No. ORBI-250	APU #2 FP/GGVM system "A" heaters did not respond when selected. System "B" heaters were selected and operated acceptably; the "B" heater was cycling high. (See Orbiter 8 below.). Postflight testing at Dryden indicated that "A" heaters were operating properly. Thermostat S27A was removed and replaced; retest was successful. The thermostat worked properly during vacuum testing at Johnson Space Center (JSC). It was sent to Sundstrand, and testing so far has shown no problem. APU #2 heater system was thoroughly examined. It was totally rewired from forward panel A12 to the APU in the aft. Retest was performed per Operations and Maintenance Instruction (OMI) V1019. The same problem occurred on STS-27 and STS-30 missions. This is an OV-104 unique problem.
5	Flash Evaporator System (FES) Hi-load inboard duct temperature low. IFA No. STS-34-07 HR No. ORBI-276B	During ascent, post-Main Engine Cutoff (MECO), the Hi-load inboard duct temperature was observed to be lower than expected. The flash evaporator is the primary heat sink during ascent, initialized at approximately 140,000 feet (ft) by avionics software. Both heaters were enabled on the Hi-load duct. Approximately 3 minutes later, the crew shut down FES primary A and switched to secondary; the temperature continued to decrease. The system stabilized under radiator flow. Heaters were left on for bakeout. On flight day 2, the topping FES functioned properly on primary A and primary B controllers. Data analysis indicated that the lower than expected duct temperature was created by high heat load and transients induced by the Radioisotope Thermoelectric Generator (RTG) cooling loop. RTGs will not fly again until STS-41.

STS-34 INFLIGHT ANOMALIES

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
6	APU #3 seal leak into drain bottle. IFA No. STS-34-08 HR No. ORBI-100	APU #3 cavity seal drain line pressure increased, and fuel pump inlet pressure decreased. The possible cause of this anomaly was a leak in the static seal. The drain bottle was drained and checked at KSC to determine if the seal leak had degraded. The seal had not degraded; catch bottle quantity was within acceptable limits. The same anomaly occurred on STS-30. The STS-30 drain bottle contained 30 cubic centimeter (cc) of propellant. This anomaly is unique for OV-104, APU #3. No leaks have been experienced an OV-103 or OV-102. The recent APU fuel pump detonation at Sundstrand highlights the concern with seal leaks. (See Section 4, Integration 3.) This leak should be fixed prior to STS-36, the next flight of OV-104.
7	Right OMS engine cover heater system "B" failed off. IFA No. STS-34-09 HR No. ORBI-120	During heater configuration to "B" heaters, the Aft Propulsion System (APS) right pod (RP03) "B" heaters failed to activate. The pod was removed. Investigation found a recessed pin in the heater connector. The connector was replaced.
8	APU #2 fuel pump heater "B" cycling high. IFA No. STS-34-10 HR No. ORBI-250	APU fuel pump heater "B" cycled erratically toward higher temperatures. This anomaly was possibly related to the failure of APU #2 fuel pump heater "A". Thermostat S27B was removed and replaced; retest was successful. The thermostat was returned to Sundstrand for failure analysis. There was no indication of improper APU heater operation on OV-103 or OV-102.

STS-34 INFLIGHT ANOMALIES

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
9	Cryogenic Oxygen (O_2) manifold #2 isolation valve did not close. IFA No. STS-34-12 HR No. ORBI-303A	The crew attempted to close the cryogenic O_2 manifold tank #2 valve on panel R-1 per the sleep configuration. The crew reported that they held the switch for 5 seconds. There was no talkback. No switch discrete was received. The valve closed properly on the first troubleshooting step while on-orbit. Postflight, the valve opened properly. There is redundancy in the valves. Review of the valve design found that it will lose the closed indication when in the relief mode. Concern would be raised if the closed indications have not been received during Main Propulsion System (MPS) dump or during reentry.
10	Right vent door #3 motor #1 operating on 2 phases. IFA No. STS-34-19 HR No. ORBI-178A	During prelaunch and landing configuration of vent doors, the right vent door #3 motor #1 operated on 2 phases. This occurred 3 times in flight. Phase B was lost when the door opened, and phase C was lost when the door closed. This anomaly also occurred with the same door motor during the STS-30 turnaround flow. During that flow, the problem occurred twice in 50 cycles. The motor control assembly was removed and replaced. Troubleshooting at Rockwell International (RI)/Downey could not duplicate any suspect relay failure during 900 relay cycles. Postflight troubleshooting at KSC repeated the anomaly; 1 phase of the Power Drive Unit (PDU) was found open. The vent door PDU was replaced and retested satisfactorily. Vent door motors are redundant and will operate on 2 phases, as demonstrated during STS-34.

