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MISSION SAFETY EVALUATION REPORT FOR STS-37

Postflight Edition

Safety Division

Office of Safety and Mission Quality

National Aeronautics and Space Administration

Washington, DC 20546

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MISSION SAFETY EVALUATION

REPORT FOR STS-37

Postflight Edition: June 14, 1991

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EXECUTIVE SUMMARY

STS-37/*Atlantis* was launched on April 5, 1991 from Kennedy Space Center launch complex 39B at 9:23 a.m. Eastern Standard Time (EST). Launch was delayed 4 minutes 45 seconds because of range safety concerns about the low cloud ceiling and the wind direction in the potential blast area.

Significant modifications were made to *Atlantis* during its 15-week stay in the Orbiter Processing Facility. These modifications included installation of 5 new General Purpose Computers (GPCs) that provide increased capabilities. Each new GPC is 52 pounds lighter and requires approximately 90 watts less power than the older computer unit it replaces. Carbon brakes were installed on the *Atlantis* Main Landing Gear for the STS-37 mission in place of the carbon-lined beryllium brakes. This new carbon brake system provides extended brake life and an improved performance margin that lowers the safety risk during landings.

The four STS-37 mission objectives were: (1) deployment of the Gamma Ray Observatory (GRO), the second of four planned "Great Observatories" being built by NASA to study the universe across the electromagnetic spectrum (the others are the Hubble Space Telescope, launched in April, 1990; the Advanced X-ray Astrophysics Facility, expected to be launched in 1998; and the Space Infrared Telescope Facility, scheduled for launch at the end of the decade; (2) evaluation of Extravehicular Activities (EVAs) for potential application to Space Station operations; (3) conduct of several middeck payload experiments; and (4) conduct of a variety of Detailed Supplementary Objectives and Development Test Objectives.

Based on the limited number and type of inflight anomalies encountered, the Space Shuttle operated satisfactorily throughout the STS-37 mission. A contingency EVA was performed by the crew on Flight Day (FD) 3 to free a sticky GRO high-gain antenna, after which the GRO primary payload was successfully deployed by the Orbiter's Remote Manipulator System. The GRO, which weighed just over 35,000 pounds, was the heaviest NASA science satellite ever deployed by the Space Shuttle into low-Earth orbit. The secondary payloads performed nominally.

The scheduled entry/landing on FD 6 was waved off for one day due to high wind conditions at Edwards Air Force Base (EAFB). *Atlantis* landed on FD 7, April 11, 1991, on EAFB lakebed runway 33 at 9:55 a.m Eastern Daylight Time (EDT).

FOREWORD

The Mission Safety Evaluation (MSE) is a National Aeronautics and Space Administration (NASA) Headquarters Safety Division, Code QS produced document that is prepared for use by the NASA Associate Administrator, Office of Safety and Mission Quality (OSMQ), and the Space Shuttle Program Director prior to each Space Shuttle flight. The intent of the MSE is to document safety risk factors that represent a change, or potential change, to the risk baselined by the Program Requirements Control Board (PRCB) in the Space Shuttle Hazard Reports (HRs). Unresolved safety risk factors impacting the STS-37 flight were also documented prior to the STS-37 Flight Readiness Review (FRR) (FRR Edition) and prior to the STS-37 Launch Minus Two-Day (L-2) Review (L-2 Edition). This final Postflight Edition evaluates performance against safety risk factors identified in the previous MSE editions for this mission.

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

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SECTION 1

INTRODUCTION

1.1 Purpose

The Mission Safety Evaluation (MSE) provides the Associate Administrator, Office of Safety and Mission Quality (OSMQ), and the Space Shuttle Program Director 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-37 safety risk factors that represent a change from previous flights, factors from previous flights that had an impact on this flight, and factors that are unique to this flight.

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

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

1.3 Organization

The MSE is presented in eight sections as follows:

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

Section 2 - Provides a summary description of the STS-37 mission, including launch data, crew size, mission duration, launch and landing sites, and other mission- and payload-related information.

Section 3 - Contains a list of safety risk factors/issues, considered resolved or not a safety concern prior to STS-37 launch, that were impacted or repeated by anomalies reported for the STS-37 flight.

Section 4 - Contains a list of safety risk factors that were considered resolved for STS-37.

Section 5 - Contains a list of Inflight Anomalies (IFAs) that developed during the STS-35 mission, the previous Space Shuttle flight.

Section 6 - Contains a list of IFAs that developed during the STS-38 mission, the previous flight of the Orbiter Vehicle (OV-104).

Section 7 - Contains a list of IFAs that developed during the STS-37 mission. Those IFAs that are considered to represent a safety risk will be addressed in the MSE for the next Space Shuttle flight.

Section 8 - Contains background and historical data on the issues, problems, concerns, and anomalies addressed in Sections 3 through 7. This section is not normally provided as part of the MSE, but is available upon request. It contains 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-37 MISSION SUMMARY

2.1 Summary Description of the STS-37 Mission

STS-37/*Atlantis* was launched on April 5, 1991, from Kennedy Space Center (KSC) launch complex 39B at 9:23 a.m. Eastern Standard Time (EST). Launch was delayed 4 minutes 45 seconds because of range safety concerns about the low cloud ceiling and the wind direction in the potential blast area.

Significant modifications were made to *Atlantis* during its 15-week stay in the Orbiter Processing Facility (OPF). These modifications included installation of 5 new General Purpose Computers (GPCs) that provide increased capabilities. Each new GPC is 52 pounds lighter and requires approximately 90 watts less power than the older computer unit it replaces. Carbon brakes were also installed on the *Atlantis* Main Landing Gear (MLG) for the STS-37 mission; STS-31/OV-103 was the first flight equipped with these carbon brakes in place of the carbon-lined beryllium brakes used on all Orbiters since the beginning of the Space Shuttle Program. This new carbon brake system provides extended brake life and improved performance margin that lowers the safety risk during landings. In addition to these modifications to the Orbiter, a Hydrogen Dispersal System (HDS) was installed on Mobile Launch Platform (MLP) #1 for STS-37. This system provides a Nitrogen (N_2) purge from the MLP to the 17" disconnect area to dilute or disperse a potential Hydrogen (H_2) leak. However, excessive H_2 leakage was not encountered at the 17" disconnect during STS-37 launch operations, and the purge system was therefore not used.

The four STS-37 mission objectives were: (1) deployment of the Gamma Ray Observatory (GRO), the second of four planned "Great Observatories" being built by NASA to study the universe across the electromagnetic spectrum [the others are the Hubble Space Telescope (HST), launched in April 1990; the Advanced X-ray Astrophysics Facility, expected to be launched in 1998; and the Space Infrared Telescope Facility, scheduled for launch at the end of the decade]; (2) evaluation of Extravehicular Activities (EVAs) for potential application to Space Station operations; (3) conduct of several middeck payload experiments; and (4) conduct of a variety of Detailed Supplementary Objectives (DSOs) and Development Test Objectives (DTOs).

The GRO was deployed on Flight Day (FD) 3. The GRO, which weighed just over 35,000 pounds, was the heaviest NASA science satellite ever deployed by the Space Shuttle into low-Earth orbit. Both solar arrays deployed successfully. The antenna latch sensors indicated that the latches were retracted in preparation for antenna deployment.

However, the GRO high-gain antenna did not deploy when commanded. A contingency EVA was performed by the crew; EVA crewmembers were successful in freeing the high-gain antenna, and it was subsequently deployed. The GRO was then released from the Orbiter's Remote Manipulator System (RMS).

On FD 4, activities were devoted almost entirely to planned EVA activities. These were accomplished successfully, and no significant problems were encountered.

Based on the limited number and type of Inflight Anomalies (IFAs) encountered, the Space Shuttle operated satisfactorily throughout the STS-37 mission. The more significant anomalies and problems are summarized below.

Postlaunch data analysis of the Backup Flight System (BFS) telemetry indicated that, from the prelaunch BFS OPS-1 transition until the T–8 second (sec) BFS reinitialization, the Z-component (altitude) of the BFS state vector was increasing at a rate of approximately 1 foot per second (ft/sec) to approximately 7700 ft. The BFS navigation errors were cleared at the T–8 sec point in the launch countdown when the BFS was reinitialized to the pad B position. Ascent telemetry review indicated that both the BFS and the Primary Avionics Software System (PASS) performed nominally. Recent pre-STS-37 tests, conducted in the Shuttle Avionics Integration Laboratory (SAIL) with the new GPCs, demonstrated errors of 4000-4500 ft. Errors were believed to be caused by gravity feedback; this eventually led to error growth in the Z-component. The investigation included a code audit of the BFS and PASS, and it was determined that the problem was only in the first initialization of the navigation function in the BFS. The PASS navigation function did not have the same problems. Testing of the BFS at the SAIL repeated the STS-37 prelaunch anomaly on each attempt and demonstrated that the problem was not from the Inertial Measurement Unit (IMU) input. It is believed that this anomaly was caused by the increased processing time of the new GPCs combined with the way the BFS sequences initialization of the navigation function. Discrepancy Report (DR) 106197 was generated to identify this problem for resolution.

During ascent, after Main Engine Cutoff (MECO), Water Spray Boiler (WSB) #2 experienced spray bar freeze-up while on controller "A" and failed to cool Auxiliary Power Unit (APU) #2 lube oil after the end of the pool boiling period. The crew switched to controller "B", and operation was normal. The crew later switched back to controller "A" just before APU shutdown, and WSB #2 continued to function normally; both controllers were then considered functional. WSB #2 on STS-37 was a new boiler, and both APU #2 and WSB #2 were hot oil flushed. The most probable cause of this problem was wax buildup in the WSB due to APU hydrazine fuel mixing with the lube oil. Research of the WSB cooling problem indicated that APU #2, Serial Number (S/N) 208, had been involved in 6 out of 13 freeze-ups; and on the flights in which APU S/N 208 and WSB #2 had been paired, the spray bar freeze-up occurred in 5 out of 5 flights. Further investigation into the cause of this anomaly is continuing.

Reaction Control System (RCS) thruster R1U failed "off" the first time it was used [during the STS-37 External Tank (ET) separation maneuver]. R1U was deselected by

Redundancy Management (RM). The immediate concern with trying to recover a failed "off" thruster is the risk of obtaining a large leakage caused by contamination after the thruster is fired. The flight rule states that a failed thruster should be kept deselected unless needed for attitude control or to protect against the loss of fail-safe redundancy. There were 2 other right, upward-firing thrusters available in addition to the failed R1U unit. The R1U thruster was not fired during the mission. It is believed that the cause of the failure was iron nitrate contamination within the thruster inlet valves, similar to that seen on STS-36 thrusters R3D and R4R. The STS-37 R1U thruster was removed when *Atlantis* returned to KSC; the unit was sent to the White Sands Test Facility (WSTF) for further failure analysis.

On-orbit operation of the ET umbilical doors was reported to be nominal for STS-37. Prior to launch, there was an issue concerning the ET umbilical doors because of starter cracks were discovered in 3 of 4 door lug clevises (see Section 4, Orbiter 1). The decision was made not to remove and replace the ET door lug housings on OV-104 prior to flight. Postflight visual inspection of the lug clevises found no apparent crack growth as a result of ET umbilical door operation on orbit. The OV-104 door lug housings were removed after the STS-37 flight and replaced with the modified "J-leg" lug design housings.

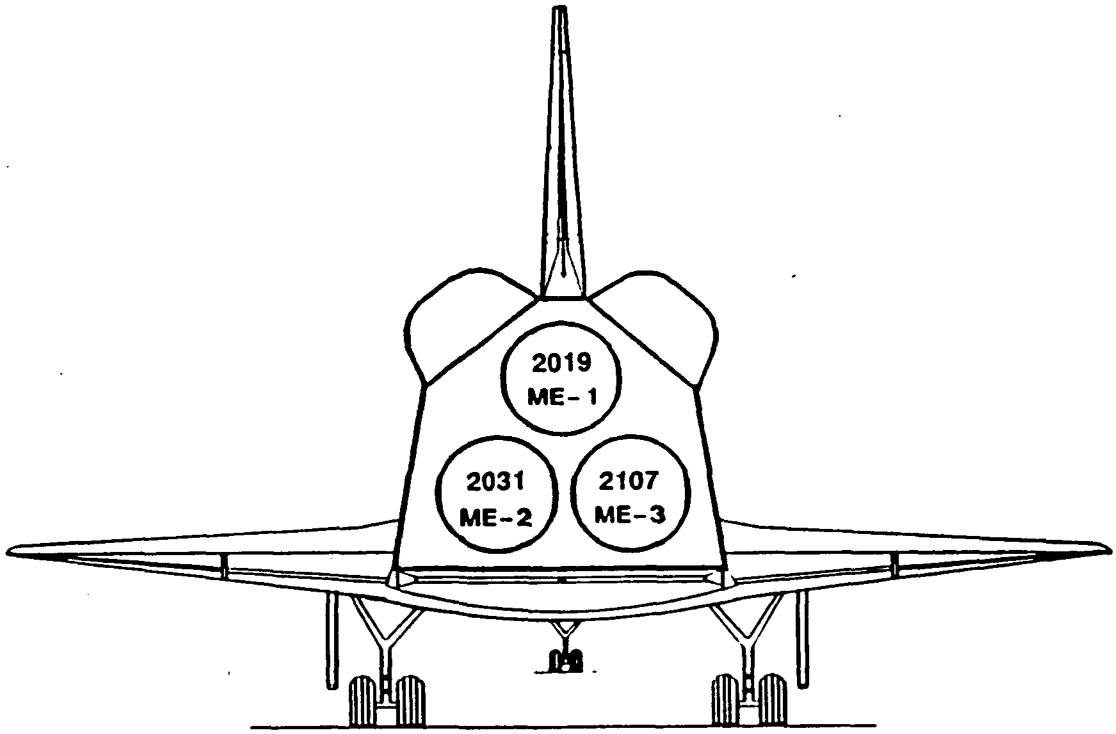
The scheduled entry/landing on FD 6 was waved off for 1 day due to high wind conditions at Edwards Air Force Base (EAFB). *Atlantis* landed on FD 7, April 11, 1991, on EAFB lakebed runway 33 at 9:55 a.m. Eastern Daylight Time (EDT). The GRO primary payload had been successfully deployed and the secondary payloads performed nominally.

STS-37/OV-104 touched down more than 600 feet (ft) short of the threshold on EAFB lakebed runway 33. During descent, *Atlantis* encountered wind shear from 13,000 ft down to 9,000 ft, which resulted in a wider than computed Heading Alignment Cone (HAC) and lower energy at the transition to the approach and landing interface. Wind shear was again encountered at approximately 1,000 ft. At preflare, *Atlantis* was approximately 1,000 ft below the referenced altitude, resulting in a range error of 3,200 ft. A second wind shear, encountered at an altitude of approximately 1,000 ft, further reduced the range by 850 ft. The crew used all remaining energy to protect against a hard landing and high nose gear slapdown loads. Postflight reviews revealed that information concerning wind shear, gathered by the Shuttle Training Aircraft (STA) during prelanding evaluation runs, could have been relayed to *Atlantis*. If the pilot had known about the wind shear in the HAC area, steps could have been taken to mitigate wind shear effects. This incident has elevated the awareness of potential wind shear conditions and the potential effects of wind shear after passing the terminal area energy management interface.

Postlaunch inspection at KSC revealed no facility anomalies. No flight hardware was found at the pad or in the area under the flightpath. About 3-4 ft of holddown post #1 firing cable was found to have remained attached to the Right Hand (RH) Solid Rocket Booster (SRB) aft skirt.

2.2 Flight/Vehicle Data

- Launch Date: April 5, 1991
- Launch Time: 9:23 a.m. EST
- Launch Site: KSC Pad 39B
- RTLS: Kennedy Space Center, Shuttle Landing Facility
- TAL Site: Banjul, The Gambia
- Alternate TAL Site: Ben Guerir, Morocco
- Landing Site: Edwards AFB, CA, Lakebed Runway 33
- Landing Date: April 11, 1991
- Landing Time: 9:55 a.m. EDT
- Mission Duration: 6 Days, 0 Hours, 32 Minutes
- Crew Size: 5
- Inclination: 28.45°
- Altitude: 243 Nautical Miles/Direct Insertion
- Orbiter: OV-104 (8) *Atlantis*
- ET-37
- SRBs: BI-042
- RSRM Flight Set #14
- MLP #1



ENGINE	#2019	#2031	#2107
POWERHEAD	#2020	#2028	#2014
MCC*	#2023	#2019	#4002
NOZZLE	#2024	#4017	#4019
CONTROLLER	F4	F29	F25
FASCOS*	#23	#12	#29
HPFTP*	#6008	#4010R3	#6003R1
LPFTP*	#2022R1	#2120R1	#4007
HPOTP*	#9309R2	#2027R3	#2521R2
LPOTP*	#2025R1	#2120	#2216

* Acronyms can be found in Appendix A.

2.3 First Flight of Upgraded General Purpose Computers

The next-generation GPCs were flown for the first time on STS-37. The upgrade, model AP101S, has an overall memory capacity of 256 kilobytes (K) and will perform 1000K operations per second. The AP101S Central Processing Unit and Input/Output Processor are in 1 box as opposed to 2 separate boxes in the model AP101B. The AP101S is approximately 52 pounds (lb) lighter than AP101B and requires approximately 90 watts less power.

AP101Ss were installed in OV-104 in all 6 positions; 5 active and 1 inflight spare. The installed units were: GPC #1 - S/N 511, GPC #2 - S/N 504, GPC #3 - S/N 501, GPC #4 - S/N 526, GPC #5 - S/N 508, and Spare - S/N 519. The 6 OV-103 GPCs have been operated for over 14,000 total hours (hr) (ranging from 1381 hr to 3840 hr). For all AP101Ss, there have been over 30,000 hr of operation.

The AP101S design includes error detection and correction for single-bit errors and detection of 2-bit errors in each word of the GPC memory. Memory scrub is performed every 1.7 sec. AP101S microcode is improved over AP101B to reduce exposure to non-universal Input/Output (I/O) errors, a potential Crit 1/1 error condition. Available memory in the AP101S is 256K, comprising 2 pages of 128K each. However, the hardware design and current addressing scheme preclude effective use of the upper 128K of memory. Effort is underway to identify software changes that will enable efficient use of the upper memory. Current plans target the OI-24 flight software release, scheduled for availability in February 1992, for incorporation of this capability. Release OI-20, scheduled to be available in the Fall of 1991, will allow limited use of the upper memory. Software releases through OI-21 will require less than 128K of memory to operate effectively. This constraint to the full use of AP101S capabilities was not an issue for STS-37 because the AP101B is only capable of utilizing 128K of memory.

