MISSION SAFETY EVALUATION
REPORT FOR STS-28

Postflight Edition: November 14, 1989

Safety Division

Office of Safety, Reliability,
Maintainability, and Quality Assurance

National Aeronautics and Space Administration

Washington, DC 20546

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Postflight Edition: November 15, 1989

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EXECUTIVE SUMMARY

Space Shuttle *Columbia* was launched from Kennedy Space Center (KSC) at 220:08:37:00.012 a.m. Eastern Daylight Time (EDT) on August 8, 1989. The primary objective of this Department of Defense (DoD) STS-28 mission was classified. All Orbiter payload services and operations in support of the DoD mission payload/cargo were provided as planned. After a successful flight of slightly over 5 days, *Columbia* landed at Edwards Air Force Base, CA at 225:09:37:53 a.m. EDT on August 13, 1989.

Significant anomalies experienced during the STS-28 mission include:

- Failure of the pilot seat motor/brake assembly resulting in the pilot's seat sliding to the full back position several times during ascent.

- Observation and subsequent investigation of excessive body flap deflection during Max Q.

- Discovery of a large divot in the External Tank intertank acreage Thermal Protection System.

- Sustained cable short by Kapton insulation.

- Early boundary layer transition from laminar to turbulent flow caused by protruding gap fillers.

These anomalies will be readdressed in the STS-34 Mission Safety Evaluation.

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. It also documents unresolved safety risk factors impacting the STS-28 flight.

The MSE is published on a mission-by-mission basis for use in the Flight Readiness Review (FRR) and is updated for the Launch Minus 2 Day (L-2) Review. For tracking and archival purposes, the MSE is issued in final postflight 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 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-28 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 items 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 will be updated subsequent to the mission to add items identified too late for inclusion in the prelaunch report and to document performance of the anomalous systems for possible future use in safety evaluations.

1.3 Organization

The MSE is presented in seven sections as follows:

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

Section 2 - Provides a description of the STS-28 mission: a brief flight/vehicle description, including launch data, crew size, flight 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-28 launch, that were impacted or repeated by anomalies reported for the STS-28 flight.

Section 4 - Contains a list of safety risk factors that were considered resolved for STS-28.

Section 5 - Contains a list of Inflight Anomalies (IFAs) that developed during the STS-30 mission.

Section 6 - Contains a list of IFAs that developed during the STS-28 mission. Those STS-28 IFAs which are considered to represent safety risks will be addressed in the MSE for the next NSTS flight.

Section 7 - Contains background and historical data on the issues, problems, concerns, and anomalies addressed in Sections 3 through 6. 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-28 MISSION SUMMARY

2.1 Summary Description of STS-28 Mission

Space Shuttle *Columbia* was launched from Kennedy Space Center (KSC) at 220:08:37:00.012 a.m. Eastern Daylight Time (EDT) on August 8, 1989. The primary objective of this Department of Defense (DoD) STS-28 mission was classified. All Orbiter payload services and operations required to support the DoD mission payload/cargo were provided as planned. After a successful flight of slightly over 5 days, *Columbia* landed at Edwards Air Force Base at 225:09:37:53 a.m. EDT on August 13, 1989.

Ascent performance was nominal. No Space Shuttle Main Engine (SSME) anomalies were reported on STS-28. Debris Containment System (DCS) modifications implemented prior to STS-28 performed well; this was the first mission since reflight with no debris losses.

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. (See Orbiter 1, IFA No. STS-28-02, page 6-3.)

During postflight ascent film review, excessive body flap deflection was believed to be observed by the film analysis team. The film was taken from the E207 tracking camera, and witnessed at Max Q for about 10 seconds. Measurements derived from the film were assessed to show a deflection of up to 9 ±4" (later analysis reduced this amplitude) at a natural frequency of 8 Hertz (Hz). Deflection of approximately 2" had been witnessed during qualification testing prior to STS-1, with a natural frequency of 12.4 Hz. (See Orbiter 15, IFA No. STS-28-24, page 6-10.)

Immediately after External Tank (ET) separation, inflight photographs of the ET were taken by the crew. When reviewing these photographs, the debris assessment team discovered that a large divot occurred in the ET intertank acreage Thermal Protection System (TPS), just above the right-hand bipod ramp. The divot size was estimated to be approximately 23" x 15" with a shallow depth of less than 1". Shallow, cohesive TPS failures should not provide sufficient mass and velocity to cause impacts on the Orbiter TPS with enough energy to result in a safety problem.

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. 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. The continuing short, sustained by the Kapton insulation, illustrates the hazards associated with extensive use of Kapton-insulated wire throughout the Orbiter. (See Orbiter 7, IFA No. STS-28-11, page 6-6.)

Unusual low-frequency aileron movement occurred in the Mach 20 to Mach 10 range during the reentry of STS-28. Unusual Reaction Control System (RCS) and aerosurface activity was also observed. The boundary layer transition from laminar to turbulent flow began approximately 250 seconds earlier than expected. Transition normally occurs 1100 to 1200 seconds following reentry. The Flight Control System began to compensate for these external forces by using the aerosurfaces and RCS jets. At no time was there a "force fight" between the aileron and RCS jets as originally reported. Postflight analysis of surface temperature measurements indicates transition from laminar to turbulent flow occurred at Mach 18. Prior to STS-28, the earliest transition was at Mach 14 during STS-1 reentry. This earlier-than-normal transition caused an extended period of aeroheating at elevated temperatures. All structural temperatures experienced were within the 350°F design limit. There is a concern that the high heating on STS-28, if coupled with the tile damage experienced on STS-27, could result in burnthroughs and vehicle instability. (See Orbiter 18, IFA No. STS-28-30, page 6-14.)

Postflight examination found that the Orbiter TPS sustained a total of 76 hits of which 20 had a major dimension of 1" or greater. This total does not include approximately 100 to 150 hits on the base heat shield and degradation to the upper-surface white tiles that was not the result of debris impact. The distribution of hits on the Orbiter TPS does not point to a single source for ascent debris, but indicates a shedding of ice and TPS debris from random sources. The majority of the lower-surface damage was concentrated aft of the main landing gear doors, with approximately an equal amount on each side of the centerline. Based on the severity of damage as indicated by surface area and depth, this flight is considered to be better than average.

Postlanding walkdown of runway 17L was performed starting approximately 15 minutes after landing. Several pieces of the outboard forward corner tile from the right-hand main landing gear door were found near the end of the runway, close to the point where the landing gear doors were opened. The missing tile corner was approximately 6" x 4". Ten pieces of Ames gap filler material were also found in this area. A small piece of foil insulation material from the SSME nozzle was found approximately 200 yards from wheel stop.

2.2 Flight/Vehicle Data

- Launch Date: August 8, 1989
- Launch Time: 8:37:00.012 a.m. EDT
- Launch Site: KSC Pad 39B
- RTLS: Kennedy Space Center, Runway 33
- TAL Site: Ben Guerir, Morocco
- Alternate TAL Site: Moron, Spain
- Landing Date: August 13, 1989
- Landing Time: 9:37.53 a.m. EDT
- Landing Site: Edwards AFB, CA, Runway 17
- Mission Duration: 5 Days, 1 Hour
- Crew Size: 5
- Inclination: 57° (declassified after mission)
- Altitude: Classified (DoD)
- Orbiter: OV-102 *Columbia*
- SSMEs: 2019, 2022, 2028
- ET: ET-31
- SRBs: BI-028

2.3 Orbiter Experiments

The Orbiter Experiments (OEX) utilize the Space Shuttle as a vehicle to collect research-quality data in the technology disciplines that will augment the Research and Technology data base to support future spacecraft design concepts and enhance the operational efficiency of current spacecraft designs. Residual Development Flight Instrumentation (DFI) sensors aboard OV-102 are utilized to provide in-place direct measurements and recordings of Orbiter environment parameters to allow computation of Orbiter flight qualities and coefficients. Experiment hardware is installed and integrated with the data systems. The equipment is treated as an integral part of the Orbiter. Design is to Orbiter requirements and specifications (NSTS 07700, Vol. X), and for autonomous closed-loop operation independent of Orbiter systems or operations (except power, Interrange Instrumentation Group B (IRIG-B) time, Multiplexer-Demultiplexer (MDM) commands, active cooling). OEX functional failure will not affect primary mission success or Orbiter operations.

The OEX Systems are unique to OV-102 and are not installed on the other Orbiter vehicles. This will be the second flight with OEX Systems installed (the first flight was on STS-61C).

The OEX Systems flown on STS-28 are:

- SEADS - Shuttle Entry Air Data System
- SILTS - Shuttle Infrared Leeside Temperature Sensing
- ACIP - Aerodynamic Coefficient Identification Package
- SSO - Support System for OEX
  - SCM - System Control Module
  - Tape Recorder
  - PCM - Pulse Code Modulator
- FFSSO - Forward Fuselage SSO
- AIP - Aerothermal Instrumentation Package.

OEX Systems to be installed on OV-102 for STS-32 are:

- OARE - Orbital Acceleration Research Equipment
- TGHE - Tile Gap Heating Effects
- CSE - Catalytic Surface Effects
- AIPEH - Aerothermal Instrumentation Package Enhanced.

Other OEX Systems are:

- SUMS – Shuttle Upper Atmospheric Mass Spectrometer (was not flown on STS-28 due to lack of SUMS Orbiter Reinforced Carbon-Carbon (RCC) Chin Panel).
- HIRAP – High Resolution Accelerometer Package (was not flown due to malfunction, and corrective action did not support STS-28 launch date).

2.4 Payload

Payload Bay: Classified (DoD)

Middeck: Classified (DoD)

NASA Headquarters Safety, Reliability, Maintainability, and Quality Assurance did not participate in the Safety Reviews for the DoD payloads. NASA Headquarters Safety Division, Code QS, did participate in review of the Integrated Cargo Hazard Report (ICHR) by the System Safety Review Panel (SSRP).

SECTION 3

SAFETY RISK FACTORS/ISSUES IMPACTED BY STS-28 ANOMALIES

This section contains a list of the safety risk factors/issues, considered resolved or not a safety concern for STS-28 prior to launch (see Sections 4, 5, and 6), that were impacted or repeated by anomalies reported for the STS-28 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		
Orbiter 1	Gaseous Oxygen (GOX) Flow Control Valve (FCV) sluggish operation or lockup due to contamination.	There were no instances of sluggish GOX FCV operation reported on STS-28. However, the first instance of a sluggish Gaseous Hydrogen (GH_2) FCV was experienced. Space Shuttle Main Engine (SSME) GH_2 FCV #1 indicated sluggish response during the first three 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. Postflight leak checks found that FCV #1 was stuck in the open position. All three GH_2 FCVs were removed and sent to the vendor for inspection. Tolerances were found to be tighter than specification: 0.007" versus 0.009" to 0.013" specification tolerance. GH_2 FCV operation will be readdressed in the STS-34 MSE.
Orbiter 15	Environmental Control and Life Support System (ECLSS) freon coolant loop flow rates are degrading on OV-102.	As expected, the OV-102 freon loops flow continued to degrade during the mission. Freon loop #1 degraded approximately 50 pounds per hour (lb/hr) when the freon loop radiator panel outside temperature dropped below -60°F. Loop #2 degraded approximately 100 lb/hr during the same time period. The degradation in both loops has been attributed to possible water contamination in the freon. In both cases, the freon flow rate did not degrade below the Flight Rule minimum limit. Plans are to replace the pump package on loop #2 prior to the next OV-102 flight, STS-32.

	ITEM	COMMENT
Section 5: STS-30 Inflight Anomalies		
Orbiter 4	Fuel Cell (FC) #2 Hydrogen (H_2) flow meter failed.	On STS-28, FC #1 H_2 flow meter began to drift high at Mission Elapsed Time 12:30 and later exhibited erratic behavior with intermittent upper limit indications. Plans are to fly as is until there is a requirement to remove FC #1, since access to the flow meter requires FC removal.

SECTION 4

RESOLVED STS-28 SAFETY RISK FACTORS

This section contains a list of the safety risk factors that were considered resolved for STS-28. These items have been reviewed by the NASA safety community. A description and information regarding problem resolution is 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 investigation findings. 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

1	Ground Umbilical Carrier Plate pyrobolt Factor of Safety.
2	Instrument and Electronic Assembly anomaly.
3	Liquid Oxygen umbilical mate anomaly.

ORBITER

1	Gaseous Oxygen Flow Control Valve sluggish operation or lockup due to contamination. (IFA on STS-26, -27, and -29)
2	Right-hand brake line vibration at 55 Hertz.
3	Debris can prevent External Tank doors from closing.
4	Helium Regulator contamination.
5	Orbital Maneuvering System engine oxidizer inlet line.
6	OV-102 has two Multiplexer-Demultiplexers which may contain Erie ceramic capacitors that are prone to failure.
7	Data Processing System Data Bus timing.
8	Engine #3 Main Propulsion System Liquid Hydrogen Recirculation Pump damage.
9	Liquid Hydrogen Recirculation Pump failure. (STS-30 Preflight Anomaly)
10	Bolt failure in the Auxiliary Power Unit Gas Turbine module.
11	Liquid Oxygen Prevalve closure software implementation.
12	Shuttle Infrared Leeside Temperature Sensing Pod mass increase at tip of tail.
13	Improved Auxiliary Power Unit failure at Sundstrand.
14	Umbilical Retract Actuator may fail in extended mode.
15	Environmental Control and Life Support System freon coolant loop flow rates are degrading on OV-102.
16	Potential Auxiliary Power Unit exhaust duct leak.
17	Auxiliary Power Unit Fuel Isolation Valve anomaly.

SSME

1	Engine 0212 High-Pressure Oxygen Turbopump failure during testing.
2	High-Pressure Fuel Turbopump leak.
3	High-Pressure Oxidizer Turbopump balance piston cavity pressure port standoffs weld defects.
4	Low-pressure fuel duct flex joint failure.
5	Main Combustion Chamber/Nozzle G-15 seal crack/discoloration.
6	A High Pressure Fuel Turbopump bearing cage taken from stock for assembly was found to be cracked.
7	Improperly-sized Lee Jets could be installed in flight engines.