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
11	External Tank (ET)/Orbiter Liquid Oxygen (LOX) aft separation hole plugger failed. IFA No. STS-34-20 HR No. ORBI-302A	The ET/Orbiter LOX aft separation hole plugger failed to extend fully by approximately 2" at ET separation. Postflight inspection found jamming by a detonator booster and detonator. A crushed backshell from the right aft connector was found on the runway after the ET umbilical door was opened. There is concern that loose debris could block the ET umbilical door from closing, resulting in the possible loss of the vehicle during reentry. Rationale for flight of subsequent missions is based on the probability being remote of escaping fragments preventing ET umbilical door closure. The vehicle performs a maneuver at separation away from the ET and moves away from possible escaping debris prior to ET umbilical door closure.
12	Right-Hand (RH) stop bolt was bent on centering ring of the forward ET attach/separation assembly. IFA No. STS-34-21 HR No. INTG-051A	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 at the attach/separation assembly between the ET and Orbiter and is not considered to be 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 pound (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 STS-34 flight. The parts were removed at Dryden and sent to RI/Downey. Research indicated that Ground Support Equipment (GSE) used to mate the forward bipod probably caused the problem. The bolt was analyzed at RI/Downey.

STS-34 INFLIGHT ANOMALIES

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
<u>ORBITER</u>		
12 (Continued)		The most probable cause of this anomaly was improper sequencing of the ET/Orbiter mating procedure resulting in a yaw moment that could bend the bolt. Sequencing employs 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. There were no anomalies recorded during ET/Orbiter mating.

STS-34 INFLIGHT ANOMALIES

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
SRB		
1	Right SRB Holddown Post (HDP) #2 broached and shoe lifted from Mobile Launch Platform (MLP) during liftoff. IFA STS-34-B-01 HR No. INTG-164 B-00-15 B-00-17	The holddown stud at HDP #2 (RH tension post) hung-up at liftoff. This resulted in broaching of the right SRB aft skirt and thread impressions at that HDP bore. Review of the liftoff photographs found that the shoe on the MLP at HDP #2 lifted 2 1/4" at the same time. In addition, thread imprints were noted on 7 of the 8 SRB HDP feet during postflight evaluation. Analysis by United Space Booster, Inc. (USBI) indicated that vehicle launch performance would not be affected if all 8 studs hang up, provided that the frangible nuts are released. Stud hangups were recorded on 5 previous flights (STS-2, STS-4, STS-51I, STS-51J, and STS-61A). Major broaching of aft skirt HDPs was experienced on 4 prior flights. Minor broaching and thread impressions were recorded on 46 HDPs on 10 previous flights. Lifting of MLP holddown shoes was seen on STS-2 and STS-29. Marshall Space Flight Center (MSFC) organized a tiger team to investigate stud hangups and the influences of recent design modifications on the holddown Debris Containment Systems (DCSs). Their review of liftoff films found similarities between the STS-34 occurrence and previous launches with stud hangups. Review of build papers relating to HDP installations revealed no anomalies. Frangible attach stud modifications in the debris containment device implemented prior to STS-28 should provide sufficient time for stud ejection. The modification reduced the holddown stud ejection velocity from 222 inches per second (in/sec) to 184 in/sec. This increased the time for stud ejection from 52 millisecond (msec) to 63 msec. With a 250-msec SRB liftoff time, 63 msec should be sufficient time for stud ejection.