There were hazards identified with the use of AP101S GPCs. However, minor additions and revisions were made to flight rules, crew procedures, and Launch Commit Criteria (LCC) to account for the use of AP101S. The launch team, crew, and mission operations team were trained with these changes in place.

Two risk factors in Section 4 of this STS-37 Mission Safety Evaluation address problems associated with the new GPCs. The first, Orbiter 5, deals with the potential for the new GPCs to erroneously overwrite memory when commanded from the "sleep" mode. Procedural workarounds made this risk factor acceptable for STS-37 flight. The second, Orbiter 8, addresses the failure of a new GPC in the SAIL. This failure was accepted as an isolated, unexplained anomaly; it was not considered to be a generic GPC problem issue.

2.4 Software Upgrade for Orbiter and Space Shuttle Main Engine Controllers

STS-37 was the first flight to use OI-8F software. The OI-8F Orbiter avionics software release was developed to support the introduction of the new AP101S GPCs. OI-8F is a combination of the OI-8D software release, first used on STS-41, and OI-9A that was developed to support the basic hardware changes (i.e., increased memory and central processor speed) between the AP101B GPCs and the AP101S GPCs; there were no other application code changes.

This was also the first flight of the AR02 software upgrade for the Space Shuttle Main Engine (SSME) controller. Modifications include extended monitoring of igniter "on-time" for verification of igniter quench, changes to KSC load timing to minimize load errors, and elimination of the Pogo precharge pressure sensor qualification limit post-shutdown to provide consistency with SSME redline logic.

2.5 Hydrogen Dispersal System Installed on Mobile Launch Platform #1, STS-37

The HDS was installed for the first time on MLP #1 for use with STS-37. This system provides a nitrogen purge from the MLP to the 17" disconnect area to dilute or disperse a potential Hydrogen (H_2) leak. The HDS includes a standpipe, approximately 18 ft in height above the MLP zero deck, and 2 standpipe support legs welded to the MLP. There is a 16" outer pipe supporting and protecting a 2" inner pipe through which Gaseous Nitrogen (GN_2) flows. A nozzle is connected to the inner pipe that is designed for nominal flow of 750 standard cubic feet per minute (scfm) of GN_2 at 125 pounds per square inch gage (psig). The acoustic level at the nozzle outlet was determined by analysis and test to be approximately 126 decibels. Purge velocity at the 17" disconnect area was determined to be approximately 35 knots.

The structure above the MLP zero level was hardened for the launch environment. A blast cover protects the nozzle, and a rain cover (butcher paper) prevents water and other contamination from entering the purge systems. The standpipe and support structure was designed to handle a 15-psig acoustical overpressure from any direction with a Factor of Safety (FOS) of 2.

Analyses were performed of worst-case conditions and potential vehicle drift at liftoff. For nominal liftoff drift, worst-case drift (3σ with a 20-knot wind), and worst-case engine-out condition (1σ), analysis indicated that body flap trailing edge and left SRB aft skirt clearances were sufficient. On-pad engine shutdown excursion clearances were also determined to be sufficient.

Criteria for the use of the HDS were established by the Space Shuttle Program. The HDS will only be used to enable a safe (or safer) detanking condition after a launch scrub has been declared due to high H_2 concentration at the 17" disconnect. The HDS will <u>not</u> be used to enable continuation of launch countdown in the presence of high H_2 concentrations.

Hazard analysis associated with the use of this system is also in work. The hazard analysis addresses the potential for debris impact on the vehicle, structural failure of the system, inadvertent operation, effects of use during fire or explosion at the pad, and contact with flight hardware during liftoff and abort. The focus of the analysis is on operation of the HDS as a "detank only" tool.

2.6 Carbon Brakes

STS-31/OV-103 was the first flight equipped with carbon brakes on the main landing gear. Carbon brakes were installed on OV-104 for the STS-37 mission. These brakes are replacing the carbon-lined beryllium brakes used on all Orbiters since the beginning of the Space Shuttle Program. The prime reasons for making this change were: improved performance margins that lower the safety risk during landings, extended brake life, and elimination of special handling procedures. STS-31 was selected for carbon brake system first flight because required instrumentation was available on OV-103. The carbon brake assembly comprises 5 rotors and 4 stators (increased from 4 and 3, respectively) to increase the friction/braking area. The beryllium brake assemblies have carbon liners fastened to beryllium rotors; this further reduces the available rotor friction area. One-piece carbon rotors are used in the improved carbon brake assembly. Hydraulic pressure regulation is reduced by 500 pounds per square inch (psi) with the carbon brakes; operating pressure is 2000 psi. Energy absorption capability of the carbon brakes increases to 82,000,000 foot-pounds (ft-lb) from the 18,000,000 ft-lb capacity of the beryllium brakes. This added capability provides a nominal brake life of over 20 landings/stops, much improved over the 5 maximum landings/stops of the beryllium brakes. The additional energy absorption capability allows an increase in nominal landing speed from 180 knots to 225 knots, lowering the risk associated with Return-To-Launch-Site (RTLS) contingency landings at KSC. In addition to increased performance and extended useful life, elimination of the beryllium brakes decreases the health risk to technicians; beryllium is a highly toxic element. DTOs involving the carbon brakes, performed on OV-103, will be repeated on OV-104; some of these DTOs were performed during the STS-37 mission.

2.7 Aft Compartment Hydrogen Concentration Launch Commit Criteria Limits

Lessons learned during the 1990 H_2 leak investigation led to a reduction in the LCC for aft compartment H_2 concentration. From the start of tanking through stable replenish, the aft compartment H_2 LCC will remain at 500 parts per million (ppm) for OV-104. To further protect against the potential for leaks in the high-pressure side of the Main Propulsion System (MPS) exceeding flammability limits after engine start, the LCC was reduced from 300 ppm to 150 ppm for the period from stable replenish through prepressurization of the liquid hydrogen tank at T–117 seconds. This reduction was due to the fact that only 5% of the high-pressure side is wetted prior to engine start. A leak in excess of 150 ppm during low-pressure operations in stable replenish was calculated to exceed the aft compartment flammability limit when entering high-pressure operations. For the balance of the launch countdown, the aft compartment H_2 concentration LCC remained the same as that for previous launches.

2.8 Payload Data

The four STS-37 mission objectives were to: deploy the Gamma Ray Observatory (GRO), evaluate a variety of Extravehicular Activities for potential application to Space Station operations, conduct several middeck payload experiments, and conduct a variety of DSOs and DTOs. The GRO is the second of 4 planned "Great Observatories"; the others are the Hubble Space Telescope, the Advanced Astrophysics Facility, and the Space Infrared Telescope Facility.

On the fourth day of the STS-37 flight, the Extravehicular Activities Developmental Flight Experiment (EDFE) required the first space walk by American astronauts since November 1985. The space walk tested 3 prototype cart designs, the Shuttle's robot arm as a work platform for astronauts, and instrumented evaluation of astronauts' ability to work with tools in a weightless environment.

Payload Bay:

- GRO – investigates extraterrestrial gamma-ray sources.
- EDFE – included 3 sets of evaluations:
  - Crew and Equipment Transaction Aid (CETA) – a multipurpose crew system that provides rapid return to the Space Shuttle airlock in case of an emergency, allows efficient translation, and carries equipment. The CETA consists of 3 carts and a tether Shuttle.
  - Crew Loads Instruments Pallet Experiment (CLIP) – provides EVA crew loads data.
  - EVA Translation Evaluation (ETE) – evaluates EVA translation rates and techniques while performing representative scenarios of Space Station operations.
- Ascent Particle Monitor (APM) – collects particulate materials from the Orbiter during ascent, using an automated mechanical/electrical assembly.
- Space Station Heat Pipe Advanced Radiator Element (SHARE) – demonstrates and quantifies the microgravity thermal vacuum performance of a high-capacity, space-constructible, heat pipe radiator element for heat rejection as a prelude to development of a Space Station heat rejection system.

Middeck:

- Protein Crystal Growth (PCG III) – obtains high-quality protein crystals in a controlled temperature module.
- Radiation Monitoring Equipment (RME III) – measures the rate and dosage of ionizing radiation to the crew at different locations throughout the Orbiter cabin. The hand-held instrument measures gamma ray, electron, neutron, and proton radiation and calculates the amount of exposure.
- Shuttle Amateur Radio Equipment (SAREX II) – provides a low-cost space-to-ground voice and slow-scan television experiment.
- Air Force Maui Optical Station (AMOS) – technology development/ geophysical environment study to calibrate AMOS ground-based electro-optical sensors and study on-orbit plume phenomenology using the Shuttle as a test object.
- Bioserve ITA Materials Dispersion Apparatus (BIMDA) – includes a wide range of tests focused on the assembly of macromolecules in a thermal enclosure.

2.9 Gamma Ray Observatory Description

The primary objective of the GRO is to obtain a large body of high-quality data to greatly enhance knowledge and understanding of the spectra and scale of gamma ray and associated galactic activity. It is expected that much of the obscuration and handicaps of telescopic observation on earth can be overcome by conducting observations from earth orbital altitudes with an observatory capable of full-sky pointing.

The GRO provides a capability for Space Shuttle crew to conduct extravehicular operations for On-Orbit Refueling (OOR), maintenance and repair, and on-orbit retrieval. The GRO is comprised of three major elements: the integrated instrument package, a carrier platform, and flight support equipment. It is deployed by the Orbiter's RMS.

Instrument Package

Gamma rays constitute a part of the electromagnetic spectrum, similar to radio waves, visible light, or x-rays. However, the gamma ray portion of the spectrum is much broader than these other regions. The gamma ray spectrum is over 10,000 times the range of visible light and over 100 times that of x-rays.

The astrophysics information of interest is spread over the full range of gamma ray energies. No single instrument can cover the entire range; thus, GRO carries 4 different instruments, including one that will look for and measure gamma ray bursts.

Oriented Scintillation Spectrometer Experiment (OSSE)

The low-energy range from 0.1-10 million electron volts (MeV) is covered by the OSSE which consists of 4 separate detectors that can rotate independently to look at different parts of the sky. The sensitivity of this instrument is over 10 times greater than that of any unit previously flown. It is able to determine the direction of a source to a fraction of a degree.

Imaging Compton Telescope (COMPTEL)

This is a midrange instrument that covers the range of energies from 1-30 MeV and is able to determine angle of arrival to within less than a degree at the higher energies. It can measure the energy of photons to within 5 percent (also at the higher energies). Special provisions were made to reduce background radiation effects.

Energetic Gamma Ray Experiment Telescope (EGRET)

For the highest energy range, from 20-30 MeV, the EGRET is capable of measuring the position of a source to a fraction of a degree and the energy of individual photons to within 15 percent.

Burst and Transient Source Experiment (BATSE)

The BATSE continuously observes the full sky (except for Earth blockage) for gamma ray bursts or other short-duration phenomena, and also interacts with other instruments when a burst is taking place. It makes a full-sky survey of long-lived (strong) sources. The BATSE modules measure gamma rays in the range from 0.05-6 MeV and incorporates a separate spectroscopy detector with a 0.02-10 MeV range.

Collectively, these 4 GRO instruments weigh nearly 7 tons. The full observatory, including these instruments, weighs approximately 35,000 lb. It was designed to be launched, serviced, and retrieved by the Space Shuttle. It can also be commanded to perform a power-controlled reentry and splashdown. The GRO provides communications, data handling, electric power, and attitude functions to all 4 instruments.

From launch until GRO deployment, all 4 instruments are unpowered except for Orbiter-powered heater operation in the payload bay after the doors are opened. These heaters are turned off prior to GRO removal from the payload bay by the RMS.

SECTION 3

SAFETY RISK FACTORS/ISSUES IMPACTED BY STS-37 ANOMALIES

This section lists safety risk factors/issues, considered resolved (or not a safety concern) for STS-37 prior to launch (see Sections 4, 5, and 6), that were repeated or related to anomalies that occurred during the STS-37 flight (see Section 7). 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 STS-37 Safety Risk Factors

ORBITER 12	Clogged Auxiliary Power Unit (APU) #3 lube oil filter on OV-104.	During the pad confidence run hot-fire of STS-37/OV-104 APU #3, S/N 307, gearbox lube oil pressure peaked at 108 pounds per square inch absolute (psia). High gearbox pressure is an indication of wax buildup and the potential for a clogged filter. Gearbox pressure is nominally 50 psia during APU operation. A clogged filter could cause Water Spray Boiler (WSB) spray bar freeze-up and an over-temperature condition of the APU post-Main Engine Cutoff (MECO). The Operational Maintenance Requirements and Specifications Document (OMRSD) requires a hot-oil flush if evidence of filter clogging is present. However, an APU hot-oil flush has never been performed in the vertical position; an OMRSD procedure would have to be written to accomplish the flush. The decision was made to drain the lube oil from APU #3 and replace the lube oil filter. STS-37/OV-104 System #3 APU/WSB post-MECO lube oil temperature ran cooler than the other 2 systems; lube oil return temperature was 231°F minimum. System #3 saw a second overcool during entry; lube oil return temperature was 211°F minimum. Contamination of System #3 APU/WSB was suspected. (IFA No. STS-37-V-12)

ITEM		COMMENT
Section 4: Resolved STS-37 Safety Risk Factors		
ORBITER 12 (Continued)	Clogged APU #3 lube oil filter on OV-104.	STS-37/OV-104 WSB #2, which did not indicate any problems during prelaunch tests, failed to cool APU #2 lube oil during STS-37 ascent. When lube oil temperature reached 280°F, the crew switched from WSB controller "A" to controller "B"; nominal cooling begins at 250°F. The most probable cause of this anomaly was freezing of the spray bar due to wax buildup in WSB #2. Investigation into APU/WSB combinations that displayed similar problems is in work. The same anomaly occurred during STS-38, the previous flight of OV-104 (IFA No. STS-38-01). Both controller "A" and WSB #2 were removed and replaced on OV-104 after STS-38. (IFA No. STS-37-V-02A/B)

ITEM		COMMENT
Section 5: STS-35 Inflight Anomalies		
ORBITER 5	WSB #3A operation was abnormal during ascent and entry. IFA No. STS-35-17	During STS-35 ascent, WSB #3A did not initiate spray cooling until APU #3 lube oil return temperature reached 277°F. WSB cooling operation should begin at 250°F. During reentry operations, WSB #3A overcooled the lube oil. A similar anomaly occurred with WSB #2A on STS-38/OV-104. (See Section 6, Orbiter 1 for more details.) Similar problems were encountered with WSB #2 and #3 operation on STS-37. WSB #2 did not cool APU lube oil while under operation of controller "A", and operation had to be switched to controller "B" when lube oil temperature reached 280°F. The most probable cause of the problem was again believed to be freezing of the spray bar due to wax buildup in WSB #2. WSB #3 overcooling was encountered post-MECO and again during entry. Contamination of System #3 APU/WSB was suspected. (See Section 7, Orbiter 2 and Orbiter 6 for more details.) (IFA No. STS-37-V-02A/02B and IFA No. STS-37-V-12)

ITEM		COMMENT
Section 5: STS-35 Inflight Anomalies		
ORBITER 8	Reaction Control System (RCS) vernier thruster R5D failed "off". IFA No. STS-35-20	During STS-35 orbital maneuvering, RCS vernier thruster R5D exhibited low Chamber Pressure (P_c) and was deselected by Redundancy Management (RM). Data evaluation indicated that helium was present in the crossfeed line. A similar failure was seen on STS-9. Vernier thruster R5D was successfully hot-fired on orbit to flush out the helium. Evaluation of the hot-fire data indicated some gas ingestion during the first pulse and none in the 4 subsequent pulses. RM was reset following nominal performance during the hot-fire. During STS-38/OV-104, low P_c was experienced on 4 primary thrusters: R1U, R3D, RF3L, and R4U. Postflight troubleshooting did not reveal any thruster leaks or other anomalies which might lead to low thruster P_c. Subsequent analysis determined that these STS-38 thrusters all indicated low P_c during interconnect operations; the right pod thruster manifold was interconnected to the left Orbital Maneuvering System (OMS) propellant tanks. When RP03 propellant source was switched from the right OMS propellant tanks back to the straight feed configuration, thruster P_c in R1U, R3D, RF3L, and R4U returned to nominal. This finding led to the decision to perform thruster firings on STS-37/OV-104 in the interconnect configuration. When this was performed, thrusters L1U and L1L showed degraded P_c, approximately 130 psia instead of 150 psia nominal. P_c in L1U and L1L returned to nominal

ITEM		COMMENT
Section 5: STS-35 Inflight Anomalies		
ORBITER 8 (Continued)	RCS vernier thruster R5D failed "off".	after reconfiguration to straight feed. It is believed that there was contamination in the oxidizer interconnect line. Troubleshooting will be performed at KSC. (See Section 7, Orbiter 4 for more details.) (IFA No. STS-37-V-08)
		RCS primary thruster R1U failed "off" during the External Tank (ET) separation maneuver on STS-37. In this case, the problem was believed to be caused by iron nitrate contamination of the oxidizer valve poppet; pressure traces from the R1U failure were similar to those seen on STS-36 thruster failures that were attributed to this type of contamination. (See Section 7, Orbiter 1 for more details.) (IFA No. STS-37-V-01)

ITEM		COMMENT
Section 6: STS-38 Inflight Anomalies		
ORBITER 1	WSB #2 did not cool APU lube oil while under operation of controller "A". IFA No. STS-38-01	STS-38/OV-104 WSB #2 controller "A" failed to cool APU lube oil after the end of the pool boiling period during ascent. The crew switched to controller "B" when the temperature reached 275°F, and APU #2 was left "on" after APUs #1 and #3 were shut down. After switching to controller "B", lube oil temperature peaked at 300°F before cooling was observed after 66 seconds (sec). Controller "A" was selected for reentry to determine if the temperature control operated properly; controller "A" operated normally. It was believed that spray bar freeze-up on controller "A" during ascent caused the problem. Freezing of the spray bar could have been caused by low heat load on APU #2, or controller "A" was not functioning properly. A similar cooling problem was experienced on STS-1 through STS-4 and on STS-35/OV-102. (IFA No. STS-35-V-17) Similar problems were encountered with WSB #2 operation on STS-37. WSB #2 did not cool APU lube oil while under operation of controller "A", and operation had to be switched to controller "B" when lube oil temperature reached 280°F. The most probable cause of the problem was again believed to be freezing of the spray bar due to wax buildup in the WSB #2. (See Section 7, Orbiter 2 for more details.) (IFA No. STS-37-V-02A/B)

SECTION 4

RESOLVED STS-37 SAFETY RISK FACTORS

This section contains a summary of the safety risk factors that were considered resolved for STS-37. These items were reviewed by the NASA safety community. A description of the risk factor, information regarding problem resolution, and rationale for flight are provided for each safety risk factor. The safety position with respect to resolution is based on findings resulting from System Safety Review Panel (SSRP), Prelaunch Assessment Review (PAR), and Program Requirements Control Board (PRCB) evaluations (or other special panel 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.