RESOLVED STS-28 SAFETY RISK FACTORS

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
INTEGRATION		
1	Ground Umbilical Carrier Plate (GUCP) pyrobolt Factor of Safety (FOS). HR No. INTG-115C INTG-141 ET P.05 ***No anomaly was reported relating to the GUCP pyrobolt.***	The actual STS-30 GUCP pyrobolt FOS is in question for STS-28 and subsequent flights. Analysis indicated that the FOS is below the NSTS 07700 Volume X requirement of 1.36 (assuming design winds of 47 knots). Some variation in the analysis outcome occurred due to lack of real loads data. For purposes of resolving this safety risk factor, the worst-case analysis result was used. Pyrobolt failure will result in premature disconnect of the Gaseous Hydrogen (GH_2) vent umbilical. During tanking operations, critical systems capability would be lost. Premature umbilical disconnect results in: • Loss of Helium injection during Liquid Oxygen (LO_2) loading (offload can be accomplished safely if detanking is started within 9 to 12 minutes of loss). • Loss of intertank purge, possibly allowing air intrusion leading to an explosive environment and frozen air in the intertank crotch area. • Loss of the Hazardous Gas Detection System (HGDS), leading to inability to determine the presence of hazardous gas. Premature umbilical separation could also cause arcing at electrical connections in the presence of vented hydrogen, resulting in possible fire or explosion. A special Level II Program Requirements Control Board (PRCB) review was held to resolve this issue and to determine the Launch Commit Criteria (LCC) to be employed for STS-28 tanking operations. Kennedy Space Center (KSC) presented calculated results of Pads A and B requalification testing relative to pyrobolt loading

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
<u>INTEGRATION</u>		
1 (Continued)		during tanking under various wind conditions; the minimum resulting FOS for the required 47-knot wind condition was 1.22. KSC also presented pyrobolt loadings and associated FOS measured using strain gages during tanking of the reflight missions. The lowest FOS recorded since STS-26 was 1.50. A key point was that current procedures for attaching the umbilical to the GUCP recommend a 0.003" gap be maintained between the GUCP and the umbilical. This is accomplished by adjusting four standoff bolts at the GUCP/umbilical interface. Failure to maintain this gap results in reduction of the pyrobolt FOS for a 47-knot wind to 1.19. Rockwell indicated that the current requirement for minimum bolt break force is 7500 pounds (lb). However, lot testing of the pyrobolts indicates that the break force is not lower than 8000 lb, thereby providing a potential additional margin of 500-lb force. The final PRCB decision relative to tanking operations was to accept an FOS of 1.22 for the pyrobolt. This resulted in LCC changes to allow tanking to begin if steady winds or low-frequency gusts do not exceed 30 knots. The LCC would allow tanking to continue after startup if 30- to 47-knot winds are experienced. If winds are 47 knots or greater, tanking would be halted, and detanking operations would commence. The PRCB also directed KSC to install strain gages on the pyrobolt for the next five launches on each Pad to collect actual pyrobolt load conditions data. The rationale for flight included: • 22% margin which assumes a minimum break force of 7500 lb. • 22% margin based on worst-case wind excursions and a 47-knot wind normal to the vent arm.

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
INTEGRATION		
1 (Continued)		• Poppets on both the External Tank (ET) and GUCP sides of the umbilical will close as soon as the umbilical separates and prevent hydrogen venting. • Detanking is possible per contingency operations. However, the appropriate value for calculating the pyrobolt FOS continues to be a subject of controversy. *This risk factor was acceptable for STS-28.*
2	Instrument and Electronic Assembly (IEA) anomaly. HR No. ORBI-038 INTG-144A *No IEA Multiplexer-Demultiplexer (MDM) anomalies were reported on STS-28.*	Erroneous readings were experienced during System Integration Test (SIT). The problem was isolated to the MDM. During failure analysis, the cause was isolated to a decoder chip within the Direct Current (DC) input to the A2-U9 control hybrid. There are 185 MDMs with this control hybrid configuration on the Orbiter. Five failures of this control hybrid configuration have occurred on Orbiter MDMs; however, none have been in the decoder chip. There is no evidence of a generic problem. A failure of this hybrid type would result in only the loss of the affected input/output module, with no mission impact of a flight critical MDM due to redundancy. On the Solid Rocket Booster (SRB), the failure affects only Criticality 3 communications. *This risk factor was acceptable for STS-28.*

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
INTEGRATION		
3	LO_2 umbilical mate anomaly. ***No anomalies were reported relating to the umbilical; however, a similar problem was experienced with the jacking bolts and umbilical plate during the STS-34 Orbiter/ET mating process.***	Three attempts were required to mate the LO_2 umbilical on STS-28. The first attempt was aborted due to high torque and a broken cotter pin on the forward, inboard jacking bolt. The second attempt was aborted when the umbilical plate moved toward the ET after removal of the jacking bolts for mate inspection. The third attempt completed the mate after the jacking bolt caps were removed due to high torque on the forward, outboard jacking bolt. Inspections were performed after each attempt. An Operational Maintenance Requirements and Specifications Document (OMRSD) waiver of in-process inspections during mating while using the jacking screws was approved. This umbilical mate was satisfactory because: • Inspections were performed up to the point where the poppet touched the flow liner; good alignment and parallelism were found at that point. • The umbilical plate was on the major diameter portion of the tapered guide pins on the three Ground Support Equipment (GSE) jacking bolts when the poppets first touched, providing substantial support and controlling alignment toward the mated position. • The two shear pins had just engaged the umbilical plate at poppet touch (visually verified, geometrically possible within tolerances), providing support and controlling alignment toward the mated position. • Turning of the three jacking bolts to full-mate position, after the plate moved freely, was very smooth, experienced very little running torque, and provided no misalignment indication or pinched hardware. • Leak checks showed zero leakage.

RESOLVED STS-28 SAFETY RISK FACTORS

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
<u>INTEGRATION</u>		
3 (Continued)		• ET monitoring showed no leakage. • Borescope inspections after the final mate showed no alignment discrepancies around the 17" flow liner and the 2" poppet. *This risk factor was resolved for STS-28.*

RESOLVED STS-28 SAFETY RISK FACTORS

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
<u>ORBITER</u>		
1	Gaseous Oxygen (GOX) Flow Control Valve (FCV) sluggish operation or lockup due to contamination. (IFA on STS-26, -27, and -29) HR No. INTG-150A ORBI-248A *No GOX FCV anomaly occurred on STS-28; however, a GH_2 FCV demonstrated sluggish operation.*	GOX FCV inflight anomalies occurred on STS-26, -27, and -29 due to contamination. During preflight checkout of STS-30/OV-104, out-of-specification GOX FCV operation was noted. All three STS-30 valve solenoid/poppet assemblies were removed and sent to Rockwell International (RI)/Downey for failure analysis; contamination was found. Subsequently, the valves were cleaned and polished before the STS-30 flight. Additionally, the ET Oxygen (O_2) tank ullage prepressurization level was lowered 2 pounds per square inch (psi) for the STS-30 flight to ensure that the valves were open at launch and stayed open for approximately 60 seconds into flight. Temperature stabilization occurs at approximately T+40 seconds. Once the temperature is stabilized, the history of these valves indicates normal cycling occurs. STS-30 flight data indicated that the GOX FCVs cycled satisfactorily. The poppets were pulled, and STS-28 GOX FCVs were inspected. No contamination was found. The valves were reassembled and tested. *This risk factor was resolved for STS-28.*
2	Right-Hand (RH) brake line vibration at 55 Hertz (Hz). HR No. ORBI-050 ORBI-180 *No further brake line vibration or noise problems were reported on STS-28*	During processing, the RH brake line on OV-102 experienced vibration at 55 Hz with brake pressure fluctuations measured at 250 pounds per square inch absolute (psia). This was the first occurrence on OV-102, although OV-099 experienced a similar condition prior to its first flight, and OV-103 also had an occurrence. The pressure was reduced on OV-099 by adding brake line brackets similar to what was done for OV-102. Testing and analysis by RI/Downey has indicated that the vibration is an acceptable condition providing that the pressure fluctuations do not exceed 75 psi. Addition of 12 clamps reduced the fluctuations to 36-48 psi. *Not a safety concern for STS-28.*

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
3	Debris can prevent ET doors from closing. HR No. ORBI-302A ***No debris was found in the umbilical cavity during STS-28 postflight inspection.***	An ET umbilical pyro retainer yoke clip, RH outboard, fell out of the umbilical cavity when the ET umbilical doors were opened. Two LO_2 detonators, one from RH Aft and one from RH Inboard, were missing and were not found on the runway. The concern was that debris could prevent ET umbilical doors from closing while in flight or on orbit. Rockwell performed a thermal analysis to determine problems resulting from the ET umbilical doors being ajar during deorbit and landing. Analysis identified that debris impingement on the ET door resulting in a step or 0.60" less is survivable, because the thermal barrier maintains contact. Results of the analysis also demonstrated that debris sources in the ET cavity can result in a worst-case step on the ET door of 3" to 4". A step of 1" was examined and found to result in a Criticality 1/1 event (loss of vehicle). The probability of debris causing a 1" or greater step appears to be remote. Rationale for risk acceptance was: • Nominal flight parameters – Orbiter moves in Z direction at ET separation and performs Orbital Maneuvering System (OMS)-1 burn prior to ET door closure (~ 7 minutes). • Transatlantic Abort Landing (TAL)/Return to Launch Site (RTLS) – ET doors close as soon as possible (~ 30 seconds). • Debris must change direction 90°, travel 9", and lodge into clevis to jam the door. • Debris must change direction 90° and travel ~ 7" to get trapped between ET door and seal.

RESOLVED STS-28 SAFETY RISK FACTORS

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
<u>ORBITER</u>		
3 (Continued)		• Door closure mechanisms are nearly totally enclosed; jamming is unlikely. • If doors fail to latch, they can be recycled in flight to dislodge debris that is preventing closure. While debris sources exist that can result in a Criticality 1/1 event, the risk to flight safety is minimal due to the small window identified for potential entrapment of debris in the door, and the fact that other debris trajectories are away from door mechanisms and the thermal barrier. ***This risk factor was acceptable for STS-28.***
4	Helium Regulator contamination. HR. No. ME-A1P ME-A2A ME-A2P ORBI-108E ORBI-111 ***No Helium Regulator anomalies were reported on STS-28.***	Main Engine (ME) #1 Channel B 750-psi Helium Regulator was removed and sent to the vendor due to excessive overshoot (880 pounds per square inch gage (psig) versus the 790-psig upper limit). Failure analysis at the vendor found contamination throughout the regulator. Inspection of the 1B leg of the Helium system found large amounts of corrosion material (FeCl) in the input side and inlet lines; the output side and outlet lines also had some contamination. Borescope inspection of the regulator inlet line identified the corrosion site as the brazed joint at the dynatube fitting. The filter upstream of the isolation valve in the 1B purge panel was found to be clean. The 1A leg was inspected and found to have normal contamination. Assessment of probable contaminant sources indicated that the chloride may have come from either the Tygon tube used for Argon purge or resulted from Freon suspected of being present during tube brazing. Investigation into the build process indicated that the fitting at the regulator inlet had been debrazed and replaced. (Chlorine disassociates from Freon or Tygon tubing when heated. If moisture is present, Hydrogen Chloride (HCl) is formed.)

RESOLVED STS-28 SAFETY RISK FACTORS

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
4 (Continued)		Extent of the contamination was determined. The lines were cleaned. The filter, regulator, Check Valve (CV) #29 and Relief Valve #8 were removed and replaced. CV #29 was found to be contaminated. After the contaminated components were removed and replaced, the panel was functionally tested with successful results. The lines were sampled again for contamination. Blowdown was performed with good results. Mechanical and braze joints were satisfactorily leak checked. *This risk factor was resolved for STS-28.*
5	OMS engine oxidizer inlet line. HR No. ORBI-054 ORBI-111 ORBI-120 *No OMS oxidizer leaks were experienced on STS-28.*	A pinhole leak was found on the OV-103 RH engine after STS-29. A droplet was found on the exterior of the tube. The leak was discovered in the Hypergol Maintenance Facility (HMF) after the pod was removed from OV-103. A pinhole was found in parent metal. The engine was flown on two missions (STS-26 and STS-29). Helium leak test indicated leakage of 8×10^{-9} standard cubic centimeters per second (sccs) at 160 psi. This is a very small leak and well within specifications. Orbiters were previously flown with leaks of this magnitude. The line was removed and sectioned through the leak location; metallurgical tests were performed. A large inclusion was found within the tube material at the leak location. Branched cracking emanated from the inclusion to the tube Outside Diameter (OD) surface. The crack at the tube OD measured 0.020" long. A corrosion pit was observed at the tube Inside Diameter (ID). The material was verified as 21-6-9 Corrosion Resistant Steel (CRES) annealed tubing.

RESOLVED STS-28 SAFETY RISK FACTORS

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
<u>ORBITER</u>		
5 (Continued)		STS-28 was not flown with a known condition of this type. In the event that a similar condition would develop, the following inlet line features reduce the risk of progressing to a serious anomaly during flight: • The material is very ductile, so the crack would not propagate. • Flight pressure is 250 psi versus 630-psi proof pressure and 825-psi burst pressure. • Flight stress is 7.5 ksi versus 100-ksi material ultimate stress. This data shows a large margin for stress. Rationale for flight was based on no detected leak on STS-28 and the large stress margin. ***Not a safety concern for STS-28.***
6	OV-102 has two MDMs which may contain Erie ceramic capacitors that are prone to failure. HR No. ORBI-038 ***No anomalies were reported relating to STS-28 MDMs.***	In 1981, Erie capacitors were found to be failure prone due to a low-resistance short. The Orbiter Program Office directed that the capacitors should be purged from increment III MDM builds and directed that replacement of the capacitors on OV-102 would be by attrition or when the MDMs were returned to the vendor. OV-102 MDM Serial Number (S/N) 63, a Flight Aft MDM of Criticality 1R2, and S/N 68, a Launch Data Bus MDM of Criticality 3/3, were not modified subsequent to this direction because they have not failed.

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
6 (Continued)		Investigation found that MDM S/N 63 has 96 analog input channels containing 96 Erie capacitors, and S/N 68 contains 32 Erie capacitors. In S/N 68, the analog input channels are not used. Worst-case failure assessment indicated that: • LCC require both MDMs to be operational. • The Launch Data Bus MDM is powered off after launch. • The Flight Aft MDM can become Criticality 1 if the first failure is not detected by redundancy management, and a second failure of the same channel of another Flight Aft MDM occurs. (The Flight Aft MDMs are employed in conjunction with the Rate Gyros.) MDMs S/N 63 and S/N 68 were considered flightworthy because: • There is channel redundancy through separate MDMs (which do not contain Erie capacitors). • The capacitors through which the critical Rate Gyro data passes were determined to be from a lot of Erie capacitors that have no history of failure. • There have been no flight failures of MDMs caused by Erie capacitors. ***This risk factor was acceptable for STS-28.***

RESOLVED STS-28 SAFETY RISK FACTORS

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
7	Data Processing System (DPS) Data Bus timing. HR No. ORBI-066 ***No Data Bus timing-related anomalies were reported on STS-28.***	New General Purpose Computers (GPCs) (AP-101S) #509 and #005 failed during testing at Johnson Space Center (JSC) Avionics Engineering Laboratory. The GPCs recorded bad data on flight-critical data buses and failed with local store parity errors. The bad data source was isolated to the new MDM simulator. Data words sent to the GPCs were spaced too close together. Nominal spacing is 5 to 6 microseconds between 28-microsecond data words. The MDM simulator spaced words 0.5-microsecond apart. As a result, the GPC stored corrupted data at one location in memory. Circuit analysis revealed single-failure points in the MDM and Serial Multiplexer Interface Adapter (SMIA). Analysis was performed for the Main Engine Controller (MEC), Engine Interface Unit (EIU), Display Electronics Unit (DEU), and other Bus Terminal Units (BTUs). All single-failure points resulted in a data stream with all zeros or all ones. System-level protection can detect this as Input/Output (I/O) errors, resulting in string bypass only. This failure mode has a low probability of occurrence based on failure history. There is also a high degree of system-level protection from bad data. The worst-case effect is one or more GPCs fail to sync. The most likely effect is bypass of a flight critical string. If all GPCs fail, the Backup Flight System (BFS) is still available.