STS-34 INFLIGHT ANOMALIES

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
<u>SRB</u>		
1 (Continued)		The tiger team also analyzed the effect of biasing of the MLP spherical bearings radially inward on the stud. Biasing of the spherical bearings was performed to increase the aft skirt Factor of Safety (FOS) for STS-34. The total HDP shoe/MLP spherical bearing mismatch for STS-34 was determined to be less than the mismatch on STS-27, STS-28, and STS-30. Compressive load on HDP #2 at frangible nut detonation was sufficient to prevent aft skirt shoe motion. The tiger team investigation determined that there was no evidence that biasing of the spherical bearings contributed to the stud hangup. MSFC analysis indicated that vehicle liftoff would be unaffected even if hangups occurred at all 8 HDPs, provided that all frangible nuts are separated properly. An RI analysis conducted in conjunction with MSFC concluded that 1 or 2 stud hangups will not adversely affect vehicle liftoff dynamics or clearances between the vehicle and facility. The RI evaluation also concluded that the spherical bearing/shoe assembly will not break free and become a debris source. Broaching of the aft skirt is a reuse issue only.
2	Right SRB forward segment missing Thermal Protection System (TPS) from forward section of systems tunnel cover. IFA No. STS-34-B-02 HR No. B-60-25 Rev. C-DCN3	A 6" wide by 24" long piece of Marshall Sprayable Ablator No. 1 (MSA-1) was missing from the forward section of a system tunnel cover on the right SRB forward skirt. This tunnel cover is the second cover from the top of the forward skirt. A clean substrate was observed indicating no evidence of heat effects. Indications were that this piece of MSA-1 was dislodged at water impact. This was based on absence of sooting or heat effects that would result if the missing MSA-1 was lost during ascent. Fuzz was also present on fractured edges of the MSA-1 and substrate; this was also an indication that water impact was the likely cause. Also, the resulting debris would not be in the Orbiter debris zone.

STS-34 INFLIGHT ANOMALIES

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
SRM		
1	Left Solid Rocket Motor (SRM) rock actuator bracket damage. IFA No. STS-34-M-01 HR No. BN-05 Rev. B	During postflight inspection of the LH SRM aft exit cone, the 45° rock actuator bracket was found to be broken, taking part of the aft exit cone shell with it. The part of the bracket remaining on the actuator had a section of the aft exit cone shell (approximately 16" by 6") still attached. The aft exit cone, which contains 2 parts of the bracket, was shipped to Thiokol/Wasatch for further failure analysis. There were no reported functional anomalies during flight associated with the actuator and nozzle vectoring. The conclusion was that the actuator bracket broke on splashdown. Water impact loads on this SRM were higher than the strength of the bracket. The actuator becomes fixed (rigid) after motor separation. The delay in parachute opening, due to the reefer cutter failure, could have caused higher horizontal drift velocities. There was no soot on any surfaces exposed after the bracket failure, which also indicated that the failure was caused by water impact. Excised samples from the actuator bracket were tested for mechanical properties; all properties (modulus, strength, and elongation) were at or above specification. Rationale for flight was based on the fact that the actuation system cannot develop loads large enough to fail the actuator bracket. The maximum actuation (stall) load is 103,424 lb; measured maximum actuation load is much lower. Actuator brackets are proof-tested to 195,132-lb tensile load, with an additional 20,000-lb side load applied. The actuator bracket under flight loads was analyzed to have a structural FOS of 2.1.