Hazard Report (HR) numbers associated with each risk factor in this section are listed beneath the risk factor title. Where there is no baselined HR associated with the risk factor, or if the associated HR has been eliminated, none is listed. Hazard closure classification, either Accepted Risk {AR} or Controlled {C}, is included for each HR listed.

The following risk factors, contained in this section, represent an increase in risk above the Level I approved Hazard Baseline.

Integration 1	New Criticality 1 and 1/R2 failure modes have been identified for the Rate Gyro Assemblies on the Orbiter and Solid Rocket Boosters.
Orbiter 1	External Tank umbilical door lug clevis cracks on STS-37/OV-104.

SECTION 4 INDEX

RESOLVED STS-37 SAFETY RISK FACTORS

RESOLVED STS-37 SAFETY RISK FACTORS

RESOLVED STS-37 SAFETY RISK FACTORS

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
INTEGRATION		
1	New Criticality (Crit) 1 and 1/R2 failure modes have been identified for the Rate Gyro Assemblies (RGAs) on the Orbiter and Solid Rocket Boosters (SRBs). HR No. INTG-144C {C} INTG-165A {C} B-50-18 Rev. C-DCN2 {C} *No RGA problems were reported on STS-37.*	Review of recent RGA test data indicated occurrence of a large output transient, up to 45% of full scale, that lasts approximately 10 seconds (sec) when power to an RGA is lost. It was previously believed that the RGA output would immediately go to zero when power was removed. In operation, Redundancy Management (RM) software normally selects the second highest output value from 1 of 4 SRB RGAs for further processing. Post-SRB separation during ascent, and during descent, RM will select the second highest output value from 1 of 4 Orbiter RGAs. However, because it is now known that RGA output can stay high for as long as 10 sec after power is removed, the potential exists for RM to select erroneous output data from an RGA that has lost power as the second highest value. Selection of erroneous data could lead to loss of vehicle control and subsequent loss of the crew and vehicle. Reevaluation of the RGA Failure Modes and Effects Analysis (FMEA) for Orbiter and SRB RGA power circuits and the effects of simultaneous loss of power to 2 RGAs identified Crit 1/R2 failure modes for both the Orbiter and SRB RGAs. The first failure could be a latent, redundant power feed circuit component (i.e., a remote power controller, a diode failing open, etc.). The second potential failure could be loss of a second string redundant path and power feed to another RGA with a non-redundant power source. These 2 failures would result in simultaneous loss of power to 2 RGAs. A Crit 1/1 failure mode was found to be associated with the SRB RGAs. No Crit 1/1 failure modes were identified for the Orbiter RGAs. In the case of the SRB RGAs, demate of a single connector (55W1P113/J3) on the Orbiter Master Event Controller (MEC) #2 or in the Orbiter Avionics Bay #5 feedthrough (50W92P299/J99) will result in simultaneous loss of power to 2 SRB RGAs. Additionally, opening of all 3 poles of the 3-pole MEC #2 power toggle switch will also cause simultaneous loss of power to 2 SRB RGAs. Power distribution to the RGAs within the SRBs is redundant.

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
INTEGRATION		
1 (Continued)	New Crit 1 and 1/R2 failure modes have been identified for the RGAs on the Orbiter and SRBs.	Two Critical Item List (CIL) waivers, CR S50260D and CR S50260S, were submitted to address the new Crit 1/1 and 1/R2 conditions identified and were approved for STS-37/OV-104 and STS-39/OV-103. CR S50260D addresses component and power bus failures in the Orbiter that create the Crit 1/R2 condition for Orbiter and SRB RGAs. CR S50260S addresses the 2 Orbiter connector demates/failures that create the Crit 1/1 condition for SRB RGAs. An existing Crit 1/1 CIL for the 3-pole MEC #2 power toggle switch is unchanged by these findings. Flight Rule (FR) 8-47 was prepared to reduce the risk of simultaneous RGA power loss and output of erroneous data. This FR directs the crew to deselect 1 Orbiter RGA when the first failure is detected. Ground test procedures were incorporated to verify the integrity of the SRB RGA backup power logic source during essential power bus tests at T-1 hour. Photographic documentation of the Crit 1/1 connectors was also mandated to ensure proper connector seating. Review of the applicable photographs and video tape determined that these connectors were properly installed. Review of recent processing records determined that the critical connectors, 55W1P113/J3 and 50W92P299/J99, had not been demated since the STS-27 flow. Additionally, a switch guard was installed over the MEC #2 power toggle switch to preclude inadvertent action by the crew. An effort is underway to obtain a design solution to eliminate these failure modes from the system. To date, there have been no failures in the Orbiter and SRB RGA power circuits. There is also a low failure rate for critical power circuit components (i.e., remote power controllers and diodes).

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
INTEGRATION		
1 (Continued)	New Crit 1 and 1/R2 failure modes have been identified for the RGAs on the Orbiter and SRBs.	Rationale for STS-37 flight was: • Redundant power circuits were tested during normal flow processing. Additional prelaunch tests were identified to verify the SRB RGA backup power logic source. • Reliability of RGA power circuit components is high. • Photographic documentation of critical connectors demonstrated proper connector installation. • Critical connectors were not demated since STS-27. • A switch guard was installed over the MEC #2 power toggle switch to preclude inadvertent actuation. *This risk factor was acceptable for STS-37.*

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
<u>ORBITER</u>		
1	External Tank (ET) umbilical door lug clevis cracks on STS-37/OV-104. HR No. ORBI-302A {AR} *No problems were experienced with umbilical door closure on STS-37. Postflight visual inspection of STS-37/OV-104 ET door lug crevises found no apparent crack growth as a result of ET umbilical door closure operations on orbit. All OV-104 ET door lug housings have now been replaced with the modified J-leg lug design.*	ET umbilical door lug clevis cracks and displacement observed on OV-103 have led to increased inspection and awareness on other Orbiters. Dye-penetrant and etch inspection of OV-104 revealed crack initiation on 3 of 4 lug clevises; the fourth clevis showed indications of pitting. Eddy current measurements of the cracks indicated a maximum depth of 0.025" ±0.005". No lug displacement was noted, and adjustments made to the door rigging during the STS-37 flow were considered unaffected by the presence of clevis cracks with the current flaw size. Discovery of these cracks on OV-104 was made after the ET umbilical doors were locked open on the centerline latches. Previous inspection of OV-104 lug clevises, with the ET umbilical doors at the 90° position, found indications of pitting only. Analysis conducted during the STS-39/OV-103 investigation determined that Low-Cycle Fatigue (LCF) coupled with a stress riser (radius) at the lug clevis could lead to initiation of small cracks in the clevis. Rockwell International (RI) and the Orbiter Project reverified this analysis following the discovery of cracks on OV-104 and confirmed by stress analysis that the peak stress of 42.3 thousand pounds per square inch (ksi) occurs at the base of the lug during normal ground-processing door cycling when the doors are latched at the centerline. This peak stress level is in the LCF range for 7075-T73 aluminum, the lug material. An independent assessment conducted by Code QT/Vitro confirmed this conclusion and further indicated that as few as 250 ground-processing door cycles, and application of associated tensile and compressive loads on the lug clevis, were sufficient to cause crack initiation. RI/Orbiter Project stress analysis of the starter cracks observed on OV-104 indicated a resulting positive safety margin of 34% above the 1.4 structural Factor of Safety (FOS). This determination was made considering the presence of a clevis crack, 0.025" in depth, with 48.5-ksi peak stress applied to the clevis. A fracture analysis, also performed by RI/Orbiter Project, indicated that the crack is stable in

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
<u>ORBITER</u>		
1 (Continued)	ET umbilical door lug clevis cracks on STS-37/OV-104.	the current configuration. Predictions made using the fracture analysis model demonstrated that a 0.025"-deep clevis crack would be stable (defined as slow, subcritical crack growth) for more than 300 ground-processing load cycles (a load cycle is defined as door swing from the open, latched position to the ready-to-latch, sag position). For the remainder of the STS-37 prelaunch activities and mission, the ET umbilical doors cycled once on orbit and were returned to the open, latched position for the ferry flight. Because repeated inspections using dye-penetrant and etching techniques were performed on OV-104 lugs, concern was raised relative to the potential for etchant entrapment in the crack leading to accelerated crack growth. Pasa-Jell 105, an acid etchant normally used for aluminum surface treatment for adhesive bonding, was used on the OV-104 lug clevises. Pasa-Jell 105 is comprised of sulfuric acid and sodium dichromate, and uses thixotropic as a thickening agent. This etchant has a gelatinous consistency and is viscous in nature. It is, therefore, not believed that the Pasa-Jell 105 could penetrate tight cracks such as those observed on OV-104 lugs. The subsequent applications of dye-penetrant fluid and saline solution, used to remove excess dye penetrant after inspection, are believed sufficient to flush out Pasa-Jell 105 residue if present. Sulfuric acid contribution to stress corrosion in 7075-T73 aluminum was evaluated. Sulfuric acid is often used to anodize aluminum and to prepare aluminum for bonding. There is no known history of aluminum stress corrosion from sulfuric acid exposure. The Orbiter Project, however, performedests on a 7075-T73 aluminum specimen with an induced crack and etched with Pasa-Jell 105 to verify the absence of stress corrosion. Preliminary results of these tests, provided on March 14, 1991, indicated no crack growth with cyclic application of compression and tension loads.

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
1 (Continued)	ET umbilical door lug clevis cracks on STS-37/OV-104.	Code QT/Vitro performed an independent analysis of a 7075-T73 aluminum lug with a starter crack, similar to that observed on OV-104, to determine the rate of crack growth. The load applied to the lug for this analysis was 2300 pounds (lb), the load determined by the Orbiter Project that results from the maximum push-up load (210 lb) on the ET umbilical door to achieve centerline latch. The 210-lb push-up load was identified as the greatest force applied to the ET door, during all ground-processing and operational scenarios, that transfers the greatest tensile stress (2300 lb) to the lug clevises. Results of this analysis indicated that the existing cracks would not grow to critical size. Crack growth, under a worst-case load without further door cycling, was projected to grow at a rate of 3.5×10^{-5} inches per hour, or 0.035" over a period of six weeks. Consideration was given to the total OV-104 analysis effort by the Space Shuttle Program Management on March 6, 1991. The consensus of the community and Program Management was favorable, with the following exceptions: • The Kennedy Space Center (KSC) Safety Director recommended that the cracked lugs on OV-104 be replaced with new lugs from OV-105 prior to STS-37 flight. This action would leave no concern regarding the acceptability for STS-37 flight. • The Deputy Associate Administrator, Office of Safety and Mission Quality, accepted the findings of the analysis but recommended that a visual inspection (borescope) be performed prior to launch to verify that the clevis cracks had not grow. After consideration of these exceptions, the Space Shuttle Program Director made the decision to accept the residual risks associated with launching STS-37/OV-104 with starter cracks in the lug clevises and to clear STS-37/OV-104 for flight. The Director decided that further visual inspection would not be required prior to flight.

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

ORBITER

1 (Continued)	ET umbilical door lug clevis cracks on STS-37/OV-104.	The Space Shuttle SSRP and NASA Headquarters Safety Division, Code QS, also considered the results of the evaluation and the relative safety for STS-37 flight. The conclusions reached by the SSRP and Code QS are as follows: • There was an increased risk associated with launching STS-37/OV-104 with starter cracks on the ET umbilical door lug clevises. • OV-104 lug clevises should be visually inspected at the pad prior to launch to verify that the existing cracks had not grow or open, and displacement of the lug(s) similar to that seen on OV-103 did not exist. • Visual verification of the lug clevis cracks would increase confidence that analysis performed to date was accurate and that OV-104 was safe for flight. After careful consideration of these conclusions and the independent analysis performed by the Orbiter Project and Code QT, the Associate Administrator for the Office of Safety and Mission Quality accepted the residual risks associated with launching STS-37/OV-104 with starter cracks and determined that a visual inspection of the lug clevises was not necessary to clear STS-37/OV-104 for flight. It was reported that, during receiving inspection of OV-105 lugs scheduled for installation on OV-103, 1 of the 4 lugs was found with indications of a starter crack. This crack was found through dye-penetrant and eddy-current testing. Indications were that the crack initiated through the same LCF phenomenon seen on the other Orbiters. This was attributed to the number of door cycles required to install and properly rig the OV-105 ET doors. Because of this finding, the decision was made to install the modified OV-102 lugs on OV-103 and to return the OV-105 lugs to RI for rework and modification.

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
1 (Continued)	ET umbilical door lug clevis cracks on STS-37/OV-104.	While inspecting the OV-103 ET door assembly at RI, it was discovered that the splined shaft index mark was not correctly marked on the RH aft housing, resulting in the pushrod adjustment being adjusted to its full available travel. Inspection of the other 3 OV-103 ET door assemblies was performed. In addition, 2 of the OV-105 assemblies being readied for shipment to KSC were found with the splined shaft index marked 180° from the drawing requirement. The OV-105 shafts will be disassembled and fixed prior to shipment to KSC. OV-102 splined shafts were inspected and found to be correctly marked. These findings called into question the condition of the splined shafts and associated index markings on STS-37/OV-104. The OV-104 assemblies could not be examined in the current, staked position. However, RI verified that pushrod measurements were made and determined that critical shaft alignments were well within drawing tolerances. Additionally, rigging of both OV-104 ET doors was functionally verified by Operational Maintenance Requirements and Specifications Document (OMRSD) checkout procedures during the STS-37 flow. Rationale for STS-37 flight was: • The Space Shuttle Program Director and the Associate Administrator of the Office of Safety and Mission Quality accepted the residual risk associated with launching STS-37/OV-104 with starter cracks in the ET door lug clevises and decided that further inspection was not required prior to launch. • Results of the Orbiter Project specimen testing indicated that there was no crack growth in the presence of the Pasa-Jell etchant. • Verification of proper spline shaft alignment was accomplished. *This risk factor was accepted for STS-37.*

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
2	STS-39/OV-103 pilot-side Display Driver Unit (DDU) Attitude Direction Indicator (ADI) ball hesitation. *No DDU ADI problems were reported that affected performance on STS-37.*	During Operational Sequence (OPS)-9 dedicated display dynamic drive testing on STS-39/OV-103, the pilot-side DDU ADI ball occasionally hesitated. Similar testing on the commander-side DDU found the ADI ball to work properly. The commander-side ADI was relocated into the pilot-side position, where it also was found to hesitate. The commander's ADI was returned to the commander-side position and was found to operate correctly. The identical OPS-9 testing was performed on OV-104 with the same results; ADI ball hesitation occurred on the pilot side only. Subsequent testing at the Shuttle Avionics Integration Laboratory (SAIL) determined that this anomalous condition was demonstrated in the pilot and aft ADIs. Testing with both the new General Purpose Computers (GPCs) and new flight software, and the old GPCs and STS-35 flight software, gave the same results. This problem was traced to the DDU and the way it processes ADI data. It was determined that the DDU does not process the ADI ball data for one update cycle on an intermittent basis. This phenomenon occurs both in the OPS-9 dynamic drive tests on the ground and when using the OPS-0, -1, -2, -3, and -6 flight software. Troubleshooting and SAIL testing are continuing to further isolate the cause of this problem. Testing is also planned for OV-105. The STS-37 crew was informed of the problem, and this condition was demonstrated to them. The crew determined that this condition was acceptable for flight and would not adversely impede their performance.

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
2 (Continued)	STS-39/OV-103 pilot-side DDU ADI ball hesitation.	Rationale for STS-37 flight was: • The ADI ball hesitation was demonstrated to the STS-37 crew and was determined not to impede performance. • There were no other known DDU processing anomalies in the new GPC OPS software. ***This risk factor was acceptable for STS-37.***
3	STS-37/OV-104 Auxiliary Power Unit (APU) #3, Serial Number (S/N) 307, uncommanded Gas Generator Valve Module (GGVM) Shutoff Valve (SOV) motion. HR No. ORBI-031 {AR} ORBI-184 {AR} ***No APU GGVM problems were reported on STS-37.***	APU #3, S/N 307, was installed on STS-37/OV-104 since the last flight. During APU fuel line high-point bleed operations, the injector temperature indicated an unexpected increase of 60°F over a 24-minute (min) period. Review of the gas generator bed temperature data confirmed the temperature rise. Injector and gas generator bed temperature rise is a positive indication that fuel is reaching the bed. Troubleshooting isolated the cause to fuel leakage through the SOV. Movement of the SOV was confirmed by a fuel pump inlet pressure decrease and an exhaust duct pressure increase during the same 24-min period. A subsequent GGVM liquid leak check of the SOV valve was performed at 370 pounds per square inch absolute (psia), with no indicated leakage. This further confirmed that the SOV had moved slightly to the open position and had not leaked. Additional leak checks were performed at pressures between 20 and 100 psia to confirm low-pressure sealing. APU #3, S/N 307, was hot-fired at the pad prior to launch. Additionally, a final GGVM liquid leak check was performed at the pad to verify SOV integrity prior to launch.

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
3 (Continued)	STS-37/OV-104 APU #3, S/N 307, uncommanded GGVM SOV motion.	The cause of the SOV valve opening is still unidentified. KSC documented this problem as an unexplained anomaly to be resolved prior to STS-39 flight. Rationale for STS-37 flight was: • APU #3, S/N 307, was hot-fired at the pad to verify APU performance integrity. • OMRSD liquid leak checks were performed at the pad; this verified GGVM valve integrity prior to launch. *This risk factor was resolved for STS-37.*
4	New Data Processing System (DPS) failure could lead to a Crit 1/1 condition. *No similar anomalies were reported on STS-37.*	During testing in the SAIL on January 12, 1991, an operator noticed that the left keyboard entry was displayed simultaneously on Cathode Ray Tube (CRT) #1 and CRT #3. Because the select switch was in the CRT #3 position, the keyboard entry should have been displayed only on CRT #3. The operator cycled the select switch several times, and the problem was corrected.