RESOLVED STS-28 SAFETY RISK FACTORS

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
<u>ORBITER</u>		
7 (Continued)		Rationale for flight included: • All data bus terminal units were analyzed. • Due to the simplicity of the multiplexer interface adapter interface, all failure modes are bounded. • All worst-case scenarios are covered by word count and checksum verification methods. • All identified single failures were determined as not a threat to the data processing system. • All identified failures are covered by existing CILs. ***This risk factor was acceptable for STS-28.***
8	Engine #3 Main Propulsion System Liquid Hydrogen (LH_2) Recirculation Pump damage. HR No. INTG-167 ***No anomalies were reported relating to STS-28 LH_2 Recirculation Pumps.***	Damage was found on Engine #3 LH_2 Recirculation Pump impeller slots during disassembly for connector potting modification. Large debris was determined to have caused damage to the pump. Damage could have occurred either during use at the Main Propulsion Test Facility as a test article or on OV-102 during a flight since STS-1. Pump operation was unaffected. The prevalve screen was found to be clean during a recent inspection. No damage was found in the scroll housing. A dry spin test was successfully completed. The pump was replaced. ***This risk factor was resolved for STS-28***

RESOLVED STS-28 SAFETY RISK FACTORS

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
<u>ORBITER</u>		
9	LH_2 Recirculation Pump failure. (STS-30 Preflight Anomaly) HR No. INTG-167 ***No anomalies were reported relating to STS-28 LH_2 Recirculation Pumps.***	During the first prelaunch countdown for STS-30, the LH_2 Recirculation Pump that supports ME #1 failed. An intermittent short and arcing in the power connector popped the phase B circuit breaker. A small amount of contamination was found to have caused a short between the phase B power pin and the case (internal) causing all pumps to shut down. This resulted in a recycle and eventual launch scrub. The pump was replaced, and the system operated properly throughout the subsequent STS-30 launch. A similar failure was seen during STS-1 tanking test and STS-51 launch attempt. A design change, the addition of connector potting, has been effected for all Recirculation Pump motors. Existing STS-28/OV-102 Recirculation Pumps were replaced with modified units. ***Not a safety concern for STS-28.***
10	Bolt failure in the Auxiliary Power Unit (APU) Gas Turbine module. HR No. ORBI-268 ***No APU anomalies were reported on STS-28 relating to bolt failure.***	Bolts used in the APU Gas Turbine module were suspected of yielding when torqued to the drawing requirement of 46-51 inch-pound (in-lb). Ten bolts are located in the Gas Generator (GG)-to-exhaust housing and 6 bolts in the balance assembly-to-containment housing. Maximum torque with a positive Margin of Safety (MS) is 31 in-lb; however, analysis indicated that this is not sufficient to maintain preload. Analysis of housing materials verified that housing threads will not yield. The condition was discovered during thermal expansion analysis of the new Orbiter exhaust housing material. Thermal expansion was evaluated to determine if seal integrity was lost. Results of independent analyses by United Space Boosters, Inc. (USBI) and Sundstrand indicated positive preload in the bolts at the maximum operating temperature of 800°F. The housing remained clamped, so E-seal compression is not affected. Twelve bolts were torqued to determine maximum permanent elongation; 6 showed elongation (max. of 0.0009"). Change to

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
10 (Continued)		higher-strength bolts for APU units is planned for flights subsequent to STS-36. Analysis of the housing indicated it can withstand high-strength bolts. Lot testing of A-286 (MS21288) bolts at Sundstrand consistently showed minimum ultimate strengths of 173 ksi. Therefore, based on the lot sampling size, there was no structural or performance issue with the specified torque condition. Analysis indicated that, even at the specification strength values, bolt failure or hot-gas leak will not occur due to this condition. The SRB and Orbiter APU qualification and flight history indicated no bolt failure or hot-gas leaks, and all APUs have successfully passed leak test at Sundstrand and KSC. ***Not a safety concern for STS-28.***
11	LO_2 Prevalve closure software implementation. HR No. INTG-019 ***There were no SSME failures or shutdown in the risk window prior to STS-28 Main Engine Cutoff (MECO).***	This problem requires a Space Shuttle Main Engine (SSME) failure within 4.5 seconds prior to MECO. The requirement states that the LO_2 Prevalve closure shall occur 1.078 seconds after three cycles of shutdown at MECO or 4.5 seconds after three cycles of shutdown for an engine which fails pre-MECO. However, no specific requirements exist for the LO_2 Prevalve closure if MECO occurs during the pre-MECO 4.5-second time. Prevalve closure at SSME shutdown was designed to protect the engines in two areas of concern: • SSME High-Pressure Oxidizer Turbopump (HPOTP) overspeed during zero-g shutdown caused by fluid cavitation in the HPOTP. (The maximum allowable pump speed is approximately 38,000 revolutions per minute (rpm).)

RESOLVED STS-28 SAFETY RISK FACTORS

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

<u>ORBITER</u>

11 (Continued)

- Overpressurization of the Orbiter 12" feedlines. (Proof pressure is 330 psig; burst pressure is 413 psig.)

In the Primary Flight Software (PFS), the prevalve timer is reset to 1.08 seconds at MECO. The PFS then commands the prevalve "closed" on the failed engine 1.16 seconds after MECO. The BFS timing for the same scenario differs. AT MECO, the BFS compares the time expended on the timer. If less than 1.08 seconds has been expended, it allows the timer to continue to 1.08 seconds and then commands the prevalve to close. If the expended time is greater than 1.08 seconds, the BFS immediately commands the prevalve to close (at MECO).

Initial pre-STS-28 analysis determined that the BFS timing for prevalve closure is adequate to meet the overspeed requirement. The PFS, however, does not close the prevalve in time to adequately protect the HPOTP from an overspeed condition. If shutdown time for the failed engine is 1.2 seconds or less before MECO, the result is a 0.1-second interval of critical exposure to the overspeed condition. This analysis also determined that conditions near MECO do not result in overpressurization of the 12" feedlines. Maximum inlet pressure at engine shutdown when the prevalve effectively closes is 130 psia. The post-shutdown pressure rise with worst-case conditions indicates that a maximum pressure of 315 psia is possible. This data was correlated with the STS-26 flight readiness firing data where there was a fast prevalve timer (1.08 seconds).

Post STS-28 investigation found an error in preflight analysis of software timing. It has been determined that the LO_2 prevalve closes 0.16 second earlier than thought prior to STS-28. The result of this determination is that a 0.10-second window for SSME pump overspeeding does not exist.

This risk factor was resolved for STS-28.

RESOLVED STS-28 SAFETY RISK FACTORS

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
12	Shuttle Infrared Leeside Temperature Sensing (SILTS) Pod mass increase at tip of tail. ***No related anomalies were reported on STS-28.***	The SILTS system is installed on OV-102. The SILTS pod is located at the tip of the vertical tail and adds 300-lb mass to the tail. This large tip mass results in significant change to the frequencies of the tail modes and causes OV-102 not to meet the descent flex stability attenuation/stability margins with the baseline bending filters. Reassessment of SILTS Pod loads, tail loads, flutter, POGO, and flight control system stability was undertaken. Pod airloads were determined to have an FOS greater than 1.4. Tail loads with and without the SILTS Pod compared within 2% using existing load indicators in critical Mach ranges. The Day of Launch (DOL) load indicators will protect the tail from load exceedances. The flutter margin increased as a result of the forward center of gravity of the SILTS mass. POGO sensitive modes couple slightly with the tail but result in an insignificant change in stability. Evaluation of the flight control system identified the requirement for a filter change during reentry. Roll filter modifications (15 I-loads) were incorporated for STS-28 and verified for flight. ***This risk factor was acceptable for STS-28.***
13	Improved Auxiliary Power Unit (IAPU) failure at Sundstrand. HR No. ORBI-030A ORBI-031 ORBI-326A INTG-113 ***No APU anomalies were reported on STS-28 relating to the Magnetic Pickup Unit (MPU).***	The IAPU failed to return to normal speed during a high-speed Acceptance Test Program (ATP) run. The IAPU was then manually shut down. MPU #3 failed open causing the IAPU to remain at high speed when the normal speed switch was activated. A broken wire coil was suspected to be the cause of failure. This was a similar failure mode to two previous APU/MPU problems. MPU design incorporates very small diameter 40-gage wire which can break easily if mishandled. There are 3 MPUs on each APU. MPU #1 is used with the safety fuel flow monitoring function and cuts off APU fuel flow if underspeed or overspeed is detected. MPU #2 controls fuel flow for high-speed APU operations. MPU #3 controls APU speed at the normal setting. This failed MPU is the same as the MPUs that are currently flown in the baseline APUs.

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
13 (Continued)		Discussion of MPU failure at the STS-28 Flight Readiness Review (FRR) Action Item Closeout Meeting identified consequences to the SSME hydraulics systems. Two main engines will go into hydraulic lockup from the loss of one APU, and the loss of two APUs could result in a catastrophe. Loss of a second APU during ascent will result in shutdown of one main engine and selection of an abort mode. While there is some thought that one APU could supply sufficient hydraulic power to maintain control during ascent, this mode has not been certified. This hazardous condition is documented in Hazard Report INTG-113 as catastrophic. Similarly, it is not certain that one APU could supply all required hydraulic power to the aerosurfaces during descent. An APU that has been shut down must have a minimum cooldown period of 209 seconds, provided that all else affecting the APU and hydraulics is normal. Where the shutdown is due to instrumentation, as in the case of an MPU failure, the failed instrumentation may be overridden by the crew. In an emergency, such as the shutdown of a second APU, the crew may elect to risk startup of an APU prior to the elapse of 209 seconds, but there is the potential of an explosion or fire in the catalyst bed. There are obviously periods in a flight when the 209 seconds could not be accommodated if the shutdown of an APU becomes mandatory. Until such time as the capability of the Orbiter to maintain control with only one APU operational during ascent or descent is certified, it was determined that a failure of MPU #3 is a Criticality 1R2 event instead of the previously determined Criticality 1R3. This is because failure of second APU becomes a Criticality 1/1 event.

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
13 (Continued)		The rationale for risk acceptance was: • The Orbiter will not be launched with one or more APUs inoperative. • In the event of an APU shutdown, flight rules result in the crew inhibiting automatic shutdown of the remaining two APUs by instrumentation. (Other risks from this action were accepted by the Program.) • The probability of multiple, concurrent APU failures is low. ***This risk factor was acceptable for STS-28.***
14	Umbilical Retract Actuator may fail in extended mode. HR No. ORBI-302A ***No Umbilical Retract Actuator failure was experienced on STS-28.***	A new failure mode was discovered that could lead to potential ET door damage or door interference -- inadvertent extension of one actuator due to leakage of the extend solenoid O-ring. During orbiter/ET mate for STS-26, it was discovered that one actuator was in hydraulic lock. The actuator was removed, replaced, and shipped to the vendor. Teardown at the vendor revealed erosion of both solenoid valve O-rings. The retract O-ring was more severely damaged, to the point of rupture. Cycling of the actuator with new O-rings installed resulted in an eroded retract O-ring similar to the failure observed in the returned actuator. The extension O-ring was undamaged after cycling with new O-rings. Analysis of the failed STS-26 umbilical plate actuator found that a port on the retract solenoid valve/manifold had been improperly drilled. The O-ring was being chewed up by the sharp edge caused by improper drilling pressure cycles. The extend solenoid valve/manifold configuration precludes this specific problem, but seepage past the O-ring could result in uncommanded extend of an actuator any time the APUs are running. A detailed geometric analysis found that if the #3 LO_2 umbilical actuator inadvertently extended, guide pin #1 would interfere with ET umbilical door closure.

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
14 (Continued)		During a TAL timeline, there is a possibility of the LO_2 Orbiter/ET umbilical plate interfering with full closure of the ET door (given an extend O-ring failure of the actuator). Due to the TAL timeline, the retract command, and thus the hydraulic power, is removed from the actuator prior to full door closure. In the worst-case scenario, the LO_2 outboard actuator could inadvertently extend or drift, causing the plate to interfere with the ET door. This would result in a 0.48" step, or opening, on the outboard side of the door (away from the door hinges). Door latch mechanisms would secure the door in the near-closed position. Thermal assessment showed that airflow (hot gas flow) into the umbilical cavity would be restricted by thermal barrier contact. Local high temperatures are predicted that would cause potential tile slumping. The structural and umbilical plate curtain seal would remain intact; therefore, there would be no flow of hot gasses into the aft fuselage. The resulting effect of the 0.48" step in the door would not result in a catastrophic condition. In an RTLS scenario, the timeline allows the ET door to close prior to removal of the retract command. The result would be an uncommanded extend of the actuator after ET door closure and a point load on the door. For the point load condition, it was determined that, while the door will be damaged, the loads are insufficient to cause the door to fail. The FOS in the worst case is 3.09. The door closure timeline for a normal MECO scenario showed interference would not prevent door closure. The timeline for ET door closure and APU shutdown would leave the actuators in free float. At APU startup for reentry, the actuator would extend and place a point load on the ET door.