STS-34 INFLIGHT ANOMALIES

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
SRM		
2	Left SRM factory joint weather seal forward edge unbonds. IFA No. STS-34-M-02 HR No. INTG-037B	Three unbonds were noted on the LH SRB on STS-34. Two of these were on the forward edge. • Center forward factory joint (forward edge), 6.6" circumferentially by 1.75" deep at 0°. • Forward dome-to-cylinder factory joint (forward edge), 225° to 248°, with a maximum axial depth of 2.05". This was associated with paint failure and corrosion immediately adjacent to the debond seal. (The third unbond was at the forward factory joint (aft edge), 20" circumferentially by 3/4".) Adjacent paint was peeled from the case and attached to the edge of the Ethylene Propylene Diene Monomer (EPDM) at the area of the unbond. Corrosion was evident on the case under the EPDM and under the peeled paint. The factory joint unbonds are adhesive failures between the Chemlok 205 primer and the motor case. The weather seal was intact with no missing material. The concern was that unbonds could lead to debris potential during ascent and loss of factory weather seal protection. Structural assessment indicated that flight loads were not sufficient to create debris; FOS is greater than 6.0. Protuberance loads on localized unbonds are much lower than loads necessary to tear EPDM. Completely unbonded weather seal would remain in-place and intact during flight. Postflight inspection found no sooting or heat affects under the weather seals, indicating that the unbonds occurred at splashdown.

STS-34 INFLIGHT ANOMALIES

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
SRM		
2 (Continued)		As corrective action, additional Conscan and surface finish requirements have been added. All pin retainer band cleaning will be done prior to assembly to eliminate potential contaminants. For the next flight (STS-33), a visual inspection and 0.005" shim stock edge probing were performed at Thiokol Corporation prior to paint closeout.
3	Putty on right SRM igniter outer gasket and left SRM igniter gasket retainer. IFA No. STS-34-M-03 HR No. BC-03 Rev. B	Putty was found up to the aft face of the outer primary gasket and into the seal void/gland area, between 234° and 5° of the right SRM igniter. Putty was also found on the aft face of the gasket retainer (0.011" max.) and under the retainer from 262° to 297° of the left SRM. The concern was that the gasket's sealing capability might be impaired by the embedded putty. Although there was no leakage or blowby past the seal (no blowhole in the putty), the seal is not designed to have putty in it. The cause of the problem was attributed to the igniter installation process. Putty located near the gasket and/or excess amounts may squeeze between the sealing surfaces during igniter installation. Corrective action was taken to improve putty layup and igniter installation processes based on results of previous installation tests. These tests demonstrated that putty does not enter the gasket area when laid up to tighter dimensional requirements (layup dimensions closely controlled, key layup dimensions recorded, and putty weight measurements monitored). This corrective action was implemented on the left SRM igniter on STS-33, on both SRM igniters on STS-32, and will be implemented on STS-36 and subsequent SRM igniters at Thiokol Corporation. In addition, after assembly all igniter joints are required to be leak checked for verification.

STS-34 INFLIGHT ANOMALIES

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
SRM		
4	Left SRM center field joint aft side unbond of K5NA closeout. IFA No. STS-34-M-04 HR No. INTG-037 B-60-24	The K5NA closeout on the trailing edge of the STS-34 LH SRM forward center field joint was debonded from the case wall. The cork leading edge at the 320° radial location also had K5NA debonded. The debond measured 5" circumferential by 1" in axial length. K5NA debonds are aeroheating and debris risks. Indications were that the debonds were caused by the nozzle severance sequence or at water impact. A scrape was found just aft of the unbond area, indicating debris impact from an external source. The unbonded K5NA remained in place. Since the unbond occurred after booster separation, there was no debris hazard to the Orbiter and no impact on flight safety.
5	Left and right SRM aft dome EPDM blisters. IFA No. STS-34-M-5 HR No. BC-10 Rev. B	During disassembly of the booster assemblies, the Carbon Fiber-Filled (CFF)-EPDM in the aft dome of both SRMs was found to have ply blistering that resulted in separations. The separations were within a 32" band from the nozzle boss forward. Separations/blisters occurred intermittently for the full 360° around the SRM: 15 blisters randomly around the RH SRM; 10 randomly around the Left-Hand (LH) SRM. Examination found that the material separated between virgin plies. The largest separation occurred in the RH SRM, measuring 4.5" circumferentially by 5.5" axially. The smallest measured 1 square inch. Separated material appeared to be tacky, indicating that the EPDM may have been improperly cured. Approximately 0.030"-thick ply separated. Normal heat effects were evident in adjacent areas. Overall CFF-EPDM erosion was deemed nominal. The CFF-EPDM is in compression during firing, and the virgin CFF-EPDM is separated from chamber gas flow by a thick char layer. The blisterings were localized occurrences; the edge of the blisters tore and did not propagate when pulled by hand. The CFF-EPDM lot used on STS-34 SRMs was also used on STS-28. There was no similar blistering occurrence experienced on STS-28. This same lot of CFF-EPDM was also used on STS-33 SRMs.