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
<u>ORBITER</u>		
4 (Continued)	New DPS failure could lead to a Crit 1/1 condition.	Troubleshooting determined that the anomaly could not be isolated to a hardware problem because it repeated with different SAIL hardware. Potential hardware failure modes that could cause the same effects were identified: • CRT select switch, Part Number (P/N) ME452-0102-7201, contact short-to-ground or contact-to-contact short. • Data Entry Unit (DEU) receiver hybrid output fails low. There were no other relevant CRT select switch, P/N ME452-0102-7201, failures in the problem data base. A toggle switch anomaly similar to this failure occurred on STS-41 (see Section 6, Orbiter 4); however, the switch was a different dash number. The STS-41 anomaly was attributed to a particle large enough to cause a contact-to-contact short. There were 2 previous failures of DEU receiver hybrids, P/N 6088602; however, both were due to manufacturing defects and were considered isolated occurrences. The existing switch FMEA lists this type of failure as Crit 1R3. This was based on 2 keyboard entries causing an unpredictable Backup Flight System (BFS) pre-engage response during ascent and entry. An assessment of displays presented during nominal ascent and entry revealed no Specification (Spec)/keystroke combinations that could result in a Crit 1/1 scenario; therefore, the current FMEA was applicable. However, further assessment of all available vehicle displays identified several Spec and single or double keystroke execute combinations that could lead to a Crit 1 scenario. These displays would only be presented in off-nominal conditions. The CRT select switch FMEA was upgraded to a Crit 1/1 CIL for STS-37. Additionally, there is a potential for a new Hazard Report to baseline the associated risks.

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
4 (Continued)	New DPS failure could lead to a Crit 1/1 condition.	Rationale for STS-37 flight was: • The hardware involved, CRT select switch and DEU receiver hybrid, has demonstrated high reliability. • The potential for a Crit 1/1 failure exists only in off-nominal scenarios. • All Spec/keystroke combinations were identified. • The STS-37 crew was trained to check for keyboard entries displayed simultaneously on 2 CRTs when entering commands. ***This risk factor was acceptable for STS-37.***
5	Potential for new GPCs to erroneously overwrite memory. HR No. ORBI-194 {AR} ***No GPC problems attributed to erroneous memory overwrite were experienced on STS-37.***	At the Level III Orbiter Flight Readiness Review, IBM reported a generic hardware problem with the new GPCs. The problem occurred when the transition was made from halt (also known as sleep or freeze-dried mode) to an operational mode; the GPC could cause random locations of memory to be overwritten. The problem was first seen with the Shuttle Mission Simulator (SMS); however, it was initially believed to be unique to the SMS. A hardware design change was made to a single page in the GPCs to fix this problem. Access to the GPCs in the horizontal position is required to implement this change. The halt position in the AP-101S (new GPC) is known as the sleep mode. During the sleep mode, a minimum amount of power is applied to retain the memory (approximately 56 watts vs 560 watts nominal). Since the new GPC has a Complementary Metal Oxide Silicon (CMOS) memory that would be lost if power is removed, FR 7-30 B was added for this first flight of the AP-101S GPCs.

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
5 (Continued)	Potential for new GPCs to erroneously overwrite memory.	This FR states that "...Since removing power from the 101S GPC causes loss of memory integrity, a 101S GPC will only be powered off under extreme power-down conditions." However, discovery of the new memory overwrite potential was a deterrent to putting 2 or 3 of the GPCs in the sleep or freeze-dried mode on orbit as was planned. The workarounds proposed for STS-37 included: • Keeping the GPCs in the standby mode, instead of the halt or sleep mode, so that a power transition is not required; or • Performing Initial Program Load (IPL) from the Mass Memory Unit (MMU) on any GPC undergoing power transition from the sleep mode (i.e., at power-up). The first workaround would eliminate the concern for memory overwrites but would consume more power than planned. It was planned to put 3 GPCs in the sleep mode when on orbit: the BFS computer and 2 of the 4 GPC redundant set. Only 2 Primary Avionics Software System (PASS) computers are nominally planned to run on orbit to conserve power and enable the crew to "freeze-dry" the G2 [on-orbit Guidance, Navigation and Control (GN&C)] on 1 machine and the G3 (entry software) on the other "sleeping" machine. In the process used to freeze- dry an AP-101S GPC, the GPC is loaded with the desired software configuration (G2 or G3 in this case) and put into the sleep mode. The reason for freeze-drying is to have a copy of critical software available without requiring access to MMUs.

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
5 (Continued)	Potential for new GPCs to erroneously overwrite memory.	Human factors and timing are of concern to IPL at GPC power-up. While the IPL is a viable workaround in any case, crew intervention is required for this workaround option. Because of this problem, a decision was made to configure the STS-37 GPCs on orbit as follows: • GPC 1 would have the on-orbit GN&C software. • GPC 2 would be put in sleep mode when not in use. The crew would power-up GPC 2 and perform an IPL to load the redundant GN&C software for the planned Gamma Ray Observatory (GRO) deployment operations on the third day. • GPC 3 would be freeze-dried for G3 and kept in the standby mode. • GPC 4 would have the Systems Management (SM) software. • GPC 5 was reserved for the BFS and would be put in sleep mode on orbit. The crew would perform an IPL to load the BFS for deorbiting operations. Rationale for STS-37 flight was: • A plan was in place to alleviate the need to power-down certain GPCs on orbit. • If unplanned or inadvertent power loss did occur, the crew could perform the required IPL to reconfigure the GPCs. *This risk factor was resolved for STS-37.*

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
<u>ORBITER</u>		
6	Cabin pressure bleed valve anomalies on OV-105. HR No. ORBI-074 {C} *No problems with cabin pressure bleed valves were reported on STS-37.*	Three cabin pressure bleed valves installed on OV-105, S/N 5, 6, and 8, recently failed leak tests. A fourth, S/N 7, was inspected at the manufacturer, Charlton Technologies, Inc. (CTI), and was found to be leaking; however, the leak was within specification. All 4 valves exhibited signs of seal debonding. Valves S/N 1 through S/N 4 had no history of leakage or seal debond. The cause of the debonding was not determined. The bond could be affected by either a lack of primer on the valve or incorrect application of primer to the valve. Poor adhesion of S/N 5 through S/N 8 molded seals, and seal leakage, was verified at CTI. Testing was inconclusive in determining proper primer application. Records show that the seals were molded in accordance with the applicable procedure; however, there were no specific inspection criteria for primer application. Historical comparison of seal material batches to seal leakage indicated no definitive correlation. All seal materials are batch tested for correct material properties. For flight vehicles, cabin pressure bleed valve leak tests at 15 pounds per square inch differential (psid) are performed every 5 flights. Maximum allowed leakage is 25 standard cubic centimeters per minute (sccm). During countdown, cabin pressure drop is monitored, with a 2-psid gross leak limit. Each valve is checked individually after venting the cabin; there is no reverification of leakage. OV-103 valves were last leak-tested before STS-41 with no problems noted. OV-104 valves were checked during the STS-37 flow with no anomalies. A requirement is in work to leak check OV-102 valves prior to STS-40.

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
6 (Continued)	Cabin pressure bleed valve anomalies on OV-105.	Rationale for STS-37 flight was: • OV-104 cabin pressure bleed valves passed all leak tests. • Launch Commit Criteria (LCC) and FRs were in place to account for valve leakage after turnaround testing. ***This risk factor was resolved for STS-37.***
7	OV-104 wing strut tubes found damaged during STS-38 postflight inspection. HR No. ORBI-277 {C} ***No anomalies attributed to wing strut tube problems were experienced on STS-37 after repair of the 2 dented tubes found during STS-37 preflight inspection.***	Wing strut tube damage was discovered during STS-31/OV-103 postflight inspection. A strut tube in the OV-103 Left-Hand (LH) wing was found dented. It was later determined to have an undersized wall thickness of 0.014"; minimum required wall thickness is 0.018". Identification of this below-minimum wall-thickness condition triggered a fleetwide ultrasonic inspection of all wing strut tubes with a calculated margin of safety of 0.35 or less. OV-104 was determined to have 2 struts below the minimum margin of safety in the Right-Hand (RH) wing and 2 in the LH wing; 2 of the 4 were determined to have a negative margin of safety. Doublers were installed to reinforce these 2 struts prior to STS-38/OV-104 flight. During preflight inspection of STS-37/OV-104, 2 strut tubes were found dented. The dented tubes were repaired using doublers (comprising hose clamps, EA934 epoxy adhesive, and 0.020" clamshell). Post-repair proof-load tests were performed, and plans were developed to certify the strut tubes for multimission use; certification is currently limited to 1 flight. Note that, prior to STS-38, repair of undersized strut tubes was dispositioned as acceptable for unrestricted use; however, a recent evaluation determined that repaired tubes should be restricted to 1 flight. Because replacement truss tubes will not be available until June 1992, continued use of repaired truss tubes will be made on a flight-by-flight basis following proof-load testing.

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
7 (Continued)	OV-104 wing strut tubes found damaged during STS-38 postflight inspection.	Rationale for STS-37 flight was: • Pre-STS-38/OV-104 wing strut tube inspection identified the location of all undersized tubes. Doublers were installed on 2 struts with a negative margin of safety, increasing the margin of safety to a positive level. • The 2 dented OV-104 truss tubes found on January 31, 1991 were repaired and successfully passed proof-load testing. • Proof-load testing is required to clear repaired strut tubes prior to each flight. *This risk factor was resolved for STS-37.*
8	New GPC, AP-101S, failure mode. *No GPC problems were reported on STS-37.*	GPC S/N 507 failed during operation in the SAIL in June 1990. S/N 507 was reported to be unable to recover from the sleep mode. Power cycling of S/N 507 restored the GPC to normal operation. This anomaly was reported on Corrective Action Report (CAR) #7274. S/N 507 was removed from the SAIL and returned to IBM for troubleshooting. Troubleshooting at IBM could not repeat the failure during vibration and thermal testing. IBM was also unsuccessful in isolating a failure using Automatic Test Equipment (ATE). The sleep mode logic was analyzed for a potential design flaw. This analysis resulted in identification of the design problem addressed in Section 4, Orbiter 5. Because no failure could be isolated at IBM, S/N 507 was returned to the SAIL and operated for over 500 hours (hr) without a repeat of the earlier failure.

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
8 (Continued)	New GPC, AP-101S, failure mode.	A recent review of SAIL videotape showed that the S/N 507 mode switch was in the "run" position instead of the "sleep" position when the June 1990 failure occurred. This finding indicated the potential for a generic power supply problem in the AP-101S GPCs. S/N 507 will be returned to IBM for additional testing and troubleshooting that will focus on GPC power supply operation and functionality. If the failure cannot be duplicated or isolated at IBM, the S/N 507 power supplies will be removed from flight status. There have been 2 previous AP-101S power supply failures, both in qualification units. These 2 qualification failures had different causes and effects; both resulted in design or procedural fixes. Rationale for STS-37 flight with new GPCs was: • There was no failure history of new, flight-unit GPC power supplies. • New GPCs installed on OV-103 were extensively tested with no similar problems. *This risk factor was resolved for STS-37.*
9	Indications of voids and debris found in review of STS-37/OV-104 Nose Landing Gear (NLG) holograms. HR No. ORBI-185 {C} *No tire problems were experienced on STS-37/OV-104 subsequent to replacement of a defective RH NLG tire.*	Debris was found in an STS-39/OV-103 NLG tire. Holograms of all fleet NLG tires were reviewed, and all NLG tires in inventory at KSC were x-rayed for debris. Holography techniques are used to inspect NLG tires, and the combination of x-ray and holographic inspection should find any abnormalities. The RH OV-104 NLG tire holograms indicated a void in the sidewall. No discrepancy was written at the time that the original hologram was evaluated; however, the inspector did indicate the presence of the void in the inspection report. The OV-104 RH NLG tire was replaced with a spare that passed holographic and x-ray inspection.

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
9 (Continued)	Indications of voids and debris found in review of STS-37/OV-104 NLG holograms.	Holograms of the LH OV-104 NLG tire indicated that it had no voids or debris. Recent x-ray inspection of this tire found an indication of a piece of wire in the tire carcass measuring 0.1" in length and 0.02" in diameter. This finding, however, was not made until after the STS-37/OV-104 NLG wheel well was closed out for flight. The debris problem appears to be generic because 11 of 19 tires recently x-rayed showed signs of embedded debris. A review of the operational history of the 11 NLG tires found with debris indicated that 3 tires had flown five missions with embedded debris; 2 of the 3 had flown 2 missions each. Debris found in the OV-104 LH NLG was smaller than debris found in the 3 flown tires. There were no failures or anomalies in the Space Shuttle Program flight history. Based on this history, and the fact that NLG tires have performed well with embedded debris, it was believed that the debris in the OV-104 LH NLG would not lead to tire failure. This tire was removed from the inventory upon return of STS-37/OV-104. Rationale for STS-37 flight was: • The OV-104 RH NLG tire was found to have no voids or debris. • Based on fleet history of NLG tires flown with embedded debris, the debris found in the OV-104 LH NLG would not lead to tire failure. *This risk factor was acceptable for STS-37.*

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
10	A Main Propulsion System (MPS) 3-way helium solenoid valve failed leak tests on OV-102. HR No. ORBI-108E {AR} ORBI-129A {C} ***No MPS helium leaks were experienced on STS-37.***	MPS leak tests on OV-102 after the STS-35 flight isolated a leak to a 3-way helium solenoid valve, LV68, that is used in the 17" disconnect latch unlock. Additional tests confirmed the leak and further isolated it to a crack in the valve bellows. Similar 3-way helium solenoid valves are used in 46 locations in the MPS. The valves control helium pressure to open or close pneumatically-operated MPS valves. The concern here was that a worst-case failure of a helium valve could lead to helium leakage or valve rupture and result in a Crit 1 failure. This failure scenario was believed to potentially deplete the onboard helium supply, resulting in the inability to close prevalves at Main Engine Cutoff (MECO) and the potential for Main Engine (ME) turbopump overspeed and explosion. LV68 was removed for evaluation and replaced. Retests indicated that the replacement valve was not leaking. Helium solenoid valve bellows are 2-ply (nickel and copper plies) and are fabricated by an electroforming/electroplating process. Convoluted plies are soldered to end fittings to complete the bellows assembly. In normal operation, the valve bellows assembly is pressurized by solenoid inlet pressure. Internal bellows pressure and spring rate provide the forces necessary to maintain the valve in the closed position when the solenoid is deenergized. Bellows assemblies are proofed at 1550 pounds per square inch (psi), more than twice the operating pressure. Bellows assemblies are reproofed after solder rework; therefore, a valve could be subjected to multiple proof-pressure tests. Initial teardown and inspection of the failed LV68 valve identified a deformation, or squirm, in the bellows that was caused by buckling instability. Further examination found a circumferential crack on the bellows convolute crown. The crack was approximately 0.150" in length and was on the tension side of the squirm. Leak checks measured the leak rate to be 22 standard cubic feet per minute (scfm)

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
10 (Continued)	An MPS 3-way helium solenoid valve failed leak tests on OV-102.	at 300 psi. Extrapolation to 750-psi operating pressure predicted a leak rate of 54 scfm. The maximum leak allowed is 10 standard cubic centimeters per second (sccs) from the valve vent port. Metallurgical analysis determined that the crack was 80% through the inner bellows ply and was due to fatigue. Final separation in each ply was determined to be due to overload. The crack did, however, coincide with a small void in the copper strike. Other cracks were discovered in adjacent convolutes. These cracks propagated from the inner diameter toward similar voids in the copper strike. Vendor stress analysis indicated that the bellows design was marginal for the 1550-psi proof test. Predictions were that the internal pressure required to initiate squirm deformation is 1551 psi. A more conservative analysis indicated that the pressure needed to initiate squirm is much lower than 1500 psi. The potential effects of a squirmed bellows on valve operation was evaluated. The investigation into this failure considered the potential for a lot-related failure mode. The failed bellows was manufactured in 1987 in a lot of 7 bellows, a start-up lot after a 5-year layoff. Records indicated that the failed bellows, and all other bellows in the lot, had been subjected to 3 proof tests because of required solder rework. A second bellows from the lot of 7 is installed in the Liquid Oxygen side outboard fill and drain valve on OV-103. The outboard fill and drain valve on OV-103 will be replaced prior to STS-39 flight. Of the 5 remaining bellows from the lot, 4 were scrapped and the fifth was rejected at KSC after the valve failed helium signature tests. This valve also showed signs of squirming. The investigation also determined that solenoid valve certification tests were inadequate for verifying bellows life. Certification testing included 12,000 valve operation cycles; however, only 50 pressure cycles were performed. Pressure cycling is believed to be the primary contributor to bellows squirming and fatigue.

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
10 (Continued)	An MPS 3-way helium solenoid valve failed leak tests on OV-102.	No other solenoid valve bellows failures were recorded during flight or ground checkout. This history includes a significant number of valve cycles and operations. Bellows problems were, however, encountered during the production of the OV-105 bellows assemblies in 1989. In this case, initial production runs were scrapped. OV-105 bellows failures were not the result of cracked bellows; however, the bellows were found squirmed and dimensionally unstable after repeated proof-pressure tests. All OV-105 bellows were reworked because of solder problems induced by numerous process and personnel deficiencies at the vendor. Prelaunch and operational procedures are in place to control potential helium leaks through the valve bellows. Prior to launch, excessive helium loss is detected by the Hazardous Gas Detection System (HGDS) and, if aft compartment helium concentrations exceed the 10,000-parts per million (ppm) LCC limit, the launch is scrubbed. After launch, helium tank pressures are monitored by the Caution and Warning System (CWS). An alarm sounds if helium tank pressures drop below 3800 psi. If this occurs during ascent, the crew is required to manually close isolation valves LV7 and LV8 to conserve helium. LV7 and LV8 would be reopened along with LV10 (engine crossover) at MECO minus 30 sec. These actions are intended to conserve sufficient helium stores to enable engine prevalve closure at MECO. Analysis performed by Johnson Space Center (JSC) determined that the worst-case inflight leakage due to a ruptured bellows is manageable. The leak rate, restricted by a 0.0930" diameter passage in the valve, was calculated to be 260 scfm. This leak rate would not deplete the helium supply during ascent; therefore, sufficient helium would remain in the system to shut engine prevalves at MECO. Additionally, a 260-scfm leak would not provide sufficient helium to overpressurize the aft compartment.