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
<u>ORBITER</u>		
14		Rationale for flight included: • Actuator extend O-ring failure is not likely; there is no experience of failure of this O-ring to date. • If the extend O-ring should fail and result in an actuator extend condition during a TAL scenario, the resultant step in the ET door is survivable. • Extension of the actuator onto a closed door does not fail the door or hardware. • The actuators on OV-102 were verified to be within acceptable limits through standard OMRSD testing. • Additional confidence testing was performed to verify no inadvertent extend indications. The actuators were allowed to sit under pressure for a period of time, and the stroke was measured. ***This risk factor was acceptable for STS-28.***

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
15	Environmental Control and Life Support System (ECLSS) freon coolant loop flow rates are degrading on OV-102. HR No. ORBI-275A ***As expected, the freon loops flow on OV-102 continued to degrade during the mission. Freon loop #1 degraded approximately 50 lb/hr when the freon loop radiator panel outside temperature dropped below −60°F. Freon loop #2 degraded approximately 100 lb/hr during the same time. See IFA No. STS-28-15. This degradation was attributed to possible water contamination in the freon. In either case, at no time did the freon flow degrade to the minimum Flight Rule redline limit. Plans are to remove and replace the inline filters in freon loop #2 prior to STS-32.***	Freon flow rates in the ECLSS have degraded on OV-102 since its first flight. Investigation revealed teflon particles in the system filters, and a significant increase in system pressure drop was found at the radiator flow control assembly inlet. The teflon particle source was later traced to Krytox lubricant, used on connection threads, that was not totally removed from the freon loop. Current OV-102 flow rate degradation is similar to the condition seen prior to STS-9, but it is not as severe. Current flow rates on OV-102 freon coolant loop #2 interchanger are approximately 2145 to 2175 lb/hr. This is in the interchanger position with the radiators bypassed. Current flight rule redline for STS-28 is 2150 lb/hr flow at the interchanger, based on early assessment by Rockwell using 5 GPCs with the avionics bay temperatures being the limiting factor. This is 5% above the determined minimum of 2025 lb/hr. The 5% is added to compensate for possible instrumentation error. Analysis methods have improved, resulting in more accurate models that correlated well with flight data. Constraining areas are the cabin temperature/humidity, avionics bay temperatures, and the fuel cell coolant return temperature. At the STS-28 FRR Action Item Closeout meeting, a change in the flight rules was proposed and approved to change the redline for the interchanger flow from 2150 lb/hr to 1975 lb/hr while maintaining a 5% instrumentation allowance. If one of the two freon coolant loops drops to this flow on orbit, a decision to return will be made (either next day or first day primary landing site). This protects the 3-GPC reentry requirement if the good freon coolant loop should then fail. If both loops are operating, and only one has dropped below 1975 lb/hr, the deorbit/reentry would be conducted with all GPCs and instrumentation up. Because the flight rule was changed, the LCC was also changed. Given that the LCC redline limit for the

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
15 (Continued)		freon coolant loop must maintain 100 lb/hr flow rate greater than the flight rule redline, the LCC is 2075 lb/hr. For the payload position, the interchanger flow redline is 1400 lb/hr. As of August 4, 1989, the readings were 2177 lb/hr and 1410 lb/hr. Rationale for acceptance was: • Better modeling and flight experience indicates adequate cooling can be maintained with the lower flow rates. • Flight history shows that the lowest flow rates occur while the Orbiter is vertical in the Vehicle Assembly Building (VAB) and on the Launch Pad (LP) because the cold fluid must be forced up 60 feet (ft) and the hot fluid must be forced down 60 ft. The 50 to 60 lb/hr flow rate lost in the VAB and on the LP recovers on orbit. • Assuming recovery on orbit occurs, there is a 200+ lb/hr margin to a single-loop 5-GPC reentry and a 300 lb/hr margin to a single-loop 3-GPC reentry. The predicted worst-case degradation would still permit a 5-GPC single-loop reentry. • Flight Controllers monitor coolant flow throughout the flight. If degradation exceeds the predicted worst case, Flight Controllers can detect the decrease in flow and plan reentry to avoid the potential of less than a 3-GPC reentry on a single loop. ***This risk factor was acceptable for STS-28.***

RESOLVED STS-28 SAFETY RISK FACTORS

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<u>ORBITER</u>		
16	Potential APU exhaust duct leak. HR No. ORBI-268 *No abnormal discoloration was seen in APU #1 and #2 exhaust ducts area during postflight inspection.*	Following the APU confidence run, inspection found discolored Koropon and charred wiring in the area adjacent to APU #1 and #2 exhaust ducts. Discoloration is normal and is present after every APU run. The duct may normally reach temperatures exceeding 400°F at exterior insulation seams; Koropon discolors at 35°F. There was no evidence of hot-gas leakage from the ducts, and leak checks verified duct integrity. Additionally, HGDS data indicated no hydrogen buildup in the aft compartment. Discoloration and scorching are in an area exposed to the STS-9 APU fire that occurred during descent. Post-STS-9 photographs of the area verified that the origin of discoloration and scorching was the STS-9 APU fire. *Not a safety concern for STS-28.*
17	APU Fuel Isolation Valve (FIV) anomaly. HR No. ORBI-103 A-20-25 *The APU FIV performed nominally during STS-28.*	There are two FIVs in parallel paths on each APU. The FIV functions to isolate Hydrazine in the fuel tank from the APU when the APU is not used. Each FIV has a reverse relief function to relieve pressure on fuel trapped in the fuel distribution line on the APU side of the isolation valve when both valves are closed. The valve relieves the APU-side pressure when the pressure is 40 psi to 200 psi above fuel tank pressure. When the APU is turned off, the FIV is commanded closed. APU #2 FIV B indicated "open" after commanded closed following the APU confidence run. The APU-side pressure and fuel tank pressure remained equal, indicating that the valve was stuck open. Tank pressure was increased to flight level, and downstream pressure remained the same, indicating that the increased tank pressure closed the isolation valve. No increase in pressure on the APU side

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
17 (Continued)		has been recorded under normal conditions. This isolation valve has also allowed pressure releases from the APU side to the tank at lower than 40-psi differential pressure for which it was designed. This FIV is the same valve that was removed from OV-104 for the identical failure and returned to the vendor. The failure could not be duplicated at the vendor. However, subsequent investigation found that the vendor did not test the FIV under flight conditions. The vendor baked out the Hydrazine prior to conducting the test. It was determined that the failure was caused by swelling of the seat material when exposed to Hydrazine. This swelling causes the poppet to displace sufficiently to activate the open indication (0.001" to 0.002"). The displacement also results in weakened magnetic force used to hold the poppet closed against pressures on the APU side. This explains why the FIV is allowing relief flow from the APU side at low differential pressures. Rationale for flight was that fuel tank pressurization to flight levels was demonstrated to ensure that the FIV is closed. ***This risk factor was acceptable for STS-28.***

RESOLVED STS-28 SAFETY RISK FACTORS

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
<u>SSME</u>		
1	Engine 0212 HPOTP failure during testing. HR No. ME-C1A Rev. A ME-C1C Rev. A ME-C1M Rev. A ***No HPOTP-related anomalies were reported for STS-28.***	Engine 0212 experienced structural damage and premature shutdown during test firing on June 23, 1989, due to low Chamber Pressure (PC) redline monitor (at 1270 seconds of planned 1338-second test). This was a development/certification engine with a nonflight-configuration HPOTP. The test pump was also used to test modifications for potential design changes to flight pumps. The potential that one of these modifications caused the failure was part of the investigation. The pressure containment wall was ruptured in two places where the HPOTP turbine end came apart. There was a post-shutdown hydraulic/Hydrogen (H_2) fire due to rupture of the Oxidizer Preburner (OPB) bowl below the girth weld which caused minor engine external damage. Pneumatic control assembly damage and main oxidizer valve neck fracture prevented engine valve closure. The engine was shipped back to Rocketdyne where detailed inspection and analysis revealed that pump bearing #2 failed. The failed unit had 14 starts and 6000 seconds. It also had bearing wear dynamic signature prior to failure test. Two other pumps in the program experienced similar failures. One failure occurred after 4700 seconds and the other after approximately 5200 seconds of operating time. All failed units had bearing wear dynamic signatures prior to the failure test. Rationale for flight was as follows: • The flight pumps are not the same configuration as the pumps that failed. • Flight hardware pumps are allowed to operate for a maximum of 2000 seconds before they are taken out of flight status. All three pumps on STS-28 had much less than 2000 seconds of operating time. There will be 4 starts and 1750 seconds on the highest OV-102 unit at end of mission (520 seconds).

RESOLVED STS-28 SAFETY RISK FACTORS

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
SSME		
1 (Continued)		• Flight units passed all preflight torque tests, turbine end bearing micro-travel checks, and borescope inspections. • Flight pumps are not allowed to have bearing wear dynamic signature (measured with external accelerometers). None of the STS-28 pumps had any wear signature when tested. ***This risk factor was resolved for STS-28.***
2	High-Pressure Fuel Turbopump (HPFTP) leak. HR No. ME-A1P ME-D3A ME-D3C ME-D3D ME-D3M ME-D3P ME-D3S ***No further leaks were reported, and the STS-28 HPFTPs performed nominally.***	A leak was discovered in the HPFTP on ME #1 during Helium signature leak test. The pump was removed and replaced. However, during post-installation testing the pump-to-engine seal was found to be leaking. The pump was backed away from position slightly, and the seal was replaced. The seal passed leak tests, but another leak was discovered at a bearing cap on the fuel pump. The cap was pulled, and the sealing surfaces were repaired. Seal leak checks were successfully conducted; no new leaks were found. ***This risk factor was resolved for STS-28.***

RESOLVED STS-28 SAFETY RISK FACTORS

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
SSME		
3	HPOTP balance piston cavity pressure port standoffs weld defects. HR No. ME-C1A ME-C1C ME-C1D ME-C1M ME-C1S ME-B6A ME-B6C ME-B6M ME-B6S	During borescope inspection of welds completed on the HPOTP housing of 16 development units (32 welds), 25 welds were found with incomplete penetration/lack of fusion. Incomplete penetration indications ranged from 30° to 360° of circumference. Seven welds had no discrepancies. An eddy current inspection on 22 welds indicated varying degrees of lack of penetration/lack of fusion in all welds. Three additional scrapped housings were identified to provide additional weld samples to correlate eddy current readings to actual defect depth. There have been no weld failures in the program. Projected worst-case failure effect is low-level Liquid Oxygen (LOX) leakage (0.00024 LBM/second) assuming a through crack, 50% of circumference on one toadstool. Leak checks on OV-102 HPOTPs were completed, and HPOTP tests were satisfactory.
	No HPOTP-related anomalies were reported for STS-28.	***This risk factor was resolved for STS-28.***
4	Low-pressure fuel duct flex joint failure. HR No. ME-D3A ME-D3C ME-D3M ME-D3S ***No flex joint failures or fires in the area of the flex joints were reported on STS-28.***	Engine 2206 experienced an external hydrogen fire and premature shutdown at 147.5 seconds of the 300-second planned test at Stennis Space Center (SSC). The failure occurred at the low-pressure fuel duct flex joint C tripod (ball end). A high-cycle fatigue crack initiated at the inner radius of tripod leg #1 in the flex joint. Its subsequent fracture resulted in the fracture of legs #2 and #3. The flex joint did not leak or fail. Debris from the failed tripod caused punctures downstream in the duct wall at the elbow. Gas flow through the punctures, had this been on a flight, would probably have caused overpressurization of the Orbiter aft compartment and possible catastrophe. Cause of the high-cycle fatigue was traced to improper machining of the radius of the leading edge on some lots of the tripods by an SSME subcontractor due to lack of specificity in the specification.

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
SSME		
4 (Continued)		The failed unit was the cycle fleet leader with 90 starts/31,853 seconds and the gimbal fleet leader with 19.5 equivalent gimbal cycles. The leg at the primary fracture was confirmed to have an undersize radius and thin profile contour. This failure was explained by existing geometry and projected stresses over 31,000 seconds of hot fire. OV-102 has legs from a suspect lot in flex joint A on ME 2022. OV-102 fabrication and vendor records showed that engine 2022 flex joint "A" with the suspected contour will have less than 10% of the fleet leader exposure after the next flight (32 units with greater exposure). Rationale for flight was based on low-exposure time. ***This risk factor was acceptable for STS-28.***
5	Main Combustion Chamber (MCC)/Nozzle G-15 seal crack/discoloration. HR No. ME-D3C ME-D3M ***No G-15 seal anomalies were reported during postflight inspection of STS-28 SSMEs.***	A stress rupture crack was discovered in the G-15 seal on engine 2019 post STS-26. High-temperature exposure resulted from hot gas recirculation. A hot gas recirculation driver is coolant tube protrusion (primary contribution); other effects involve the MCC/Nozzle annulus gap. Bluing was subsequently discovered on the seal from STS-30. For engine 2031, bluing was not predicted preflight because the protuberance was < 0. Further investigation revealed that machining of the aft end lip contour and the nozzle seal lip configuration also affected the hot gas recirculation problem. Engines were cleared for STS-30 flight by comparison with characteristics of other engines in the SSME family. OV-102 Engines were acceptable for flight based on: • Engine 2019 has a large effective protrusion/gap margin. The MCC lip is not machined; the nozzle seal lip is also not machined. This engine is acceptable for 13,000 additional seconds.

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
<u>SSME</u>		
5 (Continued)		• Engine 2022 had the seal replaced prior to flight. The nozzle seal lip is not machined. Acceptability was demonstrated in the previous hot fire (2300 seconds). 8250-second life is based on stress rupture curve. • Engine 2028 had the seal replaced prior to flight. The nozzle seal lip is not machined. Acceptability was demonstrated in the previous hot fire (1312 seconds). 8250-second life is based on stress rupture curve. ***This risk factor was acceptable for STS-28.***
6	An HPFTP bearing cage taken from stock for assembly was found to be cracked. HR No. ME-D1A Rev. A ME-D1C Rev. A ME-D1D ME-D1M ME-D1P ME-D1S ***No cage cracks were reported during postflight inspection of STS-28 HPFTPs.***	During the accumulation of hardware for HPFTP assembly, inspection of bearing components revealed a surface crack in a bearing cage ready for pump assembly. The bearing cage was just pulled from stock and had not seen hot fire. It had passed vendor inspection prior to being placed in stock. As a result, bearing cage inspection criteria have been tightened. Inspection of 708 bearing cages in stock and in process at Canoga Park resulted in rejection of 19 (2.7%). The rejected bearing cages had scratches and nicks; none were cracked. The races on OV-102 HPFTPs were not subjected to the new inspection criteria. The cages on OV-102 HPFTPs were acceptable because: • Test history indicates that cracks are related to total time. Deviation Approval Request (DAR) limits flight pump operating life to 2000 seconds based on lowest time of 4000 seconds for a through crack. The OV-102 units will not exceed 2000 seconds after a normal flight. • In the event of an aborted flight, the 2000-second limit would be exceeded by less than 6%; there is still almost a factor of 2 margin relative to the lowest time of 4000 seconds for a through crack.

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
<u>SSME</u> 6 (Continued)		• 63 bearings tested without failure for 2000 to 2200 seconds. • 3-engine probability that cages are not cracked is now 0.9998 (0.9995 after abort duration). • Wear versus time margin indicated by ball and cage are normal. ***This risk factor was acceptable for STS-28.***
7	Improperly-sized Lee Jets could be installed in flight engines. HR No. ME-B3C ME-B3M ***No SSME anomalies were reported on STS-28.***	Lee Jets are used to control flow at 5 locations in the OV-102 SSMEs: • MCC PC Sense Line • Gaseous Oxygen Control Valve (GCV) Fail-Safe Orifice • High-Pressure Valve (HPV) Check Valve • Fuel Component Drain Purge • Duct Bag Purge. An improperly-sized Lee Jet was found installed in a GCV (pneumatic override) during component acceptance test. This was due to misidentification of a Rocketdyne part number at the manufacturer. Rationale for flight was based on: • The proper Lee Jet size was verified by test/flight data for: – MCC PC Sense Line – GCV Fail-Safe Orifice – HPV Check Valve.