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
<u>SRM</u>		
5 (Continued)		Questions were raised concerning possible cold-soaking conditions during transportation. Separations such as those found on STS-34 could have been caused by cold soaking. Thiokol records indicated that there were no cold-weather conditions experienced during transportation to KSC. Rationale for flight for future missions is based on the assessment that assuming total loss/erosion of the CFF-EPDM insulation at ignition, the remaining Nitrite Butadiene Rubber (NBR) provides a minimum FOS of 1.2.

STS-34 INFLIGHT ANOMALIES

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
SSME		
1	Main injector heat shield retainer ring segment failures. IFA No. STS-34-E-01	Three segments of the retainer ring were found broken on STS-34 Main Engine (ME) #3 (engine #2029). One piece was still missing (as of the STS-36 Orbiter Rollout Review on January 10, 1989). Engine #2029 was taken out-of-flight service until the piece is found. A similar problem occurred on the next flight (STS-33) on ME #3, engine #2107. However, all pieces were found, and the engine was cleared for flight. This was not a constraint to Orbiter Processing Facility (OPF) rollout of STS-36. The MEs on STS-36/OV-104 include Engineering Change Proposal (ECP) 620 that changed the configuration of the main injector heat shield retainer ring to prevent the condition which caused the IFAs on STS-34 and STS-33. Additional information concerning this anomaly will be provided in the STS-34 IFA Section of the Mission Safety Evaluation (MSE) for the next National Space Transportation System (NSTS) mission (STS-33).

STS-34 INFLIGHT ANOMALIES

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
KSC		
1	Connectors on SRBs improperly torqued and lockwired. IFA No. STS-34-K-03 HR No. B-00-15	During disassembly of STS-34 booster assemblies at KSC, 5 connectors were discovered with either no torque, no lockwire, or improperly installed lockwire. The following is a list of torque/lockwire discrepancies reported: • RH SRB, NASA Standard Initiator (NSI) - B strut firing line jam nut was found not to be lockwired. • LH SRB, the jam nut on the 55-pin connector was lockwired in the wrong direction. • Coupling nut of the drogue deploy firing line on the RH forward Integrated Electronics Assembly (IEA) (J26) was found to be lockwired, but not torqued. • Coupling nut of the recovery battery cable on the LH forward IEA (J24) was found not to be lockwired. • LH range safety system coax connector in the rooster tail (at the aft skirt/rooster tail interface) was lockwired, but was found not threaded. For the next flight (STS-33), all accessible/viewable connectors on the pad were inspected. Prior to rollout, all connector areas inaccessible at the pad were verified for proper lockwire installation by examination of closeout photographs. These areas included all strut firing line connections in the ET attach ring and all but 3 connectors at the LH forward skirt interface.

STS-34 INFLIGHT ANOMALIES

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
<u>KSC</u>		
1 (Continued)		A review of STS-33 "as-built" paper was performed to determine if assembly teams associated with the STS-34 installation were involved in the STS-33 installation. An assembly team is comprised of a Lockheed technician, a Lockheed quality inspector, and a NASA quality inspector. This review found that, while the exact same technician/inspector/inspector team did not perform any of the assemblies on STS-33, individuals were involved with STS-33 assemblies that did the STS-34 assemblies, but in different team compositions. All technicians and quality inspectors involved with the STS-33 assemblies which could not be verified through visual inspection or close-out photographs were individually interviewed to determine if the assembly process was properly performed and inspected. All interviewed indicated that all tasks were accomplished properly. Prior to the STS-33 Flight Readiness Review (FRR), the KSC Safety, Reliability, and Quality Assurance (SR&QA) Director reviewed the findings of the investigation with NSTS Program Management to ensure that all concerns relative to the flight worthiness of STS-33 were met. NSTS Program Management accepted any residual risk associated with the findings of the KSC investigation. For future flights, more stringent test and inspection procedures are being implemented to ensure proper connector installations.

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

AC	Alternating Current
ACA	Annunciator Control Assembly
AFB	Air Force Base
AFTA	Aft Frame Tilt Actuator
AMOS	Air Force Maui Optical Site
APS	Aft Propulsion System
APU	Auxiliary Power Unit
ARS	Air Revitalization System
ATP	Acceptance Test Procedure
	Acceptance Test Program
AVVI	Altimeter Vertical Velocity Indicator
BFS	Backup Flight System
BITE	Built-In Test Equipment
CA	California
CAD	Computer Aided Drawing
cc	Cubic Centimeter
CCA	Circuit Card Assembly
ccs	Cubic Centimeters Per Second
CFF	Carbon Fiber-Filled
CH	Channel
CPM	Cell Performance Monitor
CRU	Converter Regulator Unit
CV	Check Valve
CVAS	Configuration Verification Accounting System
DCS	Debris Containment System
DCU	DigitalComputer Unit
DMA	Direct Memory Access
DWV	Dielectric Withstanding Voltage
EAFB	Edwards Air Force Base
ECLSS	Environmental Control and Life Support System
ECP	Engineering Change Proposal
ECS	Environmental Control System
EDT	Eastern Daylight Time
EIU	Engine Interface Unit
EPDM	Ethylene Propylene Diene Monomer

APPENDIX A

LIST OF ACRONYMS (Cont.)

EPS	Electrical Power Systems
ET	External Tank
ET/SEP	External Tank/Separation
ETA	External Tank Attachment, Explosive Train Assembly
F	Fahrenheit
FA	Flight-Critical Aft
FA-1	Flight Aft 1
FC	Fuel Cell
FCL	Freon Coolant Loop
FCS	Flight Control System
FCV	Flow Control Valve
FD-2	Flight Day 2
FDA	Fault Detection and Annunciator
FES	Flash Evaporator System
FID	Failure Identification
FMEA/CIL	Failure Modes and Effects Analysis/Critical Items List
FOS	Factor of Safety
FP	Fuel Pump
fps	Feet Per Second
FRR	Flight Readiness Review
ft	Feet
ft/sec	Feet Per Second
g	gravitational acceleration
GG	Gas Generator
GG/FP	Gas Generator/Fuel Pump
GGVM	Gas Generator Valve Module
GH_2	Gaseous Hydrogen
GHCD	Growth Hormone Concentration Distribution
GN_2	Gaseous Nitrogen
GOX	Gaseous Oxygen
GPC	General Purpose Computer
gpm	gallons per minute
GSE	Ground Support Equipment
H_2	Hydrogen
HDP	Holddown Post
HPFTP	High Pressure Fuel Turbopump
HPOTP	High Pressure Oxidizer Turbopump
HR	Hazard Report
HVAC	Heating, Ventilating, and Air Conditioning
Hz	Hertz

APPENDIX A

LIST OF ACRONYMS (Cont.)

I/O	Input/Output
IEA	Integrated Electronics Assembly
IFA	Inflight Anomaly
in-lb	Inch-Pounds
in/sec	Inches Per Second
INTG	Integration
IUS	Inertial Upper Stage
JPL	Jet Propulsion Laboratory
JSC	Johnson Space Center
Kbit	Kilobit
KSC	Kennedy Space Center
L-2	Launch Minus 2 Day Review
lb	Pound
lb/hr	Pounds Per Hour
LCC	Launch Commit Criteria
LDC	Lot Date Code
LH	Left Hand
LH_2	Liquid Hydrogen
LiOH	Lithium Hydroxide
LO_2	Liquid Oxygen
LOX	Liquid Oxygen
LPFP	Low-Pressure Fuel Pump
LRU	Line Replaceable Unit
LSFR	Launch Site Flow Review
MADS	Modular Auxiliary Data Systems
MCC	Main Combustion Chamber Mission Control Center
MDM	Multiplexer-Demultiplexer
ME	Main Engine
MEC	Main Engine Controller
MECO	Main Engine Cutoff
MET	Mission Elapsed Time
MLE	Mesoscale Lightning Experiment
MLI	Multilayer Insulation
MLP	Mobile Launch Platform
MPS	Main Propulsion System
MPSS	Main Parachute Support Structure
MSA-1	Marshall Sprayable Ablator No. 1
MSE	Mission Safety Evaluation

APPENDIX A

LIST OF ACRONYMS (Cont.)

msec	Millisecond
MSFC	Marshall Space Flight Center
MTBF	Mean-Time-Between Failure
mV	Millivolt
NASA	National Aeronautics and Space Administration
NBR	Nitrite Butadiene Rubber
NDI	Nondestructive Inspection
Ni	Nickel
NLG	Nose Landing Gear
NPSP	Net Positive Static Pressure
NSI	NASA Standard Initiator
NSRS	NASA Safety Reporting System
NSTS	National Space Transportation System
O_2	Oxygen
OFP	Orbiter Processing Facility
OI	Operational Instrumentation
OMI	Operations and Maintenance Instruction
OMRSD	Operational Maintenance Requirements and Specifications Document
OMS	Orbital Maneuvering System
OPO	Orbiter Project Office
OPOV	Oxidizer Preburner Oxidizer Valve
OPS-0	Operational Software Mode 0
ORBI	Orbiter
OV	Orbiter Vehicle
PAR	Prelaunch Assessment Review
PASS	Primary Avionics Software System
PDU	Power Drive Unit
PLS	Primary Landing Site
PM	Polymer Morphology
PRCB	Program Requirements Control Board
PRD	Pressure Relief Device
psi	Pounds Per Square Inch
psia	Pounds Per Square Inch Absolute
psig	Pounds Per Square Inch Gage
PTI	Program Test Inputs
Q	Dynamic Pressure
QD	Quick Disconnect

APPENDIX A

LIST OF ACRONYMS (Cont.)

RCN	Requirements Change Notice
RCS	Reaction Control System
RH	Right-Hand
RI	Rockwell International
RM	Redundancy Management
RTG	Radioisotope Thermoelectric Generator
RTLS	Return to Launch Site
RTV	Room Temperature Vulcanizate
S/N	Serial Number
S&A	Safe and Arm
SEP	Separation
SLA	Super Light Ablative
SMDC	Shielded Mild Detonating Cord
SR&QA	Safety, Reliability, and Quality Assurance
SRB	Solid Rocket Booster
SRBTS	Solid Rocket Beacon Tracking System
SRM	Solid Rocket Motor
SRM&QA	Safety, Reliability, Maintainability, and Quality Assurance
SSC	Stennis Space Center
SSBUV	Shuttle Solar Backscatter Ultraviolet
SSME	Space Shuttle Main Engine
SSRP	System Safety Review Panel
STEX	Sensor Technology Experiment
STS	Space Transportation System
TAL	Transatlantic Abort Landing
TBI	Through-Bulkhead Initiator
TCDT	Trail Countdown Test
TDRS	Tracking and Data Relay Satellite
TPS	Thermal Protection System
TVC	Thrust Vector Control
U/N	Unit Number
UCR	Unsatisfactory Condition Report
USBI	United Space Booster, Inc.

APPENDIX A

LIST OF ACRONYMS (Cont.)

VPF	Vertical Processing Facility
VREL	Relative Velocity
VSWR	Voltage Standing Wave Ratio
WONG	Weight-On-Nose Gear
WOW	Weight On Wheels
WSB	Water Spray Boiler