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
10 (Continued)	An MPS 3-way helium solenoid valve failed leak tests on OV-102.	Rationale for STS-37 flight was: • The 3-way helium solenoid valves had a highly reliable history prior to the cracked bellows found on OV-102. This history included 46 valves installed and operated on 37 Space Shuttle missions. • There were no bellows from the suspect lot installed on OV-104. • Processing flow leak checks and prelaunch HGDS monitoring have the capability to identify leaks. If a leak were to occur after launch, CWS monitoring would alert the crew to take action to conserve the helium supply. ***This risk factor was acceptable for STS-37.***
11	Gaseous Hydrogen (GH_2) Flow Control Valve (FCV) weld crack found on OV-103. HR No. ORBI-306 {AR} ***No GH_2 FCV problems were experienced on STS-37.***	During STS-39/OV-103 preparations, a small leak was detected at the engine #1 GH_2 FCV housing during mass spectrometer leak tests of the OV-103 GH_2 pressurization system. These tests were performed as part of the investigation into the high Hydrogen (H_2) concentration measured in the OV-103 aft compartment during STS-41 ascent. The leak was measured at 2.3×10^{-6} sccs, in excess of the 1×10^{-6} sccs specification limit. Initial calculations indicated that this leak rate was significant enough to account for the H_2 concentrations measured during STS-41; however, a more formal calculation of potential leak rates was performed. Analysis indicated that a worst-case leak through a circumferential crack would not provide sufficient H_2 to reach aft compartment flammability concentrations. Initial examination of the FCV found the leak source to be a 3/8" crack in the housing outlet tube weld. This weld is a sealing weld only and provides no structural integrity.

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
11 (Continued)	GH_2 FCV weld crack found on OV-103.	Examination of the cracked FCV housing outlet tube weld at RI indicated that weld quality was good (good penetration, no evidence of material defect, and good weld blend). Structural analysis determined the failure mechanism to be High-Cycle Fatigue (HCF). The source of the fatigue has not been determined; however, loads induced in the high-vibration environment is the leading candidate. Investigation into potential vibration sources is underway. Evaluation of GH_2 and Gaseous Oxygen (GO_2) qualification FCV housings for similar fatigue conditions is in work. Leak tests and Nondestructive Evaluation (NDE) methods will be employed on the qualification housings. Visual inspection of OV-104 FCV outlet tube welds by MPS engineers did not reveal signs of cracks. OV-104 FCV housings had flown only 7 flights; the OV-103 FCV housing with the weld crack was the fleet leader with 11 flights. Mass spectrometer leak checks were performed; no problems or out-of-specification leaks were found. Rationale for STS-37 flight was: • Mass spectrometer and visual inspections found no indication of leaks in OV-104 FCVs. • A worst-case circumferential crack would not provide sufficient H_2 to reach aft compartment flammability concentrations. *This risk factor was resolved for STS-37.*

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
<u>ORBITER</u>		
12	Clogged APU #3 lube oil filter on OV-104. HR No. ORBI-036 {AR} ORBI-121 {AR} *STS-37/OV-104 System #3 APU/Water Spray Boiler (WSB lube oil temperature ran cooler than the other 2 systems. WSB #3 overcooling was experienced both post-MECO and during entry (IFA No. STS-37-V-12). This anomolous WSB operation was believed to be due to lube oil wax contamination. The problem was probably exacerbated by the inability to perform a hot-oil flush of contamination from APU #3 at the pad prior to launch.* *Anomalous operation was also experienced on WSB #2 during STS-37 ascent; WSB #2 failed to cool APU #2 (IFA No. STS-37-V-02). The cause was attributed to freezing of the spray bar due to wax buildup in WSB #2. Investigation into APU/WSB combinations that displayed similar problems is in work.*	During hot-fire of APU #3, S/N 307, at the pad, gearbox lube oil pressure peaked at 108 psia. High gearbox pressure is an indication of the presence of wax buildup and the potential for a clogged filter. Gear box pressure is nominally 50 psia during APU operation. A clogged filter could cause WSB spray bar freeze-up and an over-temperature condition of the APU post-MECO. Wax, in the form of pentaerythritol, is formed when APU hydrazine fuel reacts with APU lube oil. Pentaerythritol has 2 basic constituents: a soft, waxy-type substance and crystals. The waxy substance and crystals melt in the lube oil when temperatures exceed 200°F. Several sources of contamination are possible. The most likely source is leakage across the fuel pump seal. During recent GGVM liquid leak checks on OV-104, fuel pump seal leakage was indicated by a decrease in the fuel pump inlet pressure and an associated increase in the seal cavity pressure. Another potential source of the wax contamination is the open loop hot-oil flushing procedure recently performed on WSB #3. A temperature of at least 250°F is required to flush wax from the WSB tube bundle. The open-loop technique flush temperatures only reach 150°F. As a result of using this flush procedure, contamination from the WSB tube bundle could have been deposited on the lube oil filter. Both APU #3 and WSB #3 were considered contaminated with wax. The OMRSD requires a hot-oil flush if evidence of filter clogging is present. However, an APU hot-oil flush has never been performed in the vertical position; an OMRSD procedure would have to be written to accomplish the flush. The decision was made to drain the lube oil from APU #3 and replace the lube oil filter.

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
<u>ORBITER</u>		
12 (Continued)	Clogged APU #3 lube oil filter on OV-104.	Examination found approximately 7 grams of crystalline pentaerythritol clogging the filter; experience shows that 2 to 3 grams of normal debris trapped in the filter would cause lube oil pressures to exceed 50 psi. APU #3 and WSB #3 were still considered to be contaminated after replacement of the lube oil and filter because a hot oil flush was not performed. An OMRSD waiver was approved to acknowledge this condition, which has the potential for decreasing WSB #3 efficiency and could result in freeze-up of the WSB spray bar. Rationale for STS-37 flight was: • APU #3 lube oil and filter were replaced. An OMRSD waiver for non-performance of the hot-oil flush was approved. • For a nominal ascent, contamination is not a concern. • LCC limits gearbox pressure to 110 psia prior to launch. *This risk factor was acceptable for STS-37.*

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
13	Debris found in STS-37/OV-104 window #1. HR No. ORBI-208 {AR} ORBI-339 {AR} *No further window problems were experienced on STS-37 after replacement of the window #1 thermal pane. The RTV debris found during prelaunch inspection at the pad did not affect window #1 cavity venting during ascent or entry.*	During STS-37/OV-104 window inspection at the pad, 3 small pieces of Room-Temperature Vulcanizing (RTV) were found between the outer thermal pane glass and the inner pressure pane glass. The largest piece of RTV was estimated to be 3" long and 1/4" wide. The debris was located on the ledge between the outer thermal pane and the inner pressure pane. No debris was witnessed in the window cavity vent area. The concern was that the debris could block the window cavity vents during either ascent or descent. The window #1 thermal pane was replaced during the STS-37 flow because of damage determined to be greater in depth than allowed by specification. After installation of the new thermal pane, inspection was performed in the horizontal position, and no debris was identified. The debris found during the inspection at the pad most likely shifted when OV-104 was taken to the vertical position. Analysis determined that there was no mechanism (i.e., air flow out of the cavity or vibration) that would move the existing debris to the ascent vent. Gravitational forces induced during ascent would force the debris to remain in its current position. On orbit, the debris has the potential to migrate freely; however, this is not expected to cause visibility impairment or other problems. Air flow through the descent vent is into the cavity. If the debris migrates to the descent vent while on orbit, it is not of sufficient size to overcome the air flow and block the vent. Rationale for STS-37 flight was: • Through analysis, the debris was not expected to migrate to the window cavity vents during ascent. Air flow into the cavity during descent would move the debris away from the descent vent. *This risk factor was acceptable for STS-37.*

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
<u>SSME</u>		
1	High-Pressure Oxidizer Turbopump (HPOTP) first-stage turbine disc cracking. HR No. ME-C1 (All Phases) {AR} ***No SSME anomalies were reported on STS-37.***	Dye-penetrant inspection of 4 HPOTP first-stage turbine discs identified radial cracks in the interstage pilot rib. Gradient oxide discoloration was found in 2 cracks. These cracks were not detected or obvious prior to removal of the gold plating. The high-time HPOTP, where the cracks were first found, was the fleet leader with 21,908 sec and 52 starts. It had been removed from the flight program for a long time. Seventeen turbine discs were inspected to date; 7 were found with radial cracks in the interstage pilot rib. Materials and Processing (M&P) analysis determined that the cracks initiated midspan in the disc and extended either to the outboard or inboard corner of the pilot rib. Scanning Electron Microscope (SEM) inspection of the fractures indicated a brittle crystallographic appearance. The fracture mode showed the effects of H_2 influence, indicating probable LCF or sustained load crack propagation. Structural analysis indicated a cyclic strain range, overwhelmingly dominated by thermal shock at shutdown, caused by H_2 cooling of the hot disc. Peak strain was determined through tests to follow a minimum of 40 to 100 sec of operation, or when the disc reaches steady-state high operational temperature. Evaluation of the correlation of LCF analysis to this failure mode indicated that the worst-case thermal shock strain range was insufficient to result in cracking without H_2 embrittlement. Deviation Approval Request (DAR) #2474 for fatigue damage ratio was reevaluated for STS-39/OV-103 HPOTP first-stage turbine discs. To date, the lowest damage ratio for a disc found with radial cracks was 1.0. All previously flown discs had a damage ratio margin >4. This was true for 2 of 3 discs on STS-39. However, the damage ratio of turbine disc S/N 2702270, engine #2026, HPOTP #2226R3, was calculated to be 0.258 post-STS-39 flight. Because this was below the damage ratio margin of 4, the DAR #2474 limit was increased to allow a postflight damage ratio of 0.27. This action cleared turbine disc S/N 2702270 for flight.

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
SSME		
1 (Continued)	HPOTP first-stage turbine disc cracking.	The continued evaluation of the DAR limit for turbine discs on STS-37 and future missions led to an additional change in the criteria. Rocketdyne updated the previous DAR to deal with HPOTP turbine disc cracking by utilizing a statistical analysis method rather than the damage fraction method. This revision changed the DAR criteria from 0.27 damage fraction in the interstage seal pilot rib location to a life-limit of 14 starts (the HPOTP/turbine disc must be operated in excess of 20 sec to be counted as a start). This DAR life limit is based on a fleet leader approach used for other SSME components. The 14-start life limit is half the lowest number of starts (29) for a turbine disc found with cracks. Fleet history showed 44 discs with greater than 14 starts, and 24 discs with greater than 28 starts. Discs examined to date with 12, 15, 18, and 19 starts showed no cracks. Turbine discs in STS-37/OV-104 HPOTPs had no more than 11 starts. Rationale for STS-37 flight was: • HPOTPs on OV-104 did not exceed the 14-start DAR limit for STS-37. • Fleet history encompassed all significant LCF variables. *This risk factor was acceptable for STS-37.*

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
<u>SSME</u>		
2	Suspected contamination of engine #2029 HPOTP. HR No. ME-C1 (All Phases) {AR} *No SSME anomalies were reported on STS-37.*	During leak test operations on STS-39/OV-103 engine #2029 in the Orbiter Processing Facility (OPF), the potential existed for introducing contamination into the engine's HPOTP. It was determined that an improper Ground Support Equipment (GSE) configuration was used for the leak test. As part of the MPS leak tests, tygon tubing from the Captive Air Vent (CAV) system is attached to the HPOTP intermediate seal drain line to vent helium outside the OPF in order to lower the helium background level. Upon disconnect of the tygon tube, positive pressure was observed flowing from the CAV tube in the form of a mist (visible air). The visible air was originally reported to be a hydraulic fluid mist. The potential also existed for introducing contamination into STS-37/OV-104 engines during STS-38 and STS-41 postflight drying operations. Swab samples were taken from STS-37 engines prior to installation. Engines #2019 and #2107 were found acceptable. Initial samples from engine #2031 indicated the presence of 1.8-2.3 milligrams per square foot (mg/ft^2) of hydrocarbons; the limit is 1.0 mg/ft^2. Further samples taken from engine #2031 were analyzed and found to be good. The Liquid Oxygen (LOX) drain lines were removed from engine #2031, flushed with freon, and sampled. The results of the post-flush samples were good, and the drain lines were reinstalled. Rationale for STS-37 flight was: • Any contamination introduced into the HPOTP or engine would be detected in the swab sample testing; none was detected in engines #2019 and #2107. Contamination found in engine #2031 was flushed out. *This risk factor was resolved for STS-37.*

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
SSME		
3	Pogo standpipe thermal insulator may have been inadvertently removed during final engine assembly. HR No. INTG-005 {C} ***No SSME anomalies were reported on STS-37.***	Rocketdyne recently disclosed that an engine assembly mechanic stated that he removed the thermal insulator (teflon sleeve) from the pogo standpipe on engines #2028 and #0215. The mechanic stated that he thought the sleeve was a shipping protector. Subsequent inspection of the pogo standpipe on engine #0215 confirmed that the teflon sleeve was not present. Early pogo system development tests demonstrated the need for the standpipe thermal insulator to prevent Gaseous Oxygen (GOX) from condensing on the cold standpipe surface. Thermal analysis is underway to determine the delta temperature of the standpipe surface with and without the teflon insulator. Because of this finding, inspection of the STS-37 engine pogo standpipe was required. Pogo standpipe insulation was visually verified to be in place on all STS-37/OV-104 engines. ***This risk factor was resolved for STS-37.***
4	Potential for pad abort caused by purge check valve seat leakage. HR No. ME-A1S Rev. F ***No SSME anomalies were reported on STS-37.***	During a test firing of engine #0213 at Stennis Space Center (SSC), excessive Main Combustion Chamber (MCC) dome purge check valve leakage resulted in violation of the 50-psia ignition confirmation redline; the engine shut down. Post-test investigation determined that the check valve leakage was caused by an Inco-718 particle lodging on the valve seat. The particle, 0.054" x 0.040" x 0.02", resulted in a leak through the valve of 11.5-12.5 scfm at 25 pounds per square inch gage (psig).

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
SSME		
4 (Continued)	Potential for pad abort caused by purge check valve seat leakage.	No similar leakage had been recorded in the flight program (132 engine starts), including 108 oxidizer purge check valves. However, this was the sixth occurrence during the ground test program (1808 tests). Records indicated that 2 cases were caused by Kel-F contamination from the MCC dome purge pressure actuated valve (which led to a pressure-actuated valve redesign), 2 were caused by contamination originating external to the engine, and the last from contamination of an undetermined source. In the most recent case, the source of the Inco-718 particle is unknown. Inco-718 is used in the helium precharge valve housing and the fuel preburner purge pressure actuated valve. The particle found did not resemble a machining chip or burr. The helium precharge valve was installed on test 904-087, 3 tests prior to the most recent engine #0213 test. The purge line was disconnected at the helium precharge valve during HPOTP replacement. Rationale for STS-37 flight was: • Existing SSME assembly/disassembly procedures at KSC protect the engines from contamination entry. All joints are cleaned before disassembly, and open ports are covered with Aclar film and polyethene foam. • OV-104 SSME check valves successfully passed reverse seat leak checks after the last engine hot-fire. • There were no similar occurrences affecting the redline margins. • Worst-case failure is a pad abort. *This risk factor was resolved for STS-37.*

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
SSME		
5	Potential for loss of SSME controller redundancy. HR No. INTG-165 {C} *No SSME anomalies were reported on STS-37.*	During flight readiness testing of STS-37/OV-104, engine #2031, SSME controller Unit Number (U/N) F27, channel B halted when powered up. Analysis of the controller memory dump indicated an echo check failure after loading of the channel B output electronics storage register. A change in the storage register is indicative of a hardware failure. Repeated attempts to reproduce this failure were unsuccessful. U/N F27 was removed from engine #2031 and replaced with U/N F29. This was the fifth storage register failure detected during ground checkout. There had been no storage register-related failures during SSME starts for flight. The worst-case failure of this type is loss of SSME controller redundancy. If this was to occur between SSME start and SRB ignition, the result would be a pad abort. U/N F27 was returned to Honeywell, the vendor, on January 31, 1991. Upon initial powerup, the failure repeated. However, it did not repeat during subsequent cold starts, thermal cycles, or vibration testing. Additional destructive analysis was planned. Rationale for STS-37 flight was: • U/N F27 was replaced with U/N F29; no additional anomalies were experienced. • Checks at T–34 hours prior to launch verified all SSME controller hardware functions. • There have been no related failures during SSME starts at launch. • Worst-case failure would be loss of SSME controller redundancy. *This risk factor was resolved for STS-37.*

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
SSME		
6	HPOTP second-stage turbine blades found rubbing coolant jet tubes on U/N 6009. HR No. ME-C1A Rev. F {AR} (All Phases) *No SSME anomalies were reported on STS-37.*	Normal disassembly of HPOTP U/N 6009 found that the second-stage blades rubbed 3 of 19 coolant jet tubes. Approximately 0.012" was removed from the rubbed tubes. There was believed to be no structural damage, and no effect on performance was experienced. Only minor damage to the blade shank was noted. SEM inspection of the blade found random surface cracks up to 0.005" long. Comparable cracks are usually experienced with the normal casting process. These cracks were not detectable with optics or IVc penetrant. There have been multiple cases of second-stage turbine blades rubbing. Minimum clearance occurs between the disc stiffening rib and the turbine housing during the shutdown transient. The original height of the jets was a maximum of 0.012" above the print dimension. Worst-case interference with the jet is 0.014"; this would be detected by turbine shaft micro-travel inspection. Structural analysis indicated adequate margin with the presence of rubbed blades. Rationale for STS-37 flight was: • Blade rubbing was considered benign; damage to the second-stage turbine blades was acceptable. • Cracks observed on U/N 6009 were less than the dynamic threshold flaw size. *This risk factor was acceptable for STS-37.*

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
SSME		
7	Engine #0213, G-15 seal failed during ground testing at SSC. HR No. ME-D3C Rev. F {AR} ME-D3M Rev. F {AR} *No SSME anomalies were reported on STS-37.*	During scheduled inspection of the MCC and nozzle on development engine #0213 at SSC, the G-15 seal was found cracked and buckled. This seal had been in place for 34 tests and 15,114 sec of operation. Nozzle 4011 on engine #0213 encompassed the maximum effective protrusion in the fleet. It had been removed from flight status because it exceeded the DAR limit. No leaks through the G-15 seal were evident during pre- and post-test leak checks. Bluing and cracking of the G-15 seal was expected prior to nozzle removal based on extended monitoring of deteriorating or missing Flow Recirculation Inhibitor (FRI), but not to the extent witnessed on disassembly. Seal cracking and erosion are the result of hot-gas ingestion into the G-15 cavity. Diversion of hot-gas flow into the G-15 cavity requires large physical tube protrusions or hydraulic protrusion from multiple-vented tubes or eroded tube crowns. These protrusions are considered outside of the DAR limit. All STS-37/OV-104 SSMEs were verified not to have coolant tube erosion or vented tubes. There was no degradation or missing FRI on any OV-104 nozzle. Tube protrusions and hot-fire time on STS-37/OV-104 engines were well within DAR limits. The G-15 seals were leak checked since the last engine hot-fire. Rationale for STS-37 flight was: • Conditions surrounding the G-15 seal on engine #0213 were known and were outside established DAR limits for flightworthy SSME components. • STS-37/OV-104 G-15 seals were leak checked. • Components on STS-37/OV-104 SSMEs were well within DAR limits. *This risk factor was resolved for STS-37.*

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
<u>SRB</u>		
1	SRB APU speed trace anomaly during Acceptance Checkout (ACO). HR No. A-20-16 Rev. C-DCN3 {C} B-20-22 Rev. B-DCN3 {C} ***No problems were experienced with SRB APUs on STS-37.***	Post-hot-fire data review of APU S/N 155 during ACO for STS-48/BI-047 SRBs at United Space Boosters, Inc., (USBI) found that the GSE speed trace indicated anomalous data during APU turbine wheel spindown. The speed trace anomaly occurred between 29,000 and 21,000 revolutions per minute (rpm) for approximately 1 sec. Anomalous indications were on the Magnetic Pickup Unit (MPU)-1 GSE data trace. Two MPUs per APU provide speed indication to the SRB Integrated Electronics Assembly (IEA) via the APU controller to monitor and control turbine underspeed and overspeed conditions. In this instance, the anomaly was not, and would not be, detected by the IEA because the APU controller shuts down when the APU turbine wheel is at 40,000 rpm. Loss of signal from either MPU prior to T–0 results in a launch scrub/abort. Loss of MPU-1 signal during flight results in high-speed APU operation under the control of MPU-2 at 112%. Loss of MPU-2 signal during flight results in loss of valve redundancy on that APU. Electrical isolation tests of the control circuit and GSE were performed; no anomalies were identified. GSE self-tests and tests on the SRB side of the interface were performed with no problems. A second APU hot-fire was performed, and the anomalous speed traces recurred. A third hot-fire test was performed with the MPU-1 and MPU-2 output cables swapped at the APU. During the third test, anomalous speed traces remained with the MPU-1 output in the GSE circuit only. In this case, however, anomalous MPU-1 speed traces were witnessed during both APU startup and spindown. APU S/N 155 was removed from BI-047 and sent to Sundstrand, the vendor, for further analysis. Subsequent hot-fire tests with APU S/N 132 installed were successful, exonerating the APU controller, signal conditioner, Multiplexer-Demultiplexer (MDM), flight cables, and GSE from suspicion.

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
SRB		
1 (Continued)	SRB APU speed trace anomaly during ACO.	At Sundstrand, proper installation of the speed sensor assembly connector and MPU continuity, resistance, and insulation resistance were verified to be good. Review of APU S/N155 acceptance test history found no anomalies. A non-hot-fire turbine spin of APU S/N 155 was performed with Gaseous Nitrogen (GN_2); no MPU-1 or MPU-2 output data problems were experienced. A hot-fire test was performed on March 12, 1991, and again no anomalies were recorded. Data from the hot-fire test at Sundstrand were considered to be of higher fidelity than data recorded during a hot-fire test at USBI. The high-fidelity data were taken to USBI and run through the ACO instrumentation to determine if the original problem was there. Teardown inspection of APU S/N 155 components was completed with no problems found. Rationale for STS-37 flight was: • This anomaly was screenable at ACO; STS-37/BI-042 APU-ACO data indicated no anomalies. • Loss of MPU signal prior to T–0 results in a launch scrub/abort. • Loss of signal in either MPU results in a fail-safe condition. • The APU S/N 155 anomaly did not manifest at nominal turbine speeds, only at startup and spindown. *This risk factor was acceptable for STS-37.*

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
SRB		
2	Thrust Vector Control (TVC) hydraulic reservoir found with 1/4" nut wedged between piston and cylinder head. HR No. B-20-20 Rev. C {C} B-20-21 Rev. B-DCN6 {C} *No TVC problems were experienced on STS-37.*	During disassembly of a hydraulic reservoir at USBI Florida Operations, a 1/4" nut was found wedged between the piston and the low-pressure cylinder head. The nut was similar to that used extensively in the aft skirt; 2 are located on a tube bracket installed directly above the reservoir. During reservoir installation, the Operation and Maintenance Instruction (OMI) prohibits removal of reservoir plugs until tube installation is complete. The nut was covered by a black, soot-like coating similar to that seen in the aft skirt post-SRB fire. Initial assessment by USBI determined that the 1/4" nut could have entered the reservoir when it was removed from the STS-28 SRB, the last mission that the reservoir was used. Examination of the nut also found signs of previous torque history. Hydraulic reservoirs, along with other SRB hydraulic components, are normally disassembled, inspected, and refurbished after each flight. This particular reservoir experienced extensive testing at USBI Florida Operations and Arkwin, the vendor, since STS-28. Arkwin indicated that they do not stock this nut. Bracket components, including the nut, are supplied in kits, and a review at USBI Florida Operations found no nuts missing from kits. USBI performed a flow analysis of the hydraulic system. This analysis found insufficient flow through the reservoir to carry debris, such as the 1/4" nut, from the reservoir to the pump.

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
SRB		
2 (Continued)	TVC hydraulic reservoir found with 1/4" nut wedged between piston and cylinder head.	Rationale for STS-37 flight was: • The nut probably got into the reservoir during postflight disassembly. • Reservoir installation performed per OMI reduced the potential for introduction of foreign material by requiring proximity component installation to be complete prior to reservoir plug removal. • Flow analysis indicated insufficient flow to propel the nut from the reservoir to the hydraulic pump. *This risk factor was resolved for STS-37.*

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
SRM		
1	Test and Evaluation Motor (TEM)-7 fixed housing ablative liner debond. HR No. BN-08 Rev. C {C} *No similar Solid Rocket Motor (SRM) anomalies were reported on STS-37.*	Post-test examination of the TEM-7 nozzle revealed 100% debond of the fixed housing ablative liner from the metal housing. Erosion of the 4 ground-test pressure transducer metal fittings was also witnessed. Investigation revealed that the debond was related to the ground-test configuration (pressure transducer fittings); these fittings are not used on inflight nozzles. Oval-shaped sooted flow areas were found around all 4 pressure transducer ports. There was no evidence, however, of hot-gas flow entering the liner/metal housing interface at the ends of the phenolic liner. There was no flight history of fixed housing ablative liner-to-metal housing debonds. Rationale for STS-37 flight was: • The debonds experienced were unique to the test configuration. • Flight and static test history revealed no evidence of the TEM-7 type debond. *This risk factor was resolved for STS-37.*
2	Inner Boot Ring (IBR) bond line separation on STS-38 RH SRM. HR No. BN-08 Rev. C. {C} *No similar SRM anomalies were experienced on STS-37.*	The IBR fixed-housing bond line on the STS-38 RH SRM was found to be approximately 80% separated during a special investigation conducted at postflight disassembly. There were splashdown-related impact marks made by snubber retainer bolts on the bearing end ring in the 270° region. This is indicative of high water-impact loads. The IBR and fixed-housing insulation remained in position; no displacement or edge separations were observed. Removal of IBR and fixed-housing insulation by machining revealed the IBR bond line separation. The IBR remained bonded to

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
SRM		
2 (Continued)	IBR bond line separation on STS-38 RH SRM.	the metal housing in the 90° region. The IBR remained bonded to the fixed-housing insulation, and the fixed-housing insulation was well bonded to the metal housing. No soot or combustion products were found in the separated bond line; it remained intact and/or the ends sealed throughout motor operation. The physical evidence was consistent with splashdown-induced damage; however, there was no previous documentation of this type of separation. Detailed investigation of STS-35 IBRs found bond lines completely intact. Structural analysis predicted that the IBR fixed-housing bond line exceeded a 2.0 FOS during motor operation. The analysis indicated post-burn separation was possible due to the splashdown environment; the potential existed for a contaminated and thermally-degraded bond line at the time of splashdown. There were also splashdown-induced tensile loads. Rationale for STS-37 flight was: • IBR failure was due to post-motor-burn events. Snubber damage indicated a high impact-loading event. High water-impact loads, in conjunction with elevated bond line temperatures and contamination, could cause bond line failure. • IBR processing was consistent with previous successfully-flown parts. • The flight FOS was >2.0 at the maximum potential contamination level (60 mg/ft^2). • Redesigned Solid Rocket Motor (RSRM) structural analysis indicated a potential FOS <1.0 at water impact. *This risk factor was resolved for STS-37.*

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
SRM		
3	RTV was found past the primary O-ring of nozzle joint #5 on disassembly of TEM-7. HR No. BN-03 Rev. C {AR} ***No similar SRM anomalies were reported on STS-37.***	Upon disassembly of TEM-7, RTV was found past the primary O-ring of nozzle joint #5 (fixed housing-to-aft end ring). The concern was that the RTV could prevent proper sealing of the joint #5 O-ring, allowing a gas path. This was the first time that this condition was seen on joint #5 of a High Performance Motor (HPM); similar conditions were seen at joints #3 and #4 on previous HPM nozzle configurations. There were no similar occurrences on flight motors. While the HPM configuration only has the primary O-ring, flight motors have a secondary O-ring and bolt Stat-O-Seals. Leak tests verify the integrity of the secondary seals after assembly of a flight motor. RTV typically extends partially down the axial section of the joint, and sometimes reaches the primary O-ring. The O-ring forces uncured RTV away from the seal footprint, maintaining the sealing interface. Tests have demonstrated that the RTV and the fluorocarbon O-ring are compatible, with no adverse effects on O-ring sealing properties. Under normal flight operating conditions, nozzle joint #5 primary and secondary seal gaps close or remain stationary. The thermal environment witnessed at joint #5 is reduced by its location behind the flex boot. Thermal analysis predicted no heat effects on O-ring sealing if there were blowpaths to the primary O-ring.

ELEMENT/ SEQ. NO.	RISK FACTOR	COMMENTS/RISK ACCEPTANCE RATIONALE
SRM		
3 (Continued)	RTV was found past the primary O-ring of nozzle joint #5 on disassembly of TEM-7.	Rationale for STS-37 flight was: • There was no history of similar conditions on flight motors. • The flight motor configuration provides a secondary O-ring and Stat-O-Seals for further protection. • Leak tests verify the secondary seal integrity. *This risk factor was resolved for STS-37.*

SECTION 5

STS-35 INFLIGHT ANOMALIES

This section contains a list of Inflight Anomalies (IFAs) arising from the STS-35/OV-102 mission, the previous Space Shuttle flight. Each anomaly is briefly described, and risk acceptance information and rationale are provided.

Hazard Report (HR) numbers associated with each risk factor in this section are listed beneath the anomaly title. Where there is no baselined HR associated with the anomaly, or if the associated HR has been eliminated, none is listed. Hazard closure classification, either Accepted Risk {AR} or Controlled {C}, is included for each HR listed.

SECTION 5 INDEX

STS-35 INFLIGHT ANOMALIES

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
INTEGRATION		
1	Backup Flight System (BFS) software patch for pad B definition of longitudinal location was incorrect. IFA No. STS-35-I-01 HR No. ORBI-066 {AR} ***There were no I-load patches required to support STS-37; therefore, no similar BFS anomaly was experienced.***	Relocation of STS-35 from pad A to pad B required an I-load software patch to include the pad B location definition. During ascent, a difference of 143 feet (ft) was witnessed between the position data sent from the BFS and the Primary Avionics Software System (PASS). Post-ascent evaluation of telemetry data identified an error in the sixth BFS software patch for pad B. An error was found in the sixth digit of the longitude string. Investigation determined that the error was caused by software developers at Rockwell International (RI)/Downey who incorrectly read the Change Request (CR). CR 90365 was faxed to RI/Downey and was used as the authority for the I-load software patch. All who read CR 90365 interpreted the longitude position as -1.40709036E+00; the correct value was -1.40709836E+00. Verification of this value was not made at RI/Downey prior to incorporation into the I-load. Verification could have been made through comparison with the electronic data set associated with CR 90365. The modified BFS I-load passed STS-35 certification testing. Pass/fail criteria for downrange position at Main Engine Cutoff (MECO) command is ±600 ft; a value of 322 ft was observed and accepted during testing. The worst-case effect for downrange position at MECO command if the position is greater than ±600 ft is that either the External Tank (ET) would land outside the predicted footprint or there would be insufficient propellant to continue the mission.

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
INTEGRATION		
1 (Continued)	BFS software patch for Pad B definition of longitudinal location was incorrect.	To ensure that conditions will not exist for future occurrence of a similar type of error, all CRs that require I-load patches must be accompanied by the associated electronic data set for verification. Rationale for STS-37 flight was: • There were no I-load patches required to support STS-37. • Procedures were in place to verify I-load data if a patch was required prior to launch. • Large errors are detectable during I-load software certification testing. ***This anomaly was resolved for STS-37.***

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
1	Left Reaction Control System (RCS) drain panel heater "A" was not at normal temperature. IFA No. STS-35-04 *No anomalous RCS heater operation was reported on STS-37.*	On orbit, the left RCS drain temperature indicated that the heater did not cycle at the expected 56.6°F. The temperature on heater "A" went down to 52°F before the crew was instructed to switch to heater "B". The "B" heaters operated nominally after switchover. Data analysis determined that the "A" heater cycled once normally prior to this failure. On-orbit troubleshooting included switching back to heater "A" and allowing the left RCS drain temperature to drop to 40°F, which confirmed the failure of heater "A" to cycle properly. Because of the attitude of the vehicle, the RCS drain temperature did not go below 40°F for the remainder of the mission. The Shuttle Operational Data Book (SODB) limit is +20°F; RCS oxidizer freezes at +12°F, and the fuel freezes at −60°F. This was believed to be an isolated failure, with no indication of a generic problem. The most likely cause of this anomaly was a failed thermostat. There were no reported problems with the left RCS drain panel thermostat on previous OV-102 missions. RCS heaters are Criticality (Crit) 2R3 components. RI is currently investigating if there are any Crit 1 applications of this thermostat. Rationale for STS-37 flight was: • RCS drain heaters were redundant. • Loss of both heaters required a preferred attitude maneuver for temperature control [Flight Rule (FR) 6-10B].

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
1 (Continued)	Left RCS drain panel heater "A" was not at normal temperature.	• If temperature control cannot be maintained with attitude maneuvering, the worst-case effect would be mission termination (FR 6-10B). ***Not a safety concern for STS-37.***
2	Degradation of waste water dump function. IFA No. STS-35-05 HR No. ORBI-254 {AR} ***No waste water dump problems were experienced on STS-37.***	Water from the waste water storage tank is periodically dumped overboard into space during a nominal mission. A gradual degradation of the waste water dump rate was noted during the first 3 dump cycles. The line was completely blocked on the fourth dump. Inflight maintenance was performed with no success. Waste tank offload into the Contingency Water Container (CWC) and urine collection devices was required for the remainder of the mission. A decision was made to manifest additional CWCs on all subsequent flights. Similar problems on STS-32/OV-102 led to removal and cleaning of the last 22" of the dump line. It is believed that the blockage on STS-35 was upstream of this section. Troubleshooting of this STS-35 anomaly found that the waste water dump line filter had deteriorated and was the root cause of the line blockage. The filter assembly has 3 filters (coarse, medium, and fine) and is replaced after 3 flights. It was determined that the polyurethane filter material deteriorates after approximately 8 years. A spare filter assembly obtained from the logistics stockroom showed similar signs of deterioration. This spare filter, manufactured in 1980, had never been used (still in the shipping package).

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

ORBITER

2 (Continued)	Degradation of waste water dump function.	These findings led to a check of the STS-39/OV-103 waste water dump line filter assembly. Upon removal, it was also found to be deteriorated. The 3"-long #3 filter (coarse) had approximately two-thirds of the material missing. When the #2 filter (medium) was touched, it fell apart. The #1 filter (fine) was completely gone, and a small amount of gray powder residue was found in the liquid remaining in the filter assembly housing. The STS-39/OV-103 replacement filter was manufactured in 1988. The STS-37/OV-104 waste water dump line filter assembly was also inspected; it showed no degradation of any filter elements. These filter elements were from the lot manufactured in 1988. The STS-37/OV-104 waste water dump line was flushed and tested. Rationale for STS-37 flight was: • The waste water dump line filter was believed to be the cause of the STS-35/OV-102 line blockage; STS-37/OV-104 filters were verified to be good. • The capacity of the waste storage tank was adequate for a minimum-duration mission without water dump. • Three or more failures were required to cause crew illness. A second CWC was added to the STS-37 manifest. *Not a safety concern for STS-37.*

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
3	-Z star tracker Serial Number (S/N) 006 failed 2 initial self-tests. IFA No. STS-35-10 *No star tracker anomalies were reported on STS-37.*	On the initial power-up, -Z star tracker S/N 006 failed the first 2 self-tests. Position errors were observed on the first self-test software cycle. All subsequent software cycles indicated the correct Built-In Test Equipment (BITE) star position. The -Z star tracker passed the third self-test and 5 additional self-test cycles. Performance thereafter was nominal. Initial evaluation determined that the star tracker electronics may not have responded quickly enough to start acquisition during the first 2 self-test cycles. It was believed that this slow response time could be a function of warmup time. Minimum warmup time is 15 minutes (min); however, the STS-35/OV-102 star trackers had power on for 25 min prior to the first 2 self-test cycles. This slow response condition was seen during laboratory tests on other units; however, this was the first occurrence in flight. This anomaly is a Crit 1R3 failure mode. The -Y star tracker and the Crew Optical Alignment Sight (COAS) have redundant functions to the -Z star tracker. Rationale for STS-37 flight was: • There are 3 redundant strings: -Z star tracker, -Y star tracker, and COAS. *Not a safety concern for STS-37.*

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
4	Payload Bay Door (PLBD) environmental seal debond. IFA No. STS-35-16 *No problems were experienced with PLBD environmental seals on STS-37.*	Postflight inspection of OV-102 found a 24" piece of the environmental seal loose between panels #1 and #2 at the top of the right PLBD. The loose seal material was cut off prior to the ferry flight to preclude further loosening or damage. There was no apparent damage internal to the payload bay. This was a first-time occurrence in this area. A 6" splice segment of the PLBD-to-aft bulkhead environmental seal debonded on STS-41/OV-103. Evaluation of the STS-41 problem determined the cause to be improper application of the seal (bad etching and bonding). Investigation into the cause of the STS-35 anomaly continues. STS-37/OV-104 PLBD environmental seals were visually inspected because of the problem experienced on STS-41. This inspection found no problems. The visual inspection was only sufficient to indicate whether the seal was protruding from the "monkey fur". Rationale for STS-37 flight was: • Visual inspection found no problems. *This anomaly was resolved for STS-37.*

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
<u>ORBITER</u>		
5	Water Spray Boiler (WSB) #3A operation was abnormal during ascent and entry. IFA No. STS-35-17 HR No. ORBI-036 {AR} ORBI-121 {AR} *Similar problems were encountered with WSB operation on STS-37 (IFA No. STS-37-V-02A). WSB #2 did not cool APU lube oil while under operation of controller "A", and operation had to be switched to controller "B" when lube oil temperature reached 280°F. The most probable cause of the problem was again believed to be freezing of the spray bar caused by wax buildup in the WSB. (See Section 7, Orbiter 2 for more details.)*	During ascent, WSB #3A did not initiate spray cooling until Auxiliary Power Unit (APU) #3 lube oil return temperature reached 277°F. WSB cooling operations should begin at 250°F. During reentry operations, WSB #3A overcooled the lube oil. A similar anomaly occurred with WSB #2A on STS-38/OV-104 (see Section 6, Orbiter 1 for more details). Preliminary analysis indicated that the presence of wax in the APU #3 lube oil may have caused the spray bar to freeze. The lube oil temperature increased until the spray bar thawed and proper cooling commenced. A hot-oil flush will be performed during the STS-40/OV-102 turnaround process. WSB #3A operations will be tested after the hot-oil flush. Rationale for STS-37 flight was: • WSB #2A controller was replaced on STS-37/OV-104. • Operational Maintenance Requirements and Specifications Document (OMRSD) testing on STS-37/OV-104 indicated proper WSB functioning. • Redundant systems were available. *Not a safety concern for STS-37.*

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
6	Window W-1 has a 0.15" diameter chip. IFA No. STS-35-18 HR No. ORBI-009 {AR} *No window anomalies were reported on STS-37.*	Postflight inspection of the OV-102 windows revealed a chip in window W-1, measuring 0.15" in diameter and 0.0109" in depth. A "spider web" type crack formation was found radiating from the impact point. During the crew debriefing, it was determined that the crew first noted the chip on Flight Day (FD) 6. It is believed that the chip occurred during ascent. Window W-1 will be removed and replaced prior to the next OV-102 mission. Further examination of the window will be performed to attempt to determine the cause of the chip. *This risk factor was acceptable for STS-37.*
7	WSB #2 was subjected to abnormally large quantities of wax. IFA No. STS-35-19 HR No. ORBI-121 {AR} *(See Orbiter 5 in this section.)*	During ascent and entry, indication of a large amount of wax was noted in the APU #2 lube oil system. This condition subjected WSB #2 to wax in the lube oil; therefore, WSB #2 will require a hot-oil flush during STS-40/OV-102 turnaround processing. APU #2 will be removed and replaced during this process to comply with life-limit criteria. *Not a safety concern for STS-37.*

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
8	RCS vernier thruster R5D failed "off". IFA No. STS-35-20 HR No. ORBI-056 {C} *RCS primary thruster R1U failed "off" during the ET separation maneuver on STS-37 (IFA No. STS-37-V-01). However, in this case the problem was believed to be caused by iron nitrate contamination of the oxidizer valve poppet; pressure traces from the R1U failure were similar to those seen on STS-36 thruster failures that were attributed to this type of contamination. (See Section 7, Orbiter 2 for more details.)* *There were indications of low Chamber Pressure (P_c) on STS-37/OV-104 primary thrusters L1U and L1L during firing in the interconnect configuration (IFA No. STS-37-V-08). P_c in these thrusters returned to nominal after reconfiguration to straight feed. Contamination in the oxidizer interconnect line was suspected. (See Section 7, Orbiter 4 for more details.)*	During orbital maneuvering, RCS vernier thruster R5D exhibited low P_c and was deselected by Redundancy Management (RM). Data evaluation indicated that helium was present in the crossfeed line. A similar failure was seen on STS-9. Vernier thruster R5D was successfully hot-fired on orbit to flush out the helium. Evaluation of the hot-fire data indicated some gas ingestion during the first pulse and none in the 4 subsequent pulses. RM was reset following nominal performance during the hot-fire. Rationale for STS-37 flight was: • There were redundant down-firing thrusters in each Orbital Maneuvering System (OMS) pod. • Small helium bubbles trapped in propellant lines can be removed by hot-firing the thrusters. • A vernier thruster deselected because of helium bubbles can be reselected after gas is flushed out of the system during a hot-fire. *This risk factor was acceptable for STS-37.*

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
9	Orbiter/ET Liquid Oxygen (LO_2) aft attach/separation hole plugger did not fully extend. IFA No. STS-35-21 HR No. ORBI-302A {AR} *No problems with this hole plugger were reported on STS-37.*	The Orbiter/ET LO_2 aft attach/separation hole plugger did not complete its stroke. One of the 2 pyros was jammed between the plugger and the rim of the hole. The other pyro device was not found and may have escaped. No debris was found on the runway after the ET doors were opened. Similar hole plugger failures occurred on STS-29 and STS-34. The concern was that loose debris could block the ET umbilical door from fully closing, resulting in the potential loss of the crew and vehicle during reentry. The likelihood of escaping fragments preventing the ET umbilical door from closing was determined to be remote. The ET doors may be recycled in flight if closing or latching is obstructed. The Orbiter performs a maneuver at ET separation, moving away from the ET and escaping possible debris prior to ET umbilical door closure. Rationale for STS-37 flight was: • The likelihood of debris jamming the ET umbilical door is remote. • Doors may be recycled in flight if closing or latching is obstructed. • The ET separation burn moves the Orbiter away from any escaping debris. *This risk factor was acceptable for STS-37.*

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
<u>ORBITER</u>		
10	Right-Hand (RH) stop bolt was found bent on the STS-35 centering ring of the forward ET attach/separation assembly. IFA No. STS-35-22 HR No. INTG-051B {C} ***No problems with these stop bolts were reported on STS-37.***	Postflight inspection of STS-35/OV-102 found the RH stop bolt bent approximately 5° from center. Bending of stop bolts was previously experienced on STS-34, STS-32, and STS-38 (not reported as an IFA on STS-38/OV-104). Damage to the STS-35/OV-102 stop bolt was worse than that seen on STS-38, but not as bad as the STS-34 anomaly. The left and right stop bolts restrict side rotation of the centering ring during Orbiter/ET mate. They are not designed to carry any mate or flight loads. Review of ground operations determined that mating and demating operations have the physical capability to bend the stop bolts. Mating procedures were modified after STS-34 to control the yoke position and preclude the potential for bolt damage during mating operations. No stop bolts were reported bent during the next several missions; however, there were no modified requirements for demating operations on these flights. Because of the reports of bent stop bolts on STS-38 and STS-35, where both flows required Orbiter demate from the ET, a modified demate procedure was developed and submitted for approval. New mate/demate Ground Support Equipment (GSE) with improved visual and digital readout will be available in mid-1991. Additionally, a more robust stop bolt design is in evaluation for future use. No anomalies were recorded during the STS-35 ET/Orbiter mating process. Misalignment of the ET attach points, EO-2 and EO-3, was not considered a contributor to this anomaly. A bent stop bolt is a Crit 3 failure. Analysis conducted during the investigation of previous instances of bent or damaged stop bolts determined that a moment of 430-2100 inch-pounds (in-lb) could locally deform the bolt end. This moment could be generated by either side-to-side

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
10 (Continued)	RH stop bolt was found bent on the STS-35 centering ring of the forward ET attach/separation assembly.	movement during normal handling or by the small, pyro-initiated rocking motion at separation. The rocking motion was first seen during review of pyro qualification test film. The bolts used in the qualification tests also exhibited local flat spots similar to those seen on the STS-32 stop bolts. The rocking motion, however, was determined to be insufficient to cause the bolt bending experienced on STS-34. Rationale for STS-37 flight was: • The bent stop bolt on STS-38/OV-104 was repaired during the STS-37/OV-104 processing flow. • All stop bolts, even when bent, have performed the intended function. • Stop bolts do not carry flight loads and are nonfunctional after Orbiter/ET mate. • Analysis demonstrated that there were no known flight loads that could cause stop bolt bending. ***This anomaly was resolved for STS-37.***

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
11	Pilot seat down-limit switch failure. IFA No. STS-35-23 HR No. ORBI-340 {AR} *No problems with the pilot seat were reported on STS-37.*	During ingress and prelaunch operations, the pilot attempted to make seat adjustments. The pilot seat failed to drive down. This is a repeat of an STS-32 anomaly (IFA No. STS-32-27). The seat operated properly on orbit. The down-limit switch was replaced during the STS-35 turnaround process. Further troubleshooting will be performed at KSC. This anomaly is unique to OV-102. Rationale for STS-37 flight was: • There were no problems experienced with crew seats on STS-38/OV-104. The only operational problem history has been on OV-102. *Not a safety concern for STS-37.*

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
SRM		
1	Heat-affected Carbon Cloth Phenolic (CCP) seen on the left Solid Rocket Motor (SRM) at nozzle joint #3. IFA No. STS-35-M-01 HR No. BN-03 Rev. C {AR} ***No heat effect problems associated with the SRM CCP were reported on STS-37.***	During postflight inspection of left SRM nozzle joint #3 by Thiokol Corporation (TC), a 1.5" gas path was observed through a Room-Temperature Vulcanizing (RTV) void at 195° of the CCP. Surface heat effects and associated sooting resulted. Heat effects on the virgin CCP were seen approximately 1.0" radially past the char line and appeared to be on the surface only. Soot reached the primary O-ring, approximately 12" circumferentially in both directions from the 195° position. There were no blowby erosion or heat effects to the primary O-ring. Metal nozzle components were not affected. The RTV contributes as a thermal barrier only and is not considered a seal in the nozzle joints. RTV below the char line is a design goal only and is not a performance requirement. To date, all RTV backfill nozzle joints have met design requirements. No flight or static test motor nozzle joints have exhibited primary O-ring heat effects, erosion, or blowby. This was the first occurrence of heat-affected CCP in nozzle joint #3. Heat-affected CCP, silica cloth phenolic, and glass cloth phenolic were seen in joint #2 (nose inlet bearing/cowl) of STS-36, QM-7, and PVM-1, all with no O-ring heat effects. Gas paths and soot in nozzle joints were within the experience base of 26 flight SRMs and 7 static test nozzles. TC plans to conduct an aero/thermal analysis of nozzle joint #3 to determine the gas volume and flow characteristics associated with this STS-35 anomaly.

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
SRM		
1 (Continued)	Heat-affected CCP seen on the left SRM at nozzle joint #3.	Rationale for STS-37 flight was: • There was no history of blowby, erosion, or heat effects on the primary O-ring experienced with gas paths through SRM nozzle RTV voids. • The gas path and soot witnessed on STS-35 nozzle joint #3 was within the experience base of 26 flight SRMs and 7 test motors. *This risk factor was acceptable for STS-37.*

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
ET		
1	ET Thermal Protection System (TPS) divots found at the intertank-to-hydrogen flange. IFA No. STS-35-T-01 HR No. INTG-008B {AR} INTG-037B {AR} INTG-081A {AR} *No ET anomalies were reported on STS-37.*	During review of ET photographs taken by the STS-35 crew after separation, 11 circular TPS divots were observed. All were located on the intertank-to-hydrogen flange. Six divots were on the left side of the tank; the other 5 were on the right side. The divots were estimated to be from 7" to 10" in diameter. The ET intertank flanges are closed out after the splice/mate of the LO_2 tank to the Liquid Hydrogen (LH_2) tank. The intertank flanges are then manually sprayed with BX-250 foam, which is bonded to existing tank foams by an isochem adhesive. Adhesive voids cannot be detected by visual inspection, and there is currently no available nondestructive test to verify proper adhesion. Martin Marietta Corporation (MMC) is reviewing STS-37/ET-37 build paper for potential anomalies; however, nothing of significance is expected to be found. Review of similar photographs from STS-28 found a large divot in the ET intertank acreage TPS. This divot was estimated at 23" x 15" and >1" in depth. No conclusion was reached as to the cause of the STS-28 divot; however, when possible, all crews have been asked to photograph the ET after separation. The divots seen on STS-35 were the first experienced since STS-28. Review of the STS-35 ET photographs by MMC determined that the divots did not expose ET tank metal. The "whitish" color was believed to be fresh BX-250 foam that was not exposed to the weather. Worst-case analysis performed by MMC indicated that bare ET tank metal of the divot sizes seen on STS-35 would not result in structural or thermal problems.

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
<u>ET</u>		
1 (Continued)	ET TPS divots found at the intertank-to-hydrogen flange.	Rationale for STS-37/ET-37 flight was: • No anomalous conditions were reported during the manufacturing and testing of ET-37. • MMC worst-case analysis determined that no structural or thermal problems result from bare ET-tank metal of the divot sizes seen on STS-35. ***This risk factor was acceptable for STS-37.***

SECTION 6

STS-38 INFLIGHT ANOMALIES

This section contains a list of Inflight Anomalies (IFAs) arising from the STS-38/OV-104 mission, the previous flight of the Orbiter vehicle. Each anomaly is briefly described, and risk acceptance information and rationale are provided.

Hazard Report (HR) numbers associated with each anomaly in this section are listed beneath the anomaly title. Where there is no baselined HR associated with the anomaly, or if the associated HR has been eliminated, none is listed. Hazard closure *classification, either Accepted Risk {AR} or Controlled {C}, is included for each HR* listed.

SECTION 6 INDEX

STS-38 INFLIGHT ANOMALIES

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
1	Water Spray Boiler (WSB) #2 did not cool Auxiliary Power Unit (APU) lube oil while under operation of controller "A". IFA No. STS-38-01 HR No. ORBI-036 {AR} *Similar problems were encountered with WSB operation on STS-37 (IFA No. STS-37-V-02A). WSB #2 did not cool APU lube oil while under operation of controller "A", and operation had to be switched to controller "B" when lube oil temperature reached 280°F. The most probable cause of the problem was again believed to be freezing of the spray bar caused by wax buildup in the WSB. (See Section 7, Orbiter 2 for more details.)*	WSB #2 controller "A" failed to cool APU lube oil after the end of the pool boiling period during ascent. The crew switched to controller "B" when the temperature reached 275°F, and APU #2 was left "on" after APUs #1 and #3 were shut down. After switching to controller "B", lube oil temperature peaked at 300°F before cooling was observed after 66 seconds (sec). Controller "A" was selected for reentry to determine if the temperature control operated properly; controller "A" operated normally. It was believed that spray bar freeze-up on controller "A" during ascent caused the problem. Freezing of the spray bar could have been caused by low heat load on APU #2, or controller "A" was not functioning properly. A similar cooling problem was experienced on STS-1 through STS-4 and on STS-35/OV-102. Rationale for STS-37 flight was: • WSB #2 was replaced. • Operational Maintenance Requirements and Specifications Document (OMRSD) testing on STS-37/OV-104 indicated proper WSB controller operation. *This anomaly was resolved for STS-37.*

STS-38 INFLIGHT ANOMALIES

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
<u>ORBITER</u>		
2	Flash Evaporator System (FES) water supply accumulator heater system biased low. IFA No. STS-38-02 HR No. ORBI-276B {C} *No FES problems were reported on STS-37.*	FES heater #1 did not cycle "on" within its prescribed temperature range of 55-75°F. When the temperature reached 49°F, heater string #2 was activated and cycled in the 48-54°F range with apparently normal duty cycles. Heater string #1 was reactivated and cycled like heater string #2. A temperature sensor debond problem was the suspected cause of this anomaly. FES heater #1 was removed and replaced at Kennedy Space Center (KSC). Rationale for STS-37 flight was: • FES heater #1 was replaced and satisfactorily tested. *This anomaly was resolved for STS-37.*
3	APU #3 X-axis acceleration trace erratic. IFA No. STS-38-03B *No APU acceleration trace anomalies were reported on STS-37.*	During entry, APU #3 X-axis acceleration trace was erratic. The problem was believed to be a failed accelerometer. There was no previous accelerometer failure history. Troubleshooting at KSC included connector and accelerometer checkouts and isolated the anomaly to a broken coax in connector 50P3 pin A. APU #3 was removed and replaced to comply with life-time cycle limits. Rationale for STS-37 flight was: • The anomaly was isolated to broken coax. • APU #3 was removed and replaced during the STS-37/OV-104 flow. *This anomaly was resolved for STS-37.*

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
4	Vacuum cleaner short circuit. IFA No. STS-38-04A HR No. ORBI-301 {C} *No vacuum cleaner problems were reported on STS-37.*	When the crew turned on the vacuum cleaner, Circuit Breaker (CB) #29 on panel L4 was activated by a current surge. Utility outlet M013Q was not used during the remainder of the flight; this outlet provides the electrical interface for the food heater and vacuum cleaner. Outlet testing was completed, and the outlet tested good. The vacuum cleaner was removed and sent to Johnson Space Center (JSC). Postflight troubleshooting verified a phase "B" short-to-case on the vacuum cleaner. Prelaunch vacuum cleaner checkout was modified to include a check for shorts on all 3 phases. The vacuum cleaner was replaced with a stock unit that passed the modified checkout procedure. Rationale for STS-37 flight was: • The anomalous vacuum cleaner was replaced. • New procedures verified the absence of shorts in the vacuum cleaner installed on STS-37/OV-104. *This anomaly was resolved for STS-37.*

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
<u>ORBITER</u>		
5	APU Exhaust Gas Temperature (EGT) instrumentation interaction with injector tube temperature instrumentation. IFA No. STS-38-05 HR No. ORBI-106A {AR} ***APU #2 injector tube temperature failed during STS-37 entry. The sensor unit went erratic and then failed low (IFA No. STS-37-V-10B).***	APU #2 EGT #1 and #2, and APU #2 and #3 injector tube temperatures, became erratic during launch. The APU injector tube temperatures became erratic concurrent with EGT sensor failures. The EGT failures affected the common Designated Signal Conditioner (DSC) power supply isolation card. The injector temperature instrumentation and EGTs utilize a common DSC. Analysis indicated that a momentary EGT short-to-ground may have provided a ground loop between the injector temperature and common power supply, resulting in erratic injector temperatures. There was no problem with injector tube temperature measurements; only the EGT measurements were affected. No action was taken by the crew. Injector temperature measurements remained functional. Rationale for STS-37 flight was: • The problem was isolated to an EGT short-to-ground, and repairs were made. ***This anomaly was resolved for STS-37.***

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
<u>ORBITER</u>		
6	Right vent doors #1 and #2 purge position failure. IFA No. STS-38-06 HR No. ORBI-178A {AR} *Vent door purge positioning operated normally on STS-37.*	During postlanding vent door purge positioning operations, right vent doors #1 and #2 drove to the "closed" position instead of the "purge" position. Right vents #1 and #2 are used to purge the forward Reaction Control System (RCS). STS-38 purge could not be performed via right vents #1 and #2. This failure may have been a limit switch/contact problem. There are 2 limit switches for door "open" position, 2 for door "close" position, and 2 for "purge" position. Limit switch failure is Crit 1R4. The worst-case failure for the vent doors is Crit 1R2. Troubleshooting isolated the failure to the Power Distribution Unit (PDU). The PDU was replaced, and testing indicated satisfactory performance. Rationale for STS-37 flight was: • The anomalous PDU was replaced and tested satisfactory. ***This anomaly was resolved for STS-37.***

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
7	Continuous "tire press" Fault Detection and Annunciation (FDA) message following landing gear safing. IFA No. STS-38-08 HR No. ORBI-018 {AR} *No anomalous FDA tire pressure messages were experienced on STS-37.*	Continuous "tire press" messages were observed following landing gear safing procedures. During this procedure, one set of messages is expected after removal of the landing gear "arm" flag; however, continuous messages were noted. Initial visual inspection of the Tire Pressure Monitoring System (TPMS) showed no abnormalities. Troubleshooting found no other problems. This anomaly was closed as unexplained. Rationale for STS-37 flight was: • This was a first-time occurrence; there were no indications of a generic problem. *This anomaly was resolved for STS-37.*

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
8	Transient smoke detector event indication anomaly. IFA No. STS-38-09 HR No. ORBI-300 {C} *No problems were experienced with the avionics bay smoke detectors on STS-37.*	Smoke detector "3A" in avionics bay "3A" did not have enough voltage to ring the alarm, but the event indicators (lights) lit. There were several previous instances of smoke detector failures where no apparent cause could be found. This occurrence was similar to the problem experienced on STS-41. On STS-32, avionics bay "3A" smoke detector "3A" experienced repeated transient alarms and associated lights. A decision was made to pull the sensor circuit breaker to avoid nuisance alarms during sleep, reentry, and landing periods. The sensor was removed and replaced. The defective unit was sent to the vendor for failure analysis, but the unit was damaged before the vendor could examine it. STS-38 smoke detector "3A" was removed, and failure analysis will be performed in conjunction with failure analysis of the STS-32 smoke detector anomaly. Rationale for STS-37 flight was: • Occurrences of this anomaly to date indicated a problem with the detector. • In no case was smoke found in the avionics bay. *This anomaly was resolved for STS-37.*

SECTION 7

STS-37 INFLIGHT ANOMALIES

This section contains a list of Inflight Anomalies (IFAs) arising from the STS-37/OV-104 mission. Each anomaly is briefly described, and risk acceptance information and rationale are provided.

Hazard Report (HR) numbers associated with each risk factor in this section are listed beneath the anomaly title. Where there is no baselined HR associated with the anomaly, or if the associated HR has been eliminated, none is listed. Hazard closure classification, either Accepted Risk {AR} or Controlled {C}, is included for each HR listed.

SECTION 7 INDEX

STS-37 INFLIGHT ANOMALIES

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
1	Reaction Control System (RCS) primary thruster R1U failed off during External Tank (ET) separation maneuver. IFA No. STS-37-V-01 HR No. ORBI-056 {AR}	RCS primary thruster R1U failed off during the STS-37 ET separation maneuver. Recorded pressure data indicated that the thruster Chamber Pressure (P_c) was 10 pounds per square inch absolute (psia); nominal P_c is 150 psia at thruster firing. Thruster injector temperatures indicated some oxidizer and fuel flow in R1U when firing was attempted. R1U was deselected by Redundancy Management (RM) and remained off for the remainder of the mission. Several similar thruster anomalies of this type were experienced on previous missions. Pressure traces from the STS-37 R1U failure were similar to those seen on R3D and R4R on STS-36. Iron nitrate contamination of the oxidizer valve poppet was determined to be the cause of both STS-36 thruster failures. Iron nitrate contamination forms when the oxidizer, Nitrogen Tetroxide (N_2O_4), is allowed to contact moisture in ambient air. This contamination prevented the oxidizer valves from opening in the time allotted to achieve proper P_c. It is believed that iron nitrate contamination may also have caused R1U to fail. R1U was removed when OV-104 returned to Kennedy Space Center (KSC); the unit was sent to the White Sands Test Facility (WSTF) for further analysis.
2	Water Spray Boiler (WSB) #2 did not cool Auxiliary Power Unit (APU) lube oil while under operation of controller "A". IFA No. STS-37-V-02A HR No. ORBI-036 {AR}	WSB #2 failed to cool APU #2 lube oil after the end of the pool boiling period during ascent. WSB #2 was under the operation of controller "A". The crew was directed to switch to controller "B" when lube oil temperature reached 280° Fahrenheit (F); nominal cooling begins at 250°F. Lube oil temperature had begun to drop just prior to the crew action. The same anomaly occurred during STS-38, the previous flight of OV-104. Both controller "A" and WSB #2 were removed and replaced after STS-38.

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
2 (Continued)	WSB #2 did not cool APU lube oil while under operation of controller "A".	The most probable cause of this problem was freezing of the spray bar caused by wax buildup in the WSB. Wax, in the form of pentaerythritol, is formed when the APU hydrazine fuel is allowed to mix with lube oil. Pentaerythritol will begin to melt when lube oil temperature exceeds 200°F. There were no preflight indications of wax buildup in the APU #2 lube oil or in WSB #2. Research of this WSB cooling problem indicated an emerging trend when WSBs are paired with APU Serial Number (S/N) 208. Further investigation into this and other APU/WSB combinations is in work. To date, there have been no similar WSB cooling problems on OV-103. Nor has there been any evidence of high APU lube oil pressures on OV-103, a good indication that wax has not formed in the lube oil.
3	Power Reactant Supply and Distribution (PRSD) Oxygen (O_2) manifold valve #2 failed to close when commanded. IFA No. STS-37-V-03 HR No. ORBI-094 {AR}	PRSD O_2 manifold valve #2 failed to close when commanded the first two times on orbit. The valve, S/N 28, finally closed on the third command and was left closed for the remainder of the STS-37 mission. O_2 manifold valve #2 is 1 of 2 redundant valves used to isolate the manifold or PRSD supply tank from a system leak. Failure of both manifold valves to close would result in depletion of fuel cell O_2 reactants and potential loss of the 3 fuel cell power plants. O_2 manifold valve #2, S/N 28, previously failed to close when first commanded on OV-104 during STS-34. Postflight troubleshooting found no problems with the valve operation, and the anomaly was closed as unexplained. S/N 28 worked properly on the 2 OV-104 flights between STS-34 and STS-37: STS-36 and STS-38. Troubleshooting at Dryden found no problem. S/N 28 was removed and replaced when OV-104 returned to KSC.

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
4	Indications of low P_c on primary thrusters L1U and L1L during interconnect operations. IFA No. STS-37-V-08 HR No. ORBI-056 {C}	During STS-38/OV-104, low P_c was experienced on 4 primary thrusters: R1U, R3D, RF3L, and R4U. Postflight troubleshooting did not reveal any thruster leaks or other anomalies that might lead to low thruster P_c. Recent analysis determined that STS-38 thrusters R1U, R3D, RF3L, and R4U all indicated low P_c during interconnect operations; the right pod thruster manifold was interconnected to the left Orbital Maneuvering System (OMS) propellant tanks. When RP03 propellant source was switched from the right OMS propellant tanks back to the straight feed configuration, thruster P_c in R1U, R3D, RF3L, and R4U returned to nominal. This finding led to the decision to perform thruster firings on STS-37/OV-104 in the interconnect configuration. When this was performed, thrusters L1U and L1L showed degraded P_c, approximately 130 psia instead of 150 psia nominal. P_c in L1U and L1L returned to nominal after reconfiguration to straight feed. It is believed that there may be contamination in the oxidizer interconnect line. Troubleshooting will be performed at KSC.
5	Backup Flight System (BFS) navigation initialization anomaly. IFA No. STS-37-V-09 HR No. ORBI-066 {AR}	Postlaunch data analysis of the BFS telemetry indicated that, from the prelaunch BFS OPS-1 transition until the T–8 second (sec) BFS reinitialization, the Z-component (altitude) of the BFS state vector was increasing at a rate of approximately 1 foot per second (ft/sec) to approximately 7700 feet (ft). The BFS navigation errors were cleared at the T–8 sec point in the launch countdown when the BFS was reinitialized to the pad B position. Ascent telemetry review indicated that both the BFS and the Primary Avionics Software System (PASS) performed nominally.

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
5 (Continued)	BFS navigation initialization anomaly.	Data review found that the Z-component was approximately 250 ft at the OPS-1 transition plus 3-minute (min) point; previous flight data indicated the Z-component to be 6 to 30 ft during the same time in the launch countdown. During previous launch countdowns, Z-component errors of 1500 to 3000 ft were observed up to the T−8 sec period. Recent pre-STS-37 tests, conducted in the Shuttle Avionics Integration Laboratory (SAIL) with the new General Purpose Computers (GPCs), demonstrated errors of 4000 to 4500 ft. Errors are believed to be caused by gravity feedback, and this eventually leads to error growth in the Z-component. The investigation included a code audit of the BFS and PASS. This audit determined that the problem was only in the first initialization of the navigation function in the BFS. The PASS navigation function did not have the same problems. Testing of the BFS at the SAIL repeated the STS-37 prelaunch anomaly on each attempt and demonstrated that the problem was not from the Inertial Measurement Unit (IMU) input. It is believed that this anomaly was caused by the increased processing time of the new GPCs, combined with the way the BFS sequences initialization of the navigation function. Discrepancy Report (DR) 106197 was generated to identify this problem for resolution.

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
ORBITER		
6	WSB #3 overcool during entry. IFA No. STS-37-V-12 HR No. ORBI-036 {AR}	System #3 post-Main Engine Cutoff (MECO) APU/WSB lube oil temperature ran cooler than the other 2 systems; lube oil return temperature was 231°F minimum. System #3 saw a second overcool during entry; lube oil return temperature was 211°F minimum. System #3 APU/WSB showed evidence of contamination. High gearbox pressure was observed during the pad APU confidence run. The filter and oil were changed out prior to flight.

ELEMENT/ SEQ. NO.	ANOMALY	COMMENTS/RISK ACCEPTANCE RATIONALE
SRB		
1	Left-Hand (LH) forward skirt skin panel buckling. IFA No. STS-37-B-01	During postflight inspection, the aft end of the LH forward skirt skin panel was found to have buckled on either side of the system tunnel. This forward skirt, S/N 22, had flown on STS-27R (BIO-030) and STS-33R (BIO-034). The STS-27R and STS-33 postflight inspection reports indicated no abnormal conditions of the LH forward skirt. STS-37 postflight orbiter data, reviewed through prelaunch, launch and separation, showed nominal flight conditions. Marshall Space Flight Center (MSFC) concluded that buckling was most likely caused by the slapdown load during water impact. The slapdown load on this booster was reported to be the highest ever recorded (92 g versus 12-40 g history). The dynamics of the Solid Rocket Booster (SRB) were likely affected by wave height, wave period, wave length, etc., of the sea-state 5 condition.

SECTION 8

BACKGROUND INFORMATION

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

APPENDIX A

LIST OF ACRONYMS

ACO	Acceptance Checkout
ADI	Attitude Direction Indicator
AFB	Air Force Base
AMOS	Air Force Maui Optical Station
APM	Ascent Particle Monitor
APU	Auxiliary Power Unit
AR	Accepted Risk
ATE	Automatic Test Equipment
BATSE	Burst and Transient Source Experiment
BFS	Backup Flight System
BIMDA	Bioserve ITA Materials Dispersion Apparatus
BITE	Built-In Test Equipment
C	Controlled
CA	California
CAR	Corrective Action Report
CAV	Captive Air Vent
CB	Circuit Breaker
CCP	Carbon Cloth Phenolic
CETA	Crew and Equipment Transaction Aid
CIL	Critical Item List
CLIP	Crew Loads Instruments Pallet Experiment
CMOS	Complementary Metal Oxide Silicon
COAS	Crew Optical Alignment Sight
COMPTEL	Imaging Compton Telescope
CR	Change Request
Crit	Criticality
CRT	Cathode Ray Tube
CTI	Charlton Technologies, Inc.
CWC	Contingency Water Container
CWS	Caution and Warning System
DAR	Deviation Approval Request
DDU	Display Driver Unit
DEU	Data Entry Unit
DPS	Data Processing System
DR	Discrepancy Report
DSC	Designated Signal Conditioner
DSO	Detailed Supplementary Objective
DTO	Development Test Objective

APPENDIX A

LIST OF ACRONYMS - CONTINUED

EAFB	Edwards Air Force Base
EDFE	Extravehicular Activity Developmental Flight Experiment
EDT	Eastern Daylight Time
EGRET	Energetic Gamma Ray Experiment Telescope
EGT	Exhaust Gas Temperature
EST	Eastern Standard Time
ET	External Tank
ETE	Extravehicular Activity Translation Evaluation
EVA	Extravehicular Activity
F	Fahrenheit
FASCOS	Flight Acceleration Safety Cutoff System
FCV	Flow Control Valve
FD	Flight Day
FDA	Fault Detection and Annunciation
FES	Flash Evaporator System
FMEA	Failure Modes and Effects Analysis
FMEA/CIL	Failure Modes and Effects Analysis/Critical Items List
FOS	Factor of Safety
FR	Flight Rule
FRI	Flow Recirculation Inhibitor
FRR	Flight Readiness Review
ft	Feet
ft-lb	Foot-Pounds
ft/sec	Foot Per Second
GGVM	Gas Generator Valve Module
GH_2	Gaseous Hydrogen
GN&C	Guidance, Navigation and Control
GN_2	Gaseous Nitrogen
GO_2	Gaseous Oxygen
GOX	Gaseous Oxygen
GPC	General Purpose Computer
GRO	Gamma Ray Observatory
GSE	Ground Support Equipment
H_2	Hydrogen
HAC	Heading Alignment Cone
HCF	High-Cycle Fatigue
HDS	Hydrogen Dispersal System
HGDS	Hazardous Gas Detection System
HPFTP	High-Pressure Fuel Turbopump

APPENDIX A

LIST OF ACRONYMS - CONTINUED

HPM	High Performance Motor
HPOTP	High-Pressure Oxidizer Turbopump
HR	Hazard Report
hr	Hours
HST	Hubble Space Telescope
I/O	Input/Output
IBR	Inner Boot Ring
IEA	Integrated Electronics Assembly
IFA	Inflight Anomaly
IMU	Inertial Measurement Unit
in-lb	Inch-Pounds
INTG	Integration
IPL	Initial Program Load
JSC	Johnson Space Center
K	Kilobytes
KSC	Kennedy Space Center
ksi	Thousand Pounds Per Square Inch
L-2	Launch Minus 2 Day
lb	Pounds
LCC	Launch Commit Criteria
LCF	Low-Cycle Fatigue
LH	Left-Hand
LH_2	Liquid Hydrogen
LO_2	Liquid Oxygen
LOX	Liquid Oxygen
LPFTP	Low-Pressure Fuel Turbopump
LPOTP	Low-Pressure Oxidizer Turbopump
LSFR	Launch Site Flow Review
M&P	Materials and Processing
MCC	Main Combustion Chamber
MDM	Multiplexer-Demultiplexer
ME	Main Engine
MEC	Master Event Controller
MECO	Main Engine Cutoff
MeV	Million Electron Volts
mg/ft_2	Milligrams Per Square Foot
min	Minutes

APPENDIX A

LIST OF ACRONYMS - CONTINUED

MLG	Main Landing Gear
MLP	Mobile Launch Platform
MMC	Martin Marietta Corporation
MMU	Mass Memory Unit
MPS	Main Propulsion System
MPU	Magnetic Pickup Unit
MSE	Mission Safety Evaluation
MSFC	Marshall Space Flight Center
N_2	Nitrogen
N_2O_4	Nitrogen Tetroxide
NASA	National Aeronautics and Space Administration
NDE	Nondestructive Evaluation
NLG	Nose Landing Gear
NSRS	NASA Safety Reporting System
O_2	Oxygen
OMI	Operation and Maintenance Instruction
OMRSD	Operational Maintenance Requirements and Specifications Document
OMS	Orbital Maneuvering System
OOR	On-Orbit Refueling
OPF	Orbiter Processing Facility
OPS	Operational Sequence
OSMQ	Office of Safety and Mission Quality
OSSE	Oriented Scintillation Spectrometer Experiment
OV	Orbiter Vehicle
P/N	Part Number
PAR	Prelaunch Assessment Review
PASS	Primary Avionics Software System
P_c	Chamber Pressure
PCG	Protein Crystal Growth
PDU	Power Distribution Unit
PLBD	Payload Bay Door
ppm	Parts Per Million
PRCB	Program Requirements Control Board
PRSD	Power Reactant Supply and Distribution
psi	Pounds Per Square Inch
psia	Pounds Per Square Inch Absolute
psid	Pounds Per Square Inch Differential
psig	Pounds Per Square Inch Gage

APPENDIX A

LIST OF ACRONYMS - CONTINUED

RCS	Reaction Control System
RGA	Rate Gyro Assembly
RH	Right-Hand
RI	Rockwell International
RM	Redundancy Management
RME	Radiation Monitoring Equipment
RMS	Remote Manipulator System
rpm	Revolutions Per Minute
RSRM	Redesigned Solid Rocket Motor
RTLS	Return to Launch Site
RTV	Room Temperature Vulcanizing
S/N	Serial Number
SAIL	Shuttle Avionics Integration Laboratory
SAREX	Shuttle Amateur Radio Equipment
sccm	Standard Cubic Centimeters Per Minute
sccs	Standard Cubic Centimeters Per Second
scfm	Standard Cubic Feet Per Minute
sec	Seconds
SEM	Scanning Electron Microscope
SHARE	Space Station Heat Pipe Advanced Radiator Element
SM	Systems Management
SMS	Shuttle Missile Simulator
SODB	Shuttle Operational Data Book
SOV	Shutoff Valve
Spec	Specification
SRB	Solid Rocket Booster
SRM	Solid Rocket Motor
SSC	Stennis Space Center
SSME	Space Shuttle Main Engine
SSRP	System Safety Review Panel
STA	Shuttle Training Aircraft
TAL	Transatlantic Abort Landing
TC	Thiokol Corporation
TEM	Test and Evaluation Motor
TPMS	Tire Pressure Monitoring System
TPS	Thermal Protection System
TVC	Thrust Vector Control

APPENDIX A

LIST OF ACRONYMS - CONTINUED

U/N	Unit Number
USBI	United Space Boosters, Inc.
WSB	Water Spray Boiler
WSTF	White Sands Test Facility