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
SSME		
7 (Continued)		• The proper Lee Jet size was verified by flow measurement for: – Fuel Component Drain Purge – Fuel Duct Helium Bag Supply. *Not a safety concern for STS-28.*
8	Engine 0209 Heat Exchanger leak. HR No. ME-B3A ME-B3C ME-B3M ME-B3S *No Heat Exchanger leaks were identified on STS-28.*	A Heat Exchanger leak was detected on development engine 0209. The leak was isolated near weld joint #4. No growth in the leak was seen after 5 proof cycles (3150 psig Gaseous Nitrogen (GN_2)). The equivalent leak hole diameter is 2×10^{-5} inches for a 1.2×10^{-7} sccs helium leak (engine 2027). Analysis revealed a low probability for a detrimental leak, and the leak was not hazardous to engine operation. Engine 0209 on test stand A-1 was tested at SSC on August 3, 1989. The test firing objective was to run the engine for 1075 seconds to determine if the Heat Exchanger leak would grow. The test was successful, and postfiring mass spectrometer analysis showed the same leak rate in the vicinity of the Heat Exchanger. OV-102 engines have no leaks. This was verified by mass spectrometer after last hot fire. All Heat Exchangers have numerous hot-fire cycles to screen for leaks, and the latest inspections verified the acceptability of weld joint #4. *This risk factor is resolved for STS-28.*

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
SSME		
9	Damper pocket cracks on the HPFTP first stage turbine blades. HR No. ME-D1A Rev. A ME-D1C Rev. A ME-D1M ME-D1S *No anomalies were reported relating to STS-28 HPFTPs.*	Damper pocket cracks were first observed on HPFTP first-stage turbine blades in 1987. The cracks were in the area of the blade where signs of adverse thermal transients were observed: however, there has been no correlation to adverse transients in the thermal data collected during HPFTP testing. Specification requires inspection for cracks by magnification up to 40x or by dye penetration. These cracks are tight and have passed the dye penetration test. Most cracks have been found only when magnified to 70x or 100x, others have been found using a Scanning Electron Microscope (SEM). One high-time blade set had 21 blades inspected with the SEM, with cracks found on all 21 blades. The typical length of the cracks on the surface was 0.015", with a depth of 0.006". The worst case was 0.035" long. Two cracks were opened for inspection. Multiple initiation points were found which link at the crack surface. Evidence of oxidation was found indicating that the crack may have existed for some time. Experience indicates that crack growth is stable and slow. This is demonstrated by equivalent crack lengths found on units with a broad range of operating histories; 10 to 22 starts and total run time of 4,485 to 13,997 seconds. It is estimated that the worst-case crack has an FOS greater than 7 to critical flaw size. The rationale for flight is that OV-102 HPFTPs have significant operating margins over those tested; only 4 starts and 1815 seconds or less run time. ***This risk factor was acceptable for STS-28.***

RESOLVED STS-28 SAFETY RISK FACTORS

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
<u>SSME</u>		
10	Engine 2011 nozzle tube bulge. HR No. ME-B7A ME-D7C ME-B7M ME-B7S *No nozzle tube bulges were reported on any STS-28 engines during postflight inspection.*	After a test firing at SSC, nozzle tubes on ME 2011 were found to protrude into the hot-gas path at the forward manifold. The inward bulge was 0.080" and involved 7 tubes. The bulge occurred during testing of the Flow Recirculation Inhibitor (FRI) that was provided to protect the G-15 seal. Leak check showed a Class II leak of less than 5 standard cubic inches per minute (scim) at 25 psig. It resulted from a brazed joint failure and is thought to be due to manufacture. Fatigue is suspected. The FRI is not thought to have played a part in the braze failure. There were 3 starts and 841 seconds on ME 2031 including one flight, and 4 starts and 1132 seconds on ME 2011 which is all test time. Stability of the nozzle defect was unknown, and the nozzle was replaced. While the nozzles on OV-102 have more starts, all three nozzles passed protrusion inspection and leak check. Based on engine tests, up to 57 tubes can rupture before performance degradation and hot-gas discharge occurs. *This risk factor was acceptable for STS-28.*

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
SRM		
1	Failure of the left secondary joint heater to pass the Dielectric Withstanding Voltage (DWV) test. HR No. BC-01 ***The left forward primary joint heater was used during STS-28 prelaunch preparation with no failures reported. Joint heater usage was minimal due to the high ambient temperature.***	The STS-28 left forward secondary joint heater failed the DWV test (at 1250 volts versus 1500 volts required). The problem was attributed to a potential short, probably within the connector or pigtail. To minimized recurrence of future problems associated with connector electrical shorts, a redesign effort was initiated. The redesign provides internal insulation to protect the connector and wire-to-pin connections and includes an overwrap region for the connector and wire that will toughen the resistance to handling damage. The failed secondary joint heater system was not removed and replaced, but the primary circuit was used in the normal manner; the secondary heater was not powered for the launch. In the event both primary and redundant heaters fail, the minimum redline for the affected field joint becomes 68°F based on a minimum acceptable O-ring seal temperature of 65°F using as-built hardware dimensions and a +3°F differential temperature. Thiokol analysis showed that the seal would still meet the 2.0 FOS for tracking joint motion (taking into account tolerances, interference fit, etc.). Since this was a summer launch, it was expected that the joint would meet the new LCC even without a heater. The 1500-volt test was subsequently waived to 800 volts. The system passed the DWV test at 800 volts. STS-28 was the first flow with Ground Fault Interrupt (GFI) circuitry incorporated in all SRB joint and igniter heater circuits on Mobile Launch Platform (MLP) #2. The GFI response time with Airpax Magnetic Breakers and sensing circuits is less than 500 milliseconds. Rationale for flight was based on this protective circuitry and the LCC changes. ***This risk factor was acceptable for STS-28.***

RESOLVED STS-28 SAFETY RISK FACTORS

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
<u>SRM</u>		
2	Soft Stat-O-Seal retainers. HR No. BN-03 Rev. B ***No related anomalies were experienced on STS-28.***	Potential exists for soft Stat-O-Seals on STS-28 nozzle joint #5. Soft Parker Stat-O-Seals were discovered at Thiokol, Inc., and subsequent testing of suspect lots indicated hard seals were commingled with soft seals. STS-28 (and STS-34) were originally considered acceptable for flight based on vendor certifications. However, review of Parker paperwork indicated a definite problem in verifying lot identity and traceability. Therefore, the potential existed for the presence of discrepant (soft) parts. However, the Solid Rocket Motor (SRM) Project established that the crossover in lots due to the process at Parker occurred in a forward manner, and the seals were reused ones of an early lot. Additionally, sampling of supplies on hand indicated that the probability of soft seal use was very unlikely. Marshall Space Flight Center (MSFC) testing showed that soft seals could yield during torquing. The result would be reduced bolt preload and increased joint deflection, which would prevent meeting the tracking factor requirement on the seal. Records indicated good torque on all bolts with Stat-O-Seals in question, which was further evidence that no soft seals were used on STS-28. All installed Stat-O-Seals successfully passed leak test. Stat-O-Seals from suspect lots have successfully flown on prior flights and postfire visual inspection showed no yielding. Assessment and analysis, assuming all soft Stat-O-Seals, indicated no difference in deflections with full-bolt preload or zero-bolt preload, and no effect on joint deflections at the primary and secondary O-Rings. Testing indicated that Stat-O-Seals always remain sealed, even if extensive yielding occurs. Large radial deflections of the retainer due to yielding were not possible on joint #5 because of the counterbored holes around the retainer. Furthermore, yielding of a retainer would be detected during Stat-O-Seal leak check (bubble test).

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
SRM		
2 (Continued)		The igniter inner joint was assessed assuming soft Stat-O-Seals. All bolts were ultrasonically loaded to preload without incident. Bolt load on the inner joint increased slightly during igniter operation. Increased bolt load would cause a soft retainer to yield, increasing inner joint deflection at the Gask-O-Seal elastomer (approximately 0.0002" predicted by analysis). Assuming a conservative 0.0005" increase in deflection, a 5°F increase in LCC temperature is required to maintain 1.4 tracking FOS. The LCC was changed to increase igniter joint temperature from 66°F to 71°F. Launch day temperature was well over 71°F. Based on the results of worst-case analyses and tests, it was concluded that presence of soft Stat-O-Seals would have no effect on nozzle joint sealing. With 5°F LCC increase in igniter joint temperature, a tracking FOS of 1.4 would be maintained with potentially soft Stat-O-Seals. ***This risk factor was resolved for STS-28.***
3	Cold-temperature exposure. HR No. BC-10 Rev. B BN-04 ***No anomalies were reported on STS-28 SRMs which could be related to the cold-temperature exposure experienced during transportation.***	The 360H005 segments were subjected to extremely cold temperatures prior to and during transportation to KSC. At Corinne, Utah, both STS-28 aft segments (including nozzles) were exposed to the coldest storage/transportation low-temperature environment experienced to date in the program. Ambient temperatures reached as low as −17°F. The segments experienced 9 days unprotected at the Corinne railhead, and 6 days transit to KSC (2/5/89 - 2/21/89). Propellant Mean Bulk Temperature (PMBT) reached a minimum of 24°F during this period. Segments have never been tested at these low temperatures. The specification calls for a minimum PMBT of 40°F.

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
<u>SRM</u>		
3 (Continued)		Effects of extreme cold temperatures on Redesigned Solid Rocket Motor (RSRM) components became a major concern. Thermal analysis was performed to predict the response to actual temperatures at Corinne, Utah plus a worst- case specification rail transportation environment for the segments and their components. Structural analyses were performed to verify FOSs based upon this environment. Existing Discrepancy Reports (DRs) were reviewed to assess the potential impact of the exposure to cold. The left aft segment was evaluated as the worst case; it had the longest exposure to the cold environment. Thermal analysis predicted worst-case PMBT of 24°F, localized propellant/liner bond line of 12°F, and localized Nitrite Butadiene Rubber (NBR) insulation/case bond line of −12°F. Structural analysis worst-case conditions (using worst-case environments) did not occur simultaneously, but were combined for additional conservatism. All transportation loads (shock, vibration, handling) were considered. Viscoelastic material properties for the components were developed, using laboratory test results, over the following ranges: Propellant −20°F to 140°F Liner −40°F to 120°F NBR/Chemlok 0°F to 140°F CFF/EPDM −30°F to 160°F

RESOLVED STS-28 SAFETY RISK FACTORS

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
SRM		
3 (Continued)		Material properties at predicted temperatures were derived using standard viscoelastic time/temperature shifting procedures (Williams, Landal, and Ferry equation). Minimum FOSs were: • Liner = 2.39 (at propellant/liner interface) • Propellant = 2.90 (near propellant/liner interface) • Insulation to Case = 2.4 (at interface) Five-inch CP motors were cold fired using TP-H1148 propellant. Temperature comparison data were acquired from propellant evaluations for Minuteman and SRM. • 6 motors from each evaluation were conditioned for 12 hours and fired at −15°F, 6 at 60°F, and 6 at 135°F. • 35 motors showed normal pressure - time traces (one A89 motor was not fired at 60°F). • All results were nominal and within end item specification requirements (when burn rates were corrected for temperature differences). Existing Deviation RDW-0584R1 is effective through flight 7 (calculated FOS < 1.0). The calculated FOS is based on sharp material discontinuities (ply layup); actual discontinuities will be diminished by insulation processing (vulcanization), thereby improving the FOS. Worst-case separations would not significantly reduce the thermal FOS. Worst-case failure is multiple-ply separation and complete loss of CFF/EPDM, 1.1 minimum FOS (thermal and erosion of NBR). (Methodology for calculating FOS is still under evaluation.) Previous postflight inspections

RESOLVED STS-28 SAFETY RISK FACTORS

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
SRM		
3 (Continued)		showed no staged/nonstaged bond line failures. Cold-temperature effects on CFF/EPDM at 12°F showed the same failure scenario that motivated RDW-0584R1. Structural integrity was no worse than described there. No additional risk to 360H005 hardware due to cold-temperature exposure was indicated than on previous flight hardware. Structural analysis of cold-temperature effects on all nozzle and exit cone components showed positive FOS. Minimum FOS of 2.011 occurs in fixed housing/glass phenolic EA913NA bond line. Flex bearing exposure to 20°F (worst case) is not a concern. Vulcanized bonds/elastomer maintain FOS of 5.17 at 20°F. Subzero temperature evaluation and testing were performed on a full-scale RSRM fixed housing assembly. Test temperature cycling was based on predictions using actual worst-case reported hardware environment at Corinne. The assembly was inspected by 100% X-ray (3° interval) and ultrasonic before and after cold-temperature cycling. After testing, the assembly was machined to evaluate bond line characteristics. All results were positive. No anomalies or bond crazing were evident. Witness panels for forward and aft exit cones and fixed housing were also tested by cold-temperature cycling. Tensile test showed no reduction in bond line strength. Overall results of these test and analyses indicated that all hardware, except CFF/EPDM which is covered by deviation RDW-0584R1, exceeded minimum FOSs. With measured worst-case erosion on QM-7 at this location, minimum FOS was 2.33 (1.5 required). Separation at staged/unstaged CFF/EPDM was not a concern; separation, if present, would close and be in compression. No additional risk was imposed on 360H005 hardware due to cold-temperature exposure than has flown on previous motor sets.

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
SRM		
3 (Continued)		Per discussion with Dr. Michael Greenfield, NASA Headquarters, Code QT, his independent assessment of the occurrence found that the exposure did not result in excessive bond line stresses. The adhesive has a large margin over the stresses induced. ***This risk factor was acceptable for the STS-28.***
4	PV-1 Nozzle strain aberration. HR No. BC-04 BN-02 BN-03 BN-04 BN-06 ***No SRM Nozzle anomalies were experienced on STS-28.***	Higher than expected hoop and axial strains were observed in PV-1 Nozzle test strain readings 14 seconds after motor ignition. The sudden strain changes gave rise to concern for the potential for flight nozzle failure. The largest strain changes were isolated to the aft end of the nose inlet housing. There was an axial strain increase of 1200 min./in. (450 to 1650), and a hoop strain increase of 500 min./in. (−300 to −800). The hoop strain change was equivalent to a nearly instantaneous 20-mil radially inward displacement. Post-test inspection indicated separation at the glass-carbon interface, Room Temperature Vulcanizate (RTV) in the interface, and soot in joint #2. RTV in the interface is an indication that separation was present during the joint filling operation. Char and erosion performance were normal. Detailed investigation of manufacturing and assembly sequences indicated that a possible contributor was interference at the chamfer location during final assembly. It is likely that separation was present when joint #2 was backfilled with RTV, and cured RTV at the interface held the gas path open. The gas pressurized the initial void volume and propagated the separation. PV-1 assembly was unique. Interference at the chamfer could occur since joint #2 was not shimmed, no coflex measurements were taken to ensure clearance at the chamfer, and there was 0.025"

RESOLVED STS-28 SAFETY RISK FACTORS

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
<u>SRM</u>		
4 (Continued)		possible interference on the drawing. However, all RSRM hardware except PV-1 and QM-8 were shimmed at the interface. Clearances were verified by coflex impression. STS-28 had no chamfer interference during assembly. By design, the minimum gap is 0.01" (RSRM-5A only); joint #2 was shimmed during the process to ensure a gap. Coflex data indicated that the minimum gap was 0.030" (5A) and 0.036" (5B). X-ray of STS-28 nose inlet phenolics prior to bonding showed no separation. ***This risk factor was resolved for STS-28.***
5	Barrier Booster housing bore sealing surface scratches. HR No. BI-03 Rev. B BI-04 Rev. B ***No related anomalies were reported on STS-28.***	Disassembly of 360L004 Barrier Boosters (Nos. 1 and 4) revealed scratches on the housing bore sealing surfaces. Scratches had an estimated maximum depth of 0.3 to 0.4 mil, including raised metal. Scratches with the same characteristics were found at the vendor (Eaton Consolidated Controls (ECC)). They were caused by bore measurements made by an inspection tool. Rework procedures used to eliminate scratches on three ECC units were successful. All available units were inspected for possible scratches. The ECC bore measurement inspection tool was modified. Barrier Booster assembly, refurbishment, and acceptance criteria were modified to improve the housing bore inspection criteria. Controls have been reviewed and revised, and Thiokol is training ECC personnel on correct sealing surface inspection techniques. The 360H005 Barrier Boosters were successfully tested at 3168 psi (high) and 50 psi (low) in the "armed" position. Examination of similar units at ECC has not detected any scratches. Dynamic test with 0.32-mil scratch and 11% O-ring squeeze demonstrated no leak at 2050 psi for 5 minutes (360H005 is between 11 and 12%). ***This risk factor was resolved for STS-28.***

RESOLVED STS-28 SAFETY RISK FACTORS

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
<u>SRM</u>		
6	Uncured RTV in STS-30 Nozzle Joint #3. HR No. BN-03 Rev. B ***No evidence of O-Ring blowby was witnessed during STS-28 SRBs/SRMs disassembly.***	Postflight inspection of STS-30 Nozzle Joint #3 showed uncured RTV, 5" circumferential (of 188" total) by 1" radial. The uncured RTV was surrounded by cured RTV. There were no blowpaths, and joint performance was normal. This was the first occurrence of this anomaly detected in the RSRM program. There was a concern that a blowpath could occur through uncured RTV resulting in blowby to the primary O-ring. Laboratory analysis of the uncured RTV has not positively identified the cause. The RTV is a thermal barrier, not a seal. However, blowpaths have occurred through cured RTV on all RSRM nozzle joints with no primary O-ring blowby, erosion, or heat effect. Intentional flaws introduced into joint #5 of PV-1 (no RTV in 10" gap) showed no primary O-ring blowby. Improved mixing procedures are being implemented for the RTV. Tests were conducted to determine conditions that could induce RTV reversion. Backfill operations were closely observed. For STS-28, RTV cure was verified by cure cup tests. Rationale for flight was based on the improved procedures, additional cure cup testing, and history of no primary O-ring blowby. ***This risk factor was acceptable for STS-28.***

RESOLVED STS-28 SAFETY RISK FACTORS

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
<u>SRM</u>		
7	Gouges and pits in Aft Stiffener boltholes. HR No. BC-09 BC-11 *No further gouges and no ligament cracks were noted during SRM disassembly.*	Aft Stiffener Stubs on the left-hand motor at 160°, 248°, and 268° have circumferential gouges. Forward Stiffener Stub bolthole has a cluster of pits at 336°. Defects in Stiffener Stub boltholes deeper than 0.006" are unacceptable. Radial depth of the gouges varied between 0.007" to 0.010". Ligament cracks could originate from these defects. All raised metal and sharp edges were removed by hand honing. Magnetic particle inspection indicated no cracks originating from the gouges or the pit cluster. This segment was proof tested after repair. *This risk factor was resolved for STS-28.*
8	Stiffener Stub ligament cracks. HR No. BC-09 *No related anomalies were reported on STS-28.*	The 360H005A Aft Stiffener segment had seven outer ligament cracks. With an outer ligament crack, there is potential for stress corrosion cracking on the inner ligament caused by tensile residual stress. Previous flights have flown with Stiffener Stub cracks. All X-ray diffraction data on stiffener segment aft stubs indicated compressive residual stresses. Hydraproof tests successfully screened out inner ligament cracks. Visual inspection of the cracked holes at KSC showed no indication of inner ligament cracks. There was no evidence of stress corrosion cracking in D6AC SRM hardware. Laboratory tests of unprotected D6AC steel in KSC atmosphere showed no corrosion at 135 ksi (75% yield strength). Stresses due to the ring assembly are low (2.6 ksi). Residual stresses are all compressive on the inboard surface of cracked outer ligament holes. There have been eleven successful flights with outer ligament cracks. *This risk factor was acceptable for STS-28.*

RESOLVED STS-28 SAFETY RISK FACTORS

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
<u>SRM</u>		
9	Safe and Arm (Device) (S&A) failure to cycle during bench check at KSC. HR No. AI-01 BI-01 ***No failures of the S&A devices were reported on STS-28.***	The STS-28 S&As were built to the same configuration and could fail to arm during terminal countdown or fail to safe for abort. During S&A checkout at KSC, no movement was seen through the indicator window, and no sound of motor turning was heard. Checkout cable damage was identified by electrical test and X-ray. Normal electrical and electromechanical acceptance tests were performed at the vendor (Eaton). All results were nominal. Acceptance-level vibration tests were performed prior to repeating all normal electrical and electromechanical acceptance tests at the vendor. The S&A failed to electrically cycle near the end of vibration between the fifth and sixth (final) vibration cycles. It was manually safed within allowable force limits (actual = 32 lb, allowable limit = 20-40 lb). The S&A was then disassembled, and a worn bearing was indicated. The bearing was investigated by the Lubrication and Surface Physics Laboratory at MSFC. STS-28 S&A actual performance was within historical expectations and better than the performance of the problem S&A. STS-28 S&As passed the KSC bench test and were not subjected to vibration and shock since handling was well controlled at KSC. The S&As were electrically cycled ten times at forward skirt closeout one week before launch. They will already be in the "arm" position when preflight vibration begins at SSME ignition. The S&A is still capable of manual safing if launch is aborted. ***This risk factor was acceptable for STS-28.***

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
SRM		
10	RSRM igniter inner Gask-O-Seal leakage. HR No. BC-03 Rev. B BI-02 Rev. B *No indication of RSRM igniter inner Gask-O-Seal leakage was found during postflight STS-28 SRMs/SRBs disassembly.*	Gas leakage and bolt failure occurred between the igniter adapter and the S&A device during qualification test #4 at Thiokol. Gas blowby also occurred at the inner joint gasket on qualification tests #3 and #4; no gas blowby occurred at the outer joint gasket. The tests were designed to produce worst-case pressures on the S&A device armature O-ring and were not representative of flight hardware configurations. Conditions common to both tests that were deviations from the flight hardware configuration were: • Leak checks were not performed prior to the tests. • Stat-O-Seals were not installed under the joint bolt heads. • Zinc chromate putty was not installed upstream of the inner Gask-O-Seal. • There was no quality control buyoff of the igniter assembly procedure. Qualification test #4 was performed in 20°F ambient temperature, resulting in the inner seal temperature dropping to approximately 25°F. No igniter joint heaters were used. LCC ensure that the minimum inner gasket seal temperature is above 71°F prior to launch. Post qualification test #3 disassembly inspection found that the inner joint bolts at locations 130°, 140°, 150°, and 170° were only hand tight indicating they had not been preloaded to specification as required for flight hardware. In addition, the inner gasket seal used on qualification test #3 was used for the previous two tests with no reuse inspection. The rationale for flight was that failure of the inner joint gasket on both tests was caused by anomalous, nonflight test configurations. *Not a safety concern for STS-28.*

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
<u>SRB</u>		
1	SRB K5NA application in the presence of water. HR No. INTG-037 B-60-12 Rev. C B-60-24 Rev. B BC-11 Rev. B C-60-03 *No indication of lost K5NA was found on STS-28 SRBs.*	The 1989 bonding review by NASA at USBI-Florida Operations reported concern for the effect of water on the K5NA bond line and properties. Use of water in K5NA application has been allowed to aid in smoothing and knitting during finishing only. Water is sprayed on technicians' gloves to prevent the material from sticking. K5NA balls are dunked in a bucket of water, one at a time. This procedure was allowed. Flight experience through STS-30 showed no K5NA losses except in three scenarios: • Loss due to nozzle severance debris impacting on the forward assembly. • Aft Booster Separation Motor nozzle losses, typically experienced during reentry. • Kick ring bolt head closeout, typically caused by water impact. Procedures for this flow were the same as for previous flows (wet glove method, no dunking). Analysis indicated values of 8- to 34-psi bond line strength are required. Testing showed minimum bond line strength of 54 psi. There was no loss or bond line failures during qualification tests at Arnold Engineering Development Center (AEDC). Flight history of water-applied K5NA consistently demonstrates excellent performance. Based on tests conducted during the NSTS Bonding Team review of K5NA applications, modified K5NA application procedures were approved. These procedures allow moderate misting of gloves worn during application, prohibit direct spraying of water on K5NA, and require the control of the thickness/rate of application to 1" per 1-1/2 hr. These procedures have been implemented at USBI, and modified procedures have been provided to the Shuttle Processing Contractor (SPC) for implementation.

RESOLVED STS-28 SAFETY RISK FACTORS

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
<u>SRB</u>		
1 (Continued)		Rationale for flying with K5NA applied using water included: • All K5NA applications were verified by test to worst-case design environments or by similarity. • Minimum strength value resulting from the test program (54 psi) exceeded the specification strength of 34 psi. • Flight experience demonstrates no loss of K5NA using the process and controls verified in the test program. • The process used for applying K5NA on STS-28 SRBs was the same as used for previous flights. *This risk factor was resolved for STS-28.*

RESOLVED STS-28 SAFETY RISK FACTORS

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
<u>ET</u>		
1	ET monoball rotation. HR No. P.03 *No anomalies were reported on STS-28 relating to the Orbiter/ET umbilical interface.*	During mate of Orbiter/ET umbilicals, technicians found the monoball on the ET side rotated with unexpected ease. During initial troubleshooting, the monoball was rotated up to ±45° in violation of an OMRSD requirement which limits permissible rotation to ±5°. During this time, the troubleshooters were apparently unaware of the limitation. The concern for excessive rotation was that wiring to connectors in the monoball could be broken or sustain other damage. The wiring was subsequently inspected with a borescope, and an electrical continuity check was performed with no anomalies found. *Not a safety concern for STS-28.*
2	LH_2 level sensor circuits read low resistance values. HR No. P.06 *No further problems were reported on STS-28 relating to the LH_2 level sensors.*	There are 8 propellant depletion sensors in the ET; 4 for LH_2 and 4 for LO_2. Nominal main engine cutoff is based on a predetermined velocity; however, if any two of the fuel or oxidizer sensors sense a depleted condition, the engines will undergo a controlled shutdown. There was a single occurrence of low isolation resistance on the ET-31 LH_2 level sensor circuits measured at KSC. The isolation resistance requirement is 2 megohms at 50 Volts Direct Current (VDC); KSC measured values less than 0.9 megohms at 50 VDC. The anomaly could not be repeated following removal of the Thermal Protection System (TPS) and the external connector for troubleshooting. The connector was subsequently cleaned and dried prior to repeating the successful retest. All subsequent tests were acceptable. The most probable cause of the low resistance initially measured was stated to be moisture in the connector. *This risk factor was acceptable for STS-28.*

RESOLVED STS-28 SAFETY RISK FACTORS

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
<u>ET</u>		
3	Prolongation data from two lots of vertical strut forgings did not meet stress corrosion cracking acceptance requirements. ***No indications of structural degradation were found in the STS-28 vertical strut.***	Prolongation data from two lots of vertical strut forgings, totaling 29 forgings, did not meet stress corrosion cracking acceptance requirements. The problem was identified at a second review of the process records. The cause was attributed to underaging of the materials during heat treating in the forge shop. Rationale for flight was based on: • Acceptable tests of the actual forging. • Forged parts are not susceptible to stress corrosion cracking. • Low residual stresses on the struts. • Vertical struts experience compressive stress in short transverse direction. • There is consistent test data from lot to lot. This issue was raised at the ET/SRB Mate Review, and rationale for flight was accepted at that time. ***Not a safety concern for STS-28.***

RESOLVED STS-28 SAFETY RISK FACTORS

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
ET		
4	LO_2 aft feedline elbow residue. HR No. P.06 ***No LO_2 flow or SSME performance anomalies were experienced on STS-28.***	Residue was found in the ET-31 aft feedline elbow. The residue was observed under normal and black light conditions; it exceeded the maximum nonvolatile residue requirement of 1 milligram per square foot (mg/ft^2), with 3.4 mg/ft^2 measured residue. The most probable residue source was from Freon/TMC solvent contacting the back side of the J414 tape used during the lapping process on the feedline flange. The tape secures plastic barriers on the feedline when lapping. The feedline elbow was cleaned to an acceptable value of nonvolatile residue. The residue was determined not to be detrimental to the downstream system if it comes loose. ***Not a safety concern for STS-28.***
5	Teflon material found in Gaseous Oxygen (GO_2) Quick Disconnect (QD). ***There were no anomalies on STS-28.***	On ET-38, teflon material was discovered at KSC in the GO_2 QD. The teflon source was most probably from a hose used for the first time on ET-38 at the Michoud Mod Center. No leakage of this QD was experienced prior to the Mod Center work. This anomaly was not applicable to ET-31/STS-28. The ET-31 QD was visually inspected at KSC and found to be acceptable. ***Not a safety concern for STS-38.***

RESOLVED STS-28 SAFETY RISK FACTORS

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
GFE		
1	Dale Resistors in Pyro Initiator Controllers (PICs). HR No. INTG-051 INTG-115A INTG-164 *No inadvertent PIC firings were experienced on STS-28.*	The PICs supply a calibrated energy source for firing NASA Standard Initiators (NSIs) and are used in critical functions in the Orbiter, ET/SRB, and MLP. The PICs are manufactured by Martin Marietta Corporation (MMC) and provided by JSC as Government Furnished Equipment (GFE). Redundant PICs are provided for planned Criticality 1 functions (except for Avionics Bay fire suppression and SRB functions post-separation). Suspect RLR07 Dale resistors were used in firing circuits in PICs installed for STS-28. MMC thought they had removed all Dale resistors in the original Alert from the 800-build that was on the assembly line. Post delivery, it was determined that they inadvertently included suspect Dale resistors in 133 of the 800 units as a result of an error in stock purging. MMC identified 42 PICs that may contain Dale resistors of suspect date codes for STS-28. Forty-one of the 42 PICs may contain suspect RLR07 resistors in the firing circuit. One of the 42 PICs contains a known RLR05 Dale resistor in the load test circuit and may contain suspect resistors in the firing circuit. Resistor integrity in the firing circuits was verified during load test performed at the T-10 day time frame. PIC load tests would detect a failed resistor. There is no Orbiter field failure history of the RLR07 resistors type over a greater than 10-year period in which 2,700 PICs have been built (there has been 1 PIC failure due to corrosion of a Dale resistor of the RLR05 type (1500 ohms)). The MSFC Problem Reporting and Corrective Action (PRACA) System indicated no failures of RLR07 or RLR05 resistors in the ET/SRB/SRM/SSME. Failure of the resistors would cause inability to fire. However, redundant PICs are included for each nominal planned Criticality 1 function. A Dale resistor failure would not result in inadvertent firing of PICs. *This risk factor was resolved for STS-28.*

SECTION 5

STS-30 INFLIGHT ANOMALIES

This section contains a list of inflight anomalies arising from the STS-30 mission. Each anomaly is briefly described, and risk acceptance information and rationale are provided.

SECTION 5 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 Solid Rocket Motor nozzle snubber ring displacement.
3 Cut in the secondary seal of the outer gasket.

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 reported on STS-28.***	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-28.***
2	The #2 Gaseous Hydrogen (GH_2) pressure system temperature indicator failed. (IFA No. STS-30-02D) ***No anomaly reported on STS-28.***	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-28.***
3	Center engine Liquid Hydrogen (LH_2) inlet pressure transducer failed. (IFA NO. STS-30-02E) ***On STS-28, the left engine LH_2 inlet temperature transducer failed (IFA STS-28-05A). No pressure transducer problems were experienced.***	The center engine LH_2 inlet pressure transducer failed at approximately 1 to 2 psi during ascent. The problem has been traced to a bad transducer that was removed and replaced. ***Not a safety concern for STS-28.***

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 ***The FC H_2 Flow Meter on STS-28 began to drift high at Mission Elapsed Time 12:30 (IFA No. STS-28-05C). It later exhibited erratic behavior.***	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. This failure is under investigation. ***Not a safety concern for STS-28.***
5	Left engine LH_2 inlet pressure transducer biased low. (IFA No. STS-30-02H) ***No anomaly reported on STS-28.***	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 two engines. Johnson Space Center (JSC)/KSC/Downey review indicated that this is nominal behavior. ***Not a safety concern for STS-28.***

STS-30 INFLIGHT ANOMALIES

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 *There were no R1U RCS Jet failures on STS-28. Vernier Thruster F5R leaked (IFA No. STS-28-03) and the forward RCS F5L heater failed "on" (IFA No. STS-28-07). These were the only Thruster IFAs reported on STS-28. There is no indication that these failures are related to the previously experienced R1U failures.*	RCS jet R1U failed (on STS-30/OV-104) 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 which 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 STS-28 jets were flown for the first time. The rationale for flight was based on no failures in previous first flights, test and inspection performed, and functional redundancy of other RCS jets. *This risk factor was acceptable for STS-28.*
7	Auxiliary Power Unit (APU) #2 Gas Generator (GG) fuel pump "A" heaters inoperative. (IFA No. STS-30-06) HR No. ORBI-250 *No anomaly reported on STS-28.*	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 has been unsuccessful in recreating the problem. A similar failure occurred on STS-27. Troubleshooting is continuing, including checking the controller. *Because of redundancy in the heaters, this risk factor was acceptable for STS-28.*

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) *There was no failure of the fuel total quantity gage; however, the right OMS fuel total quantity gage did read high on STS-28 (IFA No. STS-28-17).*	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-28.*
9	Right RCS A-leg oxidizer helium isolation valve failed open. (IFA No. STS-30-09) HR No. ORBI-111 *No anomaly reported on STS-28.*	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 P29 connector. During connector vacuuming, some pins were bent. The STS-28 valves were functionally verified during processing. *This risk factor was resolved for STS-28.*

STS-30 INFLIGHT ANOMALIES

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
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 reported on STS-28.*	There appeared to be a leak downstream of the GN_2 supply valve in WSB #2 as evidenced by 5 pounds per square inch (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 Rockwell International (RI)/Downey to raise the leak rate limit. *Not a safety concern for STS-28.*
11	General Purpose Computer (GPC) #4 failed to sync. (IFA No. STS-30-11) HR No. ORBI-066 ORBI-194 *No anomaly reported on STS-28.*	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-28.*

STS-30 INFLIGHT ANOMALIES

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
12	Engine Helium fill Check Valve (CV) failures. (IFA No. STS-30-12) HR No. INTG-019 *No anomaly reported on STS-28.*	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-28.*
13	The right OMS GN_2 pressure regulator regulated low. (IFA No. STS-30-14) HR No. ORBI-111 ORBI-165 *No anomaly reported on STS-28.*	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-28.*

STS-30 INFLIGHT ANOMALIES

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
14	Main landing gear fluid leak. (IFA NO. STS-30-15A & B) HR No. ORBI-188 *No anomaly reported on STS-28.*	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. Struts have been diapered to attempt to catch any additional leakage. *Not a safety concern for STS-28.*
15	Nose wheel steering enable late. (IFA No. STS-30-16) HR No. ORBI-184 *On STS-28, the nose gear Weight-On-Wheels (WOW) sensor failed "off" prior to launch indicating WOW (see IFA No. STS-28-09).*	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 two 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 the nose wheel steering. KSC troubleshooting found the Right-Hand (RH) NLG sensor out of adjustment and corrected the situation. Software changes were made to open up the window to accommodate these delays between the two sensors. The first software change lengthened the time for comparing sensor inputs prior to setting the Weight on Nose Gear (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-28.*

STS-30 INFLIGHT ANOMALIES

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
<u>ORBITER</u>		
16	Ding on forward window #6. (IFA No. STS-30-17) HR No. ORBI-009 *No anomaly reported on STS-28.*	The ding was larger than allowable specifications. The 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-28.*
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 reported on STS-28.*	During FCS checkout, the Commander's AVVI showed 20,600 ft/sec. The pilot's showed 20,100 ft/sec; both should have been 20,000 ft/sec. This problem is under investigation to determine tolerance. *Not a safety concern for STS-28.*
18	Bulkhead blanket damage. (IFA No. STS-30-20) HR No. ORBI-249A *No anomaly reported on STS-28.*	Some 1307 bulkhead blankets, adjacent to those recently modified, sustained cover damage. In addition, nine snaps were found unsnapped. The blankets will be replaced with modified blankets. *Not a safety concern for STS-28.*

STS-30 INFLIGHT ANOMALIES

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
SRM		
1	Factory joint weather seal aft edge unbonding. (IFA No. STS-30-M-01) HR No. BC-02 BC-10 Rev. B *No anomaly reported on STS-28.*	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 are 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 has been found to reduce the weather seal bond strength. A change allowing the entire bonding surface to be grit blasted is in signoff. Minimum CONSCAN requirements for these surfaces are currently in place. The left-hand booster experienced parachute failure which 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-28.*

STS-30 INFLIGHT ANOMALIES

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
<u>SRM</u>		
2	Solid Rocket Motor (SRM) nozzle snubber ring displacement. (IFA No. STS-30-M-03) HR No. BN-08 Rev. B *No anomaly reported on STS-28.*	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 that are 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-28.*
3	Cut in the secondary seal of the outer gasket. (IFA No. STS-30-02) HR No. BI-02 Rev. B *No anomaly reported on STS-28.*	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 is 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 is unclear. All gaskets in stores were reinspected for similar damage, with no anomalies found. Igniter gaskets for STS-28 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-28.*

STS-30 INFLIGHT ANOMALIES

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
<u>SRB</u>		
1	Left-Hand (LH) SRB main parachute failure. (IFA No. STS-30-B-01) ***No anomaly reported on STS-28.***	The left 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 velocity of 300 fps) resulting in distressed ribbons. Ripstop (additional bands sewn around the parachute) would have most probably prevented this parachute failure. Change is being effected to place six 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 five flights, ripstop will be implemented on one 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-28.***
2	Debris lost from multiple Debris Containment Systems (DCSs). (IFA No. STS-30-B-02) HR No. B-60-12 Rev. B ***No anomaly reported on STS-28. This is the first mission since reflight that had no debris losses. Modifications implemented preflight worked well.***	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 has failed to fully contain HDP debris on 9 HDPs (32 total) through the first four flights (STS-26,4; STS-29,1; and STS-30,4). A Class I hardware modification has been initiated to enhance the DCS. Changes include addition of a silicone rubber shock isolator between the stud attach and plug tip, and material/configuration changes on the stud attach. Experience base with the present design provides an acceptable risk. ***This risk factor was acceptable for STS-28.***

STS-30 INFLIGHT ANOMALIES

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
SRB		
3	LH SRB ET Attachment (ETA) cover sheared fasteners. (IFA No. STS-30-B-03) HR No. B-30-06 Rev. B *No anomaly reported on STS-28.*	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-28 or subsequent flights.*
4	LH SRB ET attachment ring cap and web separation. ('FA No. STS-30-B-04) HR No. B-30-06 Rev. B *No anomaly reported on STS-28.*	Separation occurred for a length of approximately 100" on ring segment 283. Maximum gap is 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-28.*

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 reported on STS-28.***	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 burst disc on the LH_2 recirculation line. The line was removed and replaced while the Orbiter and ET were on the pad. The replacement line functioned normally during launch. 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 created 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 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-28.***

SECTION 6

STS-28 INFLIGHT ANOMALIES

This section contains a list of inflight anomalies arising from the STS-28 mission. Each anomaly is briefly described, and risk acceptance information and rationale are provided.

SECTION 6 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	Environmental Control and Life Support System freon coolant loop low flow rate.
10	Right-hand Orbiter Maneuvering System fuel quantity gage reading high.
11	Auxiliary Power Unit #1 test line temperature read high.
12	STS-28 crew experienced eye irritation.
13	Hydraulic System #2 unloader valve operated out of specification.
14	Excessive body flap deflection during ascent.
15	Orbiter structural heat damage.
16	Crew reported a loud thump/thud at first OPS-1 transition.
17	Gaseous Hydrogen Flow Control Valve #1 showed sluggish response.
18	Early assymetrical boundary layer encounter resulted in anomalous aerosurface movement, usage of more than a normal amount of RCS propellant, and excessive Thermal Protection System damage.
19	Umbilical foam detached from the External Tank Liquid Oxygen 17" disconnect.

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
ORBITER		
1	Pilot seat moved during ascent. (IFA No. STS-28-02) HR No. ORBI-256C ORBI-340	The pilot's seat slid to the full back position several times during 2-g ascent periods. The pilot had to drive the seat forward 2 to 3" with the motor several times, causing spikes on the Alternating Current (AC) Bus. After the seat was repositioned, it immediately began to drift back to the stops. The crew performed inflight maintenance. There was no indication of a short in the forward/aft positioning switch, and no problems were indicated. An investigation was initiated which included examination of the clutch mechanism. Troubleshooting at Kennedy Space Center (KSC) confirmed a bad motor/brake assembly. The motor/brake assembly was removed and replaced with a part from OV-105 inventory and retested on OV-102. The failed unit was sent to the manufacturer (Western Gear) for teardown inspection. The failed motor/brake assembly was identified as a qualification test unit used for life-cycle testing in which it was subjected to 300 extend/retract cycles. This involved continuous operation for greater than one hour during which the motor became very hot, but it passed the test. It was installed in a mockup for approximately two 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 by RHFA. The qualification test motor/brake was then installed in OV-102. The unit flew one flight (STS-61C) before STS-28; no problems were noted. During standdown after STS-51L, the seat was removed from OV-102 and shipped to Wright Patterson Air Force Base (AFB) for vibration testing. It underwent vibration equivalent to greater than 900 flights. The seat was reinstalled in OV-102 by RHFA and passed the Acceptance Test Procedure (ATP) (1-g).

STS-28 INFLIGHT ANOMALIES

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
1 (Continued)		During brake assembly failure analysis teardown, the assembly fell out of the housing when the housing was removed. The screw used to hold the brake rotor to the shaft was loose and fell out. Failure analysis also showed that this unit had evidence of significant heat damage. The bond of brake pad to metal surface was degraded, and the pad had become separated from the base. Loctite on the brake assembly screw failed, and the screw had backed out. Heat discolorization was also found on the 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.
2	Vernier thruster F5R annunciated fail leak. (IFA No. STS-28-03) HR No. ORBI-056	Vernier thruster F5R (forward, #5, right) 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. The 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.

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	The NLG WOW #1 proximity sensor discrete failed to the "off" condition indicating weight on the nose gear during prelaunch activities. The NLG WOW discrete was seen toggling between "on" and "off" states before finally failing to the off/weight on nose gear discrete. The WOW "on" indication recovered on-orbit. A procedure to press the External Tank/Separation (ET/SEP) pushbutton after nose gear touchdown, a nominal crew procedure, eliminated the anomaly caused by this problem. 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.
4	Fuel Cell #1 Hydrogen (H_2) flow erratic. (IFA No. STS-28-05C)	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. A determination was made to fly OV-102 as is since the required corrective maintenance would necessitate removal of the fuel cell.
5	Abort light failure. (IFA No. STS-28-06)	During prelaunch tests, two of four 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.

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	The forward RCS F5L (forward, #5, left) heater failed on. The Pod was removed to allow F5R removal and replacement; the F5L heater was also fixed at that time. Retest was performed with no problems. The vernier thruster heater operates at low wattage; it will not overheat the thruster if it remains on.
7	Main Bus C utility outlet #1 teleprinter short circuit. (Teleprinter cable anomaly) (IFA No. STS-28-11) HR No. ORBI-301	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 had to plug 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 has been 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.

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
7 (Continued)		New cables have been 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 radius.
8	Auxiliary Power Unit (APU) isolation valve talkback failure. (IFA No. STS-28-12) HR No. ORBI-103	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 removal of the APU. 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.
9	Environmental Control and Life Support System (ECLSS) Freon Coolant Loop (FCL) low flow rate. (IFA No. STS-28-15) HR No. ORBI-275A	Freon flow rates in the ECLSS have degraded on OV-102 since its first flight. During STS-28, the FCL radiator panel exit temperature dropped below -60°F. Additionally, FCL #2 flow rate degraded about 100 pounds per hour (lb/hr). FCL #1 flow rate degraded about 50 lb/hr during the flight. Flow returned to normal as panels reheated. Reduced flow rates at colder temperatures have 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. Samples were taken of FCL #1 and #2; mositure content was within specification. Flow rate transducers were removed and replaced, and "brazed-in" filter replacement was completed. Flow rates were within specification.

STS-28 INFLIGHT ANOMALIES

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
10	Right-Hand (RH) Orbiter Maneuvering System (OMS) fuel quantity gage reading high. (IFA No. STS-28-17) HR No. ORBI-183	The RH OMS fuel quantity gage read approximately 5.7% high after deorbit burn as compared to predicted values. Analysis of the anomaly continues. Evaluation indicated fuel aft probe failure. There was no indication that this is a generic failure problem that would impact subsequent flights.
11	APU #1 test line temperature read high. (IFA No. STS-28-18) HR No. ORBI-104	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.
12	STS-28 crew experienced eye irritation. (IFA No. STS-28-21) HR No. ORBI-279	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.

STS-28 INFLIGHT ANOMALIES

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
13	Hydraulic System #2 unloader valve operated out of specification. (IFA No. STS-28-23) HR No. ORBI-052	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 are considered possible causes of this anomaly. The MC284-0438-0001 configuration unloader valve has a history of leakage. The Orbiter Project Office (OPO) directed replacement of -0001 valves with -0002 valves on an attrition basis. KSC removed and replaced this valve; it was returned to the vendor for failure analysis. Leak check of the replacement valve was satisfactory.
14	Excessive body flap deflection during ascent. (IFA No. STS-28-24) HR No. ORBI-025	Excessive body flap deflection was believed to be observed by the film analysis team from the E-207 tracking camera at approximately 46-second MET during ascent of STS-28. On STS-28, the camera was turned on at T-0 versus T+50 seconds on prior flights. Deflection of the body flap 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 and was later revised to 6.1 ±3.0". Camera photographs from previous flights did not provide the view angle needed to observed 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.

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
14 (Continued)		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 inspect 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 borescope inspected. Some evidence of heating (discoloration) and metal filings indicative of wear was 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 time. Since no significant problems were found during all of the testing and inspection of the OV-102 body flap, the flap was reinstalled on OV-102. 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 the end-to-end photo/video system performance capabilities.

C-2

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
14 (Continued)		• For each of the following peak-to-peak body flap deflections (4", 6", 9", 13"), determine area and type of predicted damage, and if no predicted damage, the margin. <u>Results of the STS-34 FRR Action Item</u>: Estimates of potential visual amplification and distortion associated with camera views through the SSME plume have been 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 the plume and readability 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. Based on the predicted tile and structural damage, coupled with the latest prediction of the peak-to-peak deflection seen on STS-28. 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.

STS-28 INFLIGHT ANOMALIES

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
14 (Continued)		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 load thumping noise during testing; OV-103 was much quieter. Only the port, outboard actuator on OV-103 thumped. Freeplay tests performed on OV-103 resulted in exceeding the test criteria. This result was deemed inconclusive because it was later determined that the freeplay test setup on OV-103 was not correct. Rerun of the OV-103 freeplay tests was not possible due to the unavailability of the vehicle; however, tests and analyses performed on other Orbiters indicates that a body flap deflection problem does not exist on any vehicle.
15	Orbiter structural heat damage. (IFA No. STS-28-26) HR No. ORBI-084 ORBI-245A	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 have reviewed the evidence. They agreed there was no burnthrough or overheating. This condition was expected due to the out-of-tolerance step and gap around the ET door. The out-of-tolerance condition was waived prior to flight. Tile removal was completed, and structural inspection was performed. No damage was noted. Tile was reinstalled. A problem closeout report was written and approved.
16	Crew reported a loud thump/thud at the first OPS-1 transition. (IFA No. STS-28-27)	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.

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
16 (Continued)		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 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 the cockpit acceleration instrumentation found inconclusive evidence of motion. No malfunctions were reported during STS-34 trial countdown. For future flights, the decision was made to turn on the Modular Auxiliary Data Systems (MADS) during OPS-1 transition and measure vehicle data in an attempt to record any repeat of this anomaly and isolate the cause.

STS-28 INFLIGHT ANOMALIES

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
17	Gaseous Hydrogen (GH_2) Flow Control Valve (FCV) #1 showed sluggish response. (IFA No. STS-28-28) HR No. ORBI-151 ORBI-338A	SSME GH_2 FCV #1 indicated sluggish response during the first three 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. 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.
18	Early assymetrical boundary layer encounter resulted in anomalous aerosurface movement, usage of more than a normal amount of RCS propellant, and excessive Thermal Protection System (TPS) damage. (IFA No. STS-28-30) HR No. ORBI-136A ORBI-249A	Unusual low frequency aileron movement occurred in the Mach 20 to Mach 10 range during STS-28 entry. Unusual RCS and aerosurface activity was observed during roll reversal. The boundary layer transition from laminar to turbulent flow began to occur approximately 250 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 elevons is 3°. Similar aileron activity was observed during early transition on STS-1. During this same interval, two 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 aileron and the RCS jets as previously reported.

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
18 (Continued)		Total RCS 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 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 control and consumable margins were maintained for the required aerosurface movements and jet firings. Postflight analysis of surface temperature measurements indicated a transition from laminar to turbulent flow 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 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 three were installed at Palmdale in 1985 during the OV-102 modification period. Review of the 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 have been 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.

STS-28 INFLIGHT ANOMALIES

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
19	Umbilical foam detached from the ET LO_2 17" disconnect. (IFA No. STS-28-31) HR No. ORBI-302A INTG-037A INTG-081A	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. Similar problems have been noted on STS-4, STS-9, and STS-61A; most flights have evidence of minor damage. Possible causes of the problems included installation anomalies, LO_2 impingement, aerodynamic effects during ascent, or a combination thereof. The failure mode is not totally understood. There were approximately 65 cryogenic ET/Orbiter separation tests conducted during the ET/Orbiter Separation Ground Test Program, with only the first test resulting in forward foam damage. A bracket was installed to protect the foam for the remaining 64 ground tests. No additional foam damage was recorded during these tests. Debris damage to the Orbiter is unlikely. Interference with the umbilical door closure from foam debris is considered remote.

STS-28 INFLIGHT ANOMALIES

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
SRB		
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	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 is required.

STS-28 INFLIGHT ANOMALIES

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	During postflight disassembly inspection of the STS-28 right SRM Igniter, a small depression was found at 210° on the inner primary seal on the aft face of the inner gask-o-seal (360H005B). The crown of the seal was depressed inward and measured approximately 0.100" long circumferentially by 0.025" radially; it extended across the crown width. It appeared that a possible subsurface void may have existed in the inner primary seal prior to flight. There was no evidence of a leak path in the putty (primary seal not pressurized). The joint passed preflight low- and high-pressure leak test. No blowby past the inner primary seal or pressure path to the seal was found. However, leak test may not be sufficient if an indentation exists in the seal. The joint gap is predicted to open 3.5 mils at the outer gasket, 3.0 mils at the inner gasket. Indentation, if present, may not dynamically track the gap opening on pressurization, and the leak test is not flight dynamic. Additionally, crown indentations were also discovered during disassembly on new gaskets on DM-9 and QM-6. Subsurface void was found in both cases; contamination was also present on DM-9. Standard nondestructive inspection techniques, such as X-ray, cannot reliably detect subsurface voids. Current known gasket defects are detectable by visual and touch inspection at disassembly. Indentation is easily detectable after gasket removal. It should be noted that indentations have never been detected on reused gaskets. Corrective action is in process to develop an inspection technique to detect subsurface voids: design of a plexiglass fixture for seal test; reinvestigation of N-Ray and X-ray; and investigation of ultrasonics and background scatter.

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
SRM		
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 three 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".

STS-28 INFLIGHT ANOMALIES

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
KSC		
1	Mobile Launch Platform (MLP) recorders were accidentally turned off. (IFA No. STS-28-K-01)	At T-15 seconds, the MLP fans were turned off. At this time, the MLP recorders were also turned off inadvertently 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.

SECTION 7

BACKGROUND INFORMATION

This section contains pertinent background information on the safety risk factors and anomalies addressed in Sections 3 through 6. It is intended as a supplement to provide more detailed data if required.

APPENDIX A

LIST OF ACRONYMS

AC	Alternating Current
ACA	Annunciator Control Assembly
ACIP	Aerodynamic Coefficient Identification Package
AEDC	Arnold Engineering Development Center
AFB	Air Force Base
AIP	Aerothermal Instrumentation Package
AIPEH	Aerothermal Instrumentation Package Enhanced
a.m.	Before Noon (Ante Meridiem)
APU	Auxiliary Power Unit
ARS	Air Revitalization System
ATP	Acceptance Test Program
AVVI	Altitude/Vertical Velocity Indicator
BFS	Back-Up Flight System; Backup Flight Software
BTU	Bus Terminal Unit
CA	California
CRES	Corrosion Resistant Steel
CSE	Catalytic Surface Effects
CV	Check Valve
CVAS	Configuration Verification Accounting System
DAR	Deviation Approval Request
DC	Direct Current
DCS	Debris Containment System
DEU	Display Electronics Unit
DFI	Development Flight Instrumentation
DoD	Department of Defense
DOL	Day of Launch
DPS	Data Processing System
DR	Discrepancy Report
DWV	Dielectric Withstanding Voltage

APPENDIX A

LIST OF ACRONYMS (CONT.)

ECC	Eaton Consolidated Controls Corporation
ECLSS	Environmental Controls and Life Support System
EDT	Eastern Daylight Time
EIU	Engine Interface Unit
ET	External Tank
ET/SEP	External Tank/Separation
ETA	External Tank Attachment
F	Fahrenheit
FC	Fuel Cell
FCL	Freon Coolant Loop
FCS	Flight Control System
FCV	Flow Control Valve
FDA	Fault Detection and Annunciator
FeCl	Iron Chloride
FFSSO	Forward Fuselage Support System for Orbiter Experiments
FIV	Fuel Isolation Valve
FMEA/CIL	Failure Modes and Effects Analysis/Critical Items List
FOS	Factor of Safety
fps	Feet Per Second
FRI	Flow Recirculation Inhibitor
FRR	Flight Readiness Review
ft	Feet
g	Gravitational Acceleration
GCV	Gaseous Oxygen Control Valve
GFE	Government Furnished Equipment
GFI	Ground Fault Interrupt
GG	Gas Generator
GH_2	Gaseous Hydrogen
GN_2	Gaseous Nitrogen
GO_2	Gaseous Oxygen
GOX	Gaseous Oxygen
GPC	General Purpose Computer
GSE	Ground Support Equipment
GUCP	Ground Umbilical Carrier Plate

APPENDIX A

LIST OF ACRONYMS (CONT.)

H_2	Hydrogen
HCl	Hydrogen Chloride
HDP	Holddown Post
HGDS	Hazardous Gas Detection System
HIRAP	High Resolution Accelerometer Package
HMF	Hypergol Maintenance Facility
HPFTP	High Pressure Fuel Turbopump
HPOTP	High-Pressure Oxidizer Turbopump
HPV	High Pressure Valve
HR	Hazard Report
hr	Hour
Hz	Hertz
I/O	Input/Output
IAPU	Improved Auxiliary Power Unit
ICHR	Integrated Cargo Hazard Report
ID	Inside Diameter
IEA	Instrument and Electronic Assembly, Integrated Electronic Assembly
IFA	Inflight Anomaly
in-lb	Inch-Pound
INTG	Integration
IRIG-B	Interrange Instrumentation Group B
JSC	Johnson Space Center
KSC	Kennedy Space Center
L-2	Launch Minus 2 Days (Review)
lb	Pounds
lb/hr	Pounds Per Hour
LCC	Launch Commit Criteria
LH	Left-Hand
LH_2	Liquid Hydrogen
LiOH	Lithium Hydroxide
LO_2	Liquid Oxygen
LOX	Liquid Oxygen
LP	Launch Pad
LSFR	Launch Site Flow Review

APPENDIX A

LIST OF ACRONYMS (CONT.)

MADS	Modular Auxiliary Data Systems
MCC	Main Combustion Chamber
MDM	Multiplexer-Demultiplexer
ME	Main Engine
MEC	Maine Engine Controller
MECO	Main Engine Cutoff
MET	Mission Elapsed Time
mg/ft^2	Milligram Per Square Foot
MLP	Mobile Launch Platform
MMC	Martin Marietta Corporation
MPS	Main Propulsion System
MPSS	Main Parachute Support Structure
MPU	Magnetic Pickup Unit
MS	Margin of Safety
MSE	Mission Safety Evaluation
MSFC	Marshall Space Flight Center
NASA	National Aeronautics and Space Administration
NBR	Nitrite Butadiene Rubber
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
OARE	Orbiter Acceleration Research Equipment
OD	Outside Diameter
OEX	Orbiter Experiments
OMI	Operations and Maintenance Instruction
OMRSD	Operational Maintenance Requirements and Specifications Document
OMS	Orbital Maneuvering System
OPB	Oxidizer Preburner
OPO	Orbiter Project Office
ORBI	Orbiter
OV	Orbiter Vehicle

APPENDIX A

LIST OF ACRONYMS (CONT.)

PAR	Prelaunch Assessment Review
PC	Chamber Pressure
PCASS	Program Compliance Assurance and Status System
PCM	Pulse Code Modulator
PFS	Primary Flight Software
PIC	Pyro Initiator Controller
PMBT	Propellant Mean Bulk Temperature
ppm	Parts Per Million
PRACA	Problem Reporting and Corrective Action
PRCB	Program Requirements Control Board
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
RCC	Reinforced Carbon-Carbon
RCN	Requirements Change Notice
RCS	Reaction Control System
RH	Right-Hand
RI	Rockwell International
RM	Redundancy Management
rpm	Revolutions Per Minute
RSRM	Redesigned Solid Rocket Motor
RTLS	Return to Launch Site
RTV	Room-Temperature Vulcanizate

APPENDIX A

LIST OF ACRONYMS (CONT.)

S/N	Serial Number
S&A	Safe & Arm (Device)
sccs	Standard Cubic Centimeters per Second
scim	Standard Cubic Inches Per Minutes
SCM	System Control Module
SEADS	Shuttle Entry Air Data System
SEM	Scanning Electron Microscope
SEP	Separation
SILTS	Shuttle Infrared Leeside Temperature Sensing
SIT	System Integration Test
SLA	Super Light Ablator
SMIA	Serial Multiplexer Interface Adapter
SPC	Shuttle Processing Contractor
SRB	Solid Rocket Booster
SRM	Solid Rocket Motor
SRM&QA	Safety, Reliability, Maintainability and Quality Assurance
SSC	Stennis Space Center
SSME	Space Shuttle Main Engine
SSO	Support System for Orbiter Experiments
SSRP	System Safety Review Panel
STS	Space Transportation System
SUMS	Shuttle Upper Atmospheric Mass Spectrometer
TAL	Transatlantic Abort Landing
TGHE	Tile Gap Heating Effects
TPS	Thermal Protection System
TVC	Thrust Vector Controlf
USBI	United Space Boosters, Inc.
VAB	Vehicle Assembly Building
VDC	Volts Direct Current
VREL	Relative Velocity
WONG	Weight-On-Nose-Gear
WOW	Weight on Wheels
WSB	Water Spray Boiler