# VEHICLE ENGINEERING

# AGENDA

Presenter:

Organization/Date:
Orbiter/02-14-02

| | |
|---|---|
| **ORBITER** | **To Be Presented** |
| **SOFTWARE** | **To Be Presented** |
| **FCE** | **No Constraints** |
| **GFE** | **No Constraints** |
| **FLIGHT READINESS STATEMENT** | **To Be Presented** |
| **BACKUP INFORMATION** | |

# STS-109
# FLIGHT READINESS REVIEW

# FEBRUARY 14, 2002

# Orbiter

# AGENDA

**Presenter:**

**Organization/Date:**
Orbiter/02-14-02

## Engineering Readiness Assessment

| | |
|---|---|
| • Previous Flight Anomalies | To Be Presented |
| • Critical Process Changes | To Be Presented |
| • Engineering Requirement Changes | No Constraints |
| • Configuration Changes and Certification Status | To Be Presented |
| • Mission Kits | No Constraints |
| • Unexplained Anomalies | No Constraints |
| • Safety, Reliability and Quality Assessment | No Constraints |

## Special Topics — To Be Presented

- WCS Check Valve Failure
- STS-108 Post-Landing Drag Chute Damage Observed
- Hydraulic Main Pump Mounting Flange Washers
- Hydraulic Main Pump Port Cap Bolts
- Investigation of Dedicated Signal Conditioner (DSC) Transistor Failures

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| | **Presenter:** |
| | **Organization/Date:** Orbiter/02-14-02 |

# PREVIOUS FLIGHT ANOMALIES

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|---|---|
| | **Presenter:** |
| | **Organization/Date:** Orbiter/02-14-02 |

# STS-108 IN-FLIGHT ANOMALIES

# PREVIOUS IN-FLIGHT ANOMALIES

**Presenter:**
Doug White
**Organization/Date:**
Orbiter/02-14-02

## STS-108 In-Flight Anomalies, Previous Mission:

- Four problems identified
  - STS-108-V-01: RCS Thruster R4U Failed Off
  - STS-108-V-02: RCS Thruster F3F Failed Off
  - STS-108-V-03: IMU-2 Z-Axis Redundant Anomaly
  - STS-108-V-04: FES Controller Anomaly

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| | **Presenter:** |
| | **Organization/Date:** Orbiter/02-14-02 |

# STS-93 IN-FLIGHT ANOMALIES

| PREVIOUS SPACE SHUTTLE MISSION OV-102 STS-93 IN-FLIGHT ANOMALIES | **Presenter:** Doug White |
|---|---|
| | **Organization/Date:** Orbiter/02-14-02 |

**STS-93 In-Flight Anomalies, Previous OV-102 Mission:**

- One problem identified
  - STS-93-V-01: AC1 Phase A Short
  - Details will be presented on following pages

**All anomalies and funnies have been reviewed and none constrain STS-109 Flight**

# PREVIOUS SPACE SHUTTLE MISSION OV-102 STS-93 IN-FLIGHT ANOMALIES

**Presenter:** Doug White
**Organization/Date:** Orbiter/02-14-02

| Modification | 102 | 103 | 104 | 105 |
|---|---|---|---|---|
| **Aft sidewall protection** | ✔ 2/01 | ✔ 1/01 | ✔ 12/00 | ✔ 10/00 |
| **Landing gear down crit 1/1 elimination** | ✔ 2/01 | ✔ 1/01 | ✔ 12/00 | ✔ 10/00 |
| **Pyro harness heat - shrink** | **✔(fwd/aft) mid STS-118** | **✔(fwd/aft) mid OMM** | **✔(fwd/aft) mid STS-114** | **✔(fwd/aft) mid STS-117** |
| **Convoluted tubing through the clamps** | ✔ 2/01 | **OMM** | ✔ 6/01 | ✔ 3/01 |
| **129 redundancy separations** | **✔(5) STS-118 OMM** | **OMM** | **✔(53) OMM** | **✔(52) OMM** |
| **Monoball production break** | **STS-118** | **OMM** | **110** 2/02 | ✔ 10/01 |

# PREVIOUS SPACE SHUTTLE MISSION OV-102 STS-93 IN-FLIGHT ANOMALIES

**Presenter:** Doug White
**Organization/Date:** Orbiter/02-14-02

| Modification | 102 | 103 | 104 | 105 |
|---|---|---|---|---|
| Redundancy separation/ protection for 12 flight deck AC circuits | STS-118<br>OMM | OMM | ✔(9)<br>2/02<br>OMM | ✔(9)<br>10/01<br>OMM |
| Redesign midbody crossover bracket | STS-118 | OMM | STS-114 | STS-111 |
| Remove midbody wire tray risers | OMM | OMM<br>J4 | OMM | OMM |
| Crit 1R2 circuit redundancy improvement | Protection plan presented at VECB. SSVEO decided insufficient risk reduction achieved vs cost and did not recommend implementation | | | |
| APU heater crit 1/1 elimination | Presented to VECB. SSVEO approved implementation of protective covers during turnaround | | | |

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| | **Presenter:** |
| | **Organization/Date:** Orbiter/02-14-02 |

# CRITICAL PROCESS CHANGES

# STS-109 CRITICAL PROCESS CHANGE REVIEW SUMMARY

**Presenter:** Doug White

**Organization/Date:** Orbiter/02-14-02

| Item Reviewed | No. of Items Reviewed | Period or Effectivity Covered | No. Found To Be Critical Process Changes |
|---|---|---|---|
| OMRSD Changes (RCNs) | 22 | STS-109 Specific & Non-Flight Specific Changes Approved 10/6/01 – 12/9/01 | 0 |
| OMRSD Waivers & Exceptions | 31 | STS-109 Specific | 0 |
| IDMRD Changes (MCNs) | 8 | Approved 10/6/01 – 12/9/01 | 0 |
| IDMRD Waivers & Exceptions | 5 | Approved 10/6/01 – 12/9/01 | 0 |
| EDCPs | 6 | Closed 10/6/01 – 12/9/01 | 0 |
| Boeing Specifications | 37 | Released 10/6/01 – 12/9/01 | 2 |
| Boeing Drawings | 339 | Released 10/6/01 – 12/9/01 | 0 |
| Material Review | 457 | Approved 10/6/01 – 12/9/01 | 0 |

- All process changes were reviewed and none constrain STS-109

# CRITICAL PROCESS CHANGES

**Presenter:**
Doug White
**Organization/Date:**
Orbiter/02-14-02

## Boeing Specification MB0170-084, 3A1-2.5V Titanium Alloy Tubing

- This specification change replaced NDE penetrant inspection with ultrasonic inspection technique
- Change made for consistency with current industry standards, minimizing material removal and wall thinning

## Boeing Specification ML0601-9024, TPS Reusable Surface Insulation (RSI) Maintenance, Tile Installation (Process 301)

- This specification change incorporates improvements from OV-103 lost tile investigation
- Specifies fabrication of IML/SIP Mylar for 0.090/0.115 SIP tiles and certain 0.160 SIP tiles for additional verification of no SIP-to-filler bar interference
- Incorporates manual deflection test for all 0.090/0.115 SIP tiles

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| | **Presenter:** |
| | **Organization/Date:** Orbiter/02-14-02 |

# CONFIGURATION CHANGES

| CONFIGURATION CHANGES AND CERTIFICATION STATUS | Presenter: Doug White |
|---|---|
| | Organization/Date: Orbiter/02-14-02 |

## 133 Modifications Were Incorporated During The OMM/STS-109 Processing Flow

- Four modifications are flying for the first time
  - MCR 19029 Device Driver LRU Replacement
    - Details presented on following pages
  - MCR 19047 $X_O$576 Bulkhead Coldplate/Coolant Line Removal
  - MCR 19652 Sleep Restraint Upgrades
  - MCR 19653 Window #7 Flight Cover Modification

- Details provided in the backup section

# CONFIGURATION CHANGES AND CERTIFICATION STATUS

Presenter: Doug White

Organization/Date: Orbiter/02-14-02

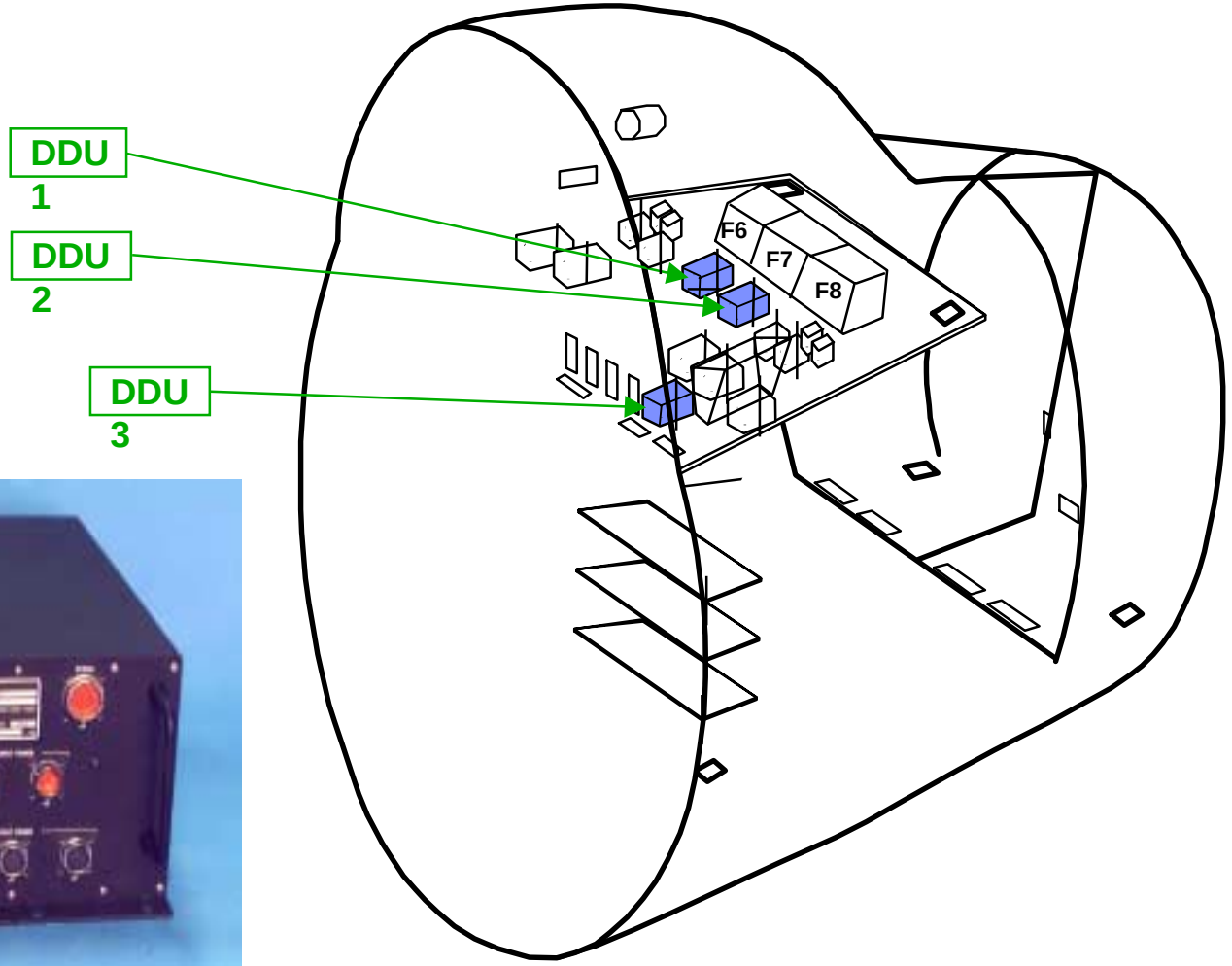
## MCR 19029 Device Driver Unit (DDU)

- New DDU replaces the existing DDUs in conjunction with MEDS
  - Display function removed from existing DDUs with MEDS
  - DDU provides triple redundant power to the orbiter flight controllers
- New DDU improves system safety and provides logistics benefits to the program
  - Solves progressively worsening EEE parts obsolescence problems, high failure rates and high repair turnaround times with old DDUs
- There are three DDU LRUs per Orbiter
  - STS-109 flight configuration - new DDU in CDR, PLT and AFT stations - P/N MC464-0154-001 S/Ns 5, 6 & 7

# CONFIGURATION CHANGES AND CERTIFICATION STATUS

**Presenter:**
Doug White

**Organization/Date:**
Orbiter/02-14-02



# CONFIGURATION CHANGES AND CERTIFICATION STATUS

**Presenter:** Doug White
**Organization/Date:** Orbiter/02-14-02

## Device Driver Unit (DDU) (Cont)

- Key design features and differences between old and new DDU are:
  - Power-on/off stagger timing requirement precludes hand controller transient effects
  - BITE status discretes
    - All BITE discretes “on” for at least 1.1 seconds
    - Added 20 ± 10 millisecond BITE filter timing
  - Reduced part count, solder joints, weight and power
  - Incorporated bolt-on mounting bracket provision into LRU chassis
    - Eliminates intermediate assembly by KSC Ground Ops
  - No active cooling required
- Differences between old and new DDU were evaluated, tested, and pose no performance or safety concerns

# CONFIGURATION CHANGES AND CERTIFICATION STATUS

**Presenter:**
Doug White
**Organization/Date:**
Orbiter/02-14-02

## Device Driver Unit (DDU) (Cont)

- DDUs installed in OV-102 successfully completed ATP at Smiths Aerospace and have been subjected to over 200 hours of burn-in testing at SAIL with no anomalies
  - DDUs were installed in OV-102 in September 2001
- Subsequent system testing requiring use of DDUs has demonstrated successful use in an operational environment
- Orbiter document changes have been completed for STS-109:
  - FMEA/CIL update completed and approved in September 2001
  - OMRSD RCN OV15649 update completed in November 2001
  - Launch Commit Criteria (LCC) change notice LCN 01073R2 has been approved

# SUMMARY OF SIGNIFICANT MODIFICATION AND MAINTENANCE ACTIVITIES

**Presenter:**
Doug White

**Organization/Date:**
Orbiter/02-14-02

- Multifunction Electronic Display System (MEDS)
- Single-string GPS/3-string GPS scar
- PLBD radiator orbital debris protection and panel isolation
- Orbiter structural and avionics scar modifications for installation of external airlock/ODS
- $X_O$576 bulkhead floodlight coldplate and cooling line removal
  - Eliminates criticality 1R2 hazard of freezing/rupture of coldplate and/or cooling lines and subsequent loss of water coolant loop
  - Installed modified TCS insulation to maintain bulkhead structure temperature within OVEI requirements
- Wireless Video System
- UHF space communication scar modifications for SSOR

# SUMMARY OF SIGNIFICANT MODIFICATION AND MAINTENANCE ACTIVITIES

**Presenter:**
Doug White

**Organization/Date:**
Orbiter/02-14-02

- Development Flight Instrumentation (DFI) wiring removal for weight reduction (-686 lbs)
- Orbiter/ET umbilical plate gap delta pressure transducers
  - Associated ground side modifications complete
- 20g floor modification (CDR, PLT and MS3)
- Nose cap and wing leading edge panel (6 per wing) RCC coating refurbishment
- OMS/RCS cross-feed line replacement of 2.5 inch diameter line with 1.5 inch diameter line (OV-103 & subs configuration) and removal of high point bleed lines
  - Eliminates on-orbit thermal constraint and unique ground servicing requirements
- OMS/RCS heater test point connector relocation
- APU system fuel and $GN_2$ servicing QD upgrade

# SUMMARY OF SIGNIFICANT MODIFICATION AND MAINTENANCE ACTIVITIES

**Presenter:** Doug White

**Organization/Date:** Orbiter/02-14-02

- MPS helium check valve replacement/upgrade
- MPS $LH_2$ fill & drain line replacement
  - Replaced limited life line with 100-mission configuration
- MPS fill & drain valve replacement/refurbishment (3 of 4)
- Payload bay door re-rig for additional centerline clearance
- Elevon seal panel (flipper door) weight reduction (-265 lbs)
- Wing modifications
  - Wing glove fastener upgrade to eliminate ascent constraints
  - Spar web doublers to eliminate flight restrictions and allow utilization of additional performance capability
  - Strut tube clam-shell doublers to eliminate negative safety margin

# SUMMARY OF SIGNIFICANT MODIFICATION AND MAINTENANCE ACTIVITIES

**Presenter:** Doug White

**Organization/Date:** Orbiter/02-14-02

- Hydraulic oleophobic filter removal and drain line re-route to reservoirs
- Hydraulic bellows accumulator
- Body flap removal/refurbishment
- Aft avionics bay coldplate replacements
- $X_O$ 582 frame rework
  - Removed corrosion, replaced accessible TCS blankets and applied corrosion prevention compound
  - Condition documented for comparison at next OMM

| SUMMARY OF SIGNIFICANT MODIFICATION AND MAINTENANCE ACTIVITIES | Presenter: Doug White |
|---|---|
| | Organization/Date: Orbiter/02-14-02 |

## Payload Bay Re-painted at KSC

- Unacceptable paint condition noted post-OMM
  - Poor general condition of paint existed prior to OMM, although thermal/optical properties remained technically acceptable
  - Contamination concern from loose paint based on HST payload sensitivity led to decision to re-paint
  - Acceptable out-gassing characteristics of new paint were verified by coupon testing at WSTF
- Following PLBD closure at the pad, small areas near door hinges not visible in the OPF had peeling paint removed by vacuum and tape – no new paint was applied

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| | **Presenter:** |
| | **Organization/Date:** Orbiter/02-14-02 |

# SPECIAL TOPICS

| SPECIAL TOPICS FOR THE STS-109 FLIGHT READINESS REVIEW | Presenter: |
|---|---|
| | Organization/Date: Orbiter/02-14-02 |

| Topic | Presenter |
|---|---|
| WCS Check Valve Failure | D. White |
| STS-108 Post-Landing Drag Chute Damage Observed | D. White |
| Hydraulic Main Pump Mounting Flange Washers | D. White |
| Hydraulic Main Pump Port Cap Bolts | D. White |
| Investigation of Dedicated Signal Conditioner (DSC) Transistor Failures | D. White |

# WCS CHECK VALVE FAILURE

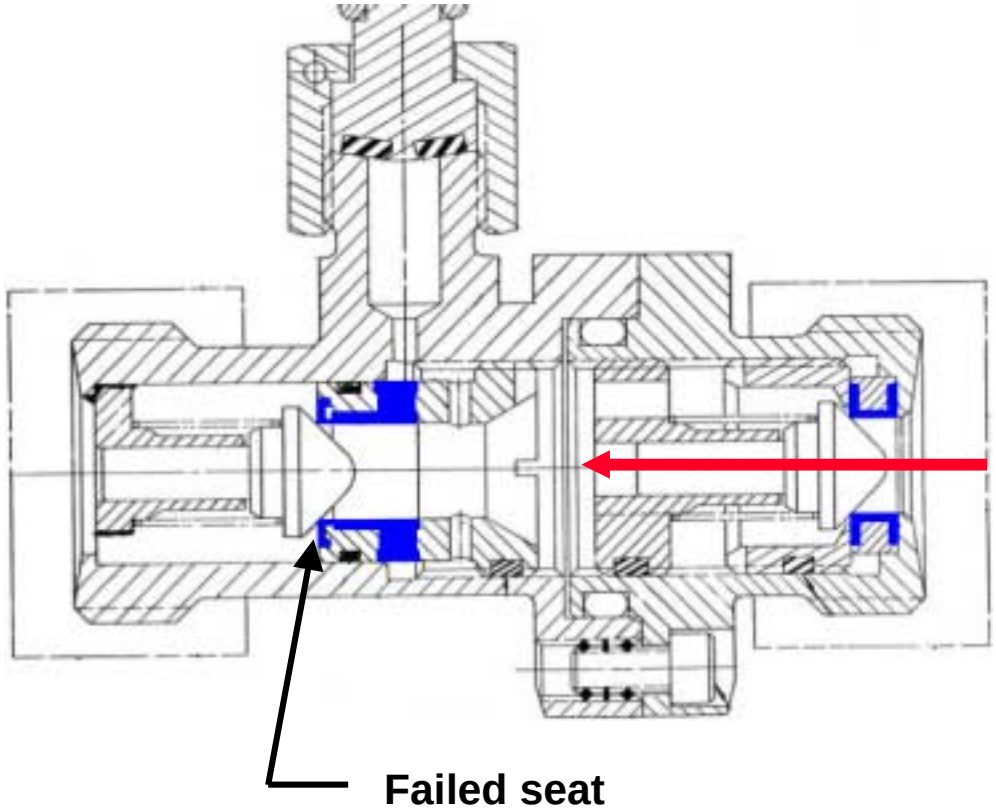
**Presenter:**
Doug White
**Organization/Date:**
Orbiter/02-14-02

- **Observation:**
  - During turn around processing, a WCS fan separator check valve (S/N 021) failed bubble leak check test
    - Flown on STS-98 and STS-105 in primary fan separator
    - Used for entire mission on both flights with no problems
- **Concern:**
  - Failure of both check valves could allow waste water to leak into the crew compartment
- **Discussion:**
  - Check valve was disassembled and inspected
  - Approximately 90% of the seat material was missing, and it is believed to never have been there
  - No evidence of residual material in areas where material is required
  - Material found was smooth; no appearance of cuts, tears, etc.

# WCS CHECK VALVE FAILURE

**Presenter:**
Doug White
**Organization/Date:**
Orbiter/02-14-02

## Check Valve Assembly




## Seat Assembly

# WCS CHECK VALVE FAILURE

**Presenter:**
Doug White
**Organization/Date:**
Orbiter/02-14-02

## Discussion:

- S/N 021 check valve was manufactured in a lot with two other check valves delivered on 2/10/99
  - S/N 022 installed on STS-109 WCS unit - Fan Sep 2
    - First flight of this check valve - passed vendor ATP (crack and reseat, and bubble leak check)
  - S/N 023 installed on STS-110 WCS unit - Fan Sep 1
    - Second flight of this valve - flew previously on STS-100, in primary fan separator
- All three valves assembled by experienced Carleton personnel
  - Root cause of anomaly appears to be inadequate inspection criteria
- Seven of fourteen check valves in inventory have been inspected and are manufactured correctly
  - Remaining valves will be inspected by 2/22/02
- Seven spare seat assemblies are per print

# WCS CHECK VALVE FAILURE

**Presenter:**
Doug White
**Organization/Date:**
Orbiter/02-14-02

## Failure History:

- All previous failures have been leakage due to debris
- No failures where seat was a debris generator
- No failed closed history

## Risk Assessment:

- Low risk
  - Fan separator 1 planned for use the entire mission—check valves not suspect
  - Requires failure of Fan Sep. 1 before Fan Sep. 2 would be used
  - Suspect fan separator 2 check valve is redundant within assembly
    - If failure occurs in downstream valve, then must have second failure in upstream valve to present risk of waste water in the cabin
    - Upstream check valve is an unlike design configuration/assembly, not susceptible to this type of failure
  - No failure scenario for generating FOD (up or downstream)

# WCS CHECK VALVE FAILURE

**Presenter:**
Doug White
**Organization/Date:**
Orbiter/02-14-02

## Risk Assessment:

- Crew procedures exist if fan separator 1 and upstream check valve both fail
  - Leave fan separator running OR
  - Disconnect at floor QD - must reconnect for urine use

## Acceptable for STS-109 Flight:

- Suspect check valve has passed sensitive bubble leak check
  - More sensitive than liquid leak check
- Multiple failures required before impact to mission operations
  - Crew procedures exist to deal with multiple failure effects

# STS-108 POST-LANDING DRAG CHUTE DAMAGE OBSERVED

**Presenter:**
Doug White
**Organization/Date:**
Orbiter/02-14-02

## Observation #1: Drag Chute Ribbon Damage

- STS-108 rollout videos show damage to the drag chute canopy
  - Hole appears shortly after deploy from bag
  - Parachute Refurbishment Facility (PRF) found ribbons 34 through 40 and one vertical tape on gore 31 damaged

## Concern

- Damage/holes in drag chute canopy may produce uneven drag forces during rollout

## Discussion:

- First ever incidence of damage to seven, 300-lb nylon ribbons in one location
  - Typical repair on a refurbished parachute shows one damaged ribbon at one or two locations
- Damaged vertical tape material is 90 lb strength double ply nylon tape

# STS-108 POST-LANDING DRAG CHUTE DAMAGE OBSERVED

**Presenter:**
Doug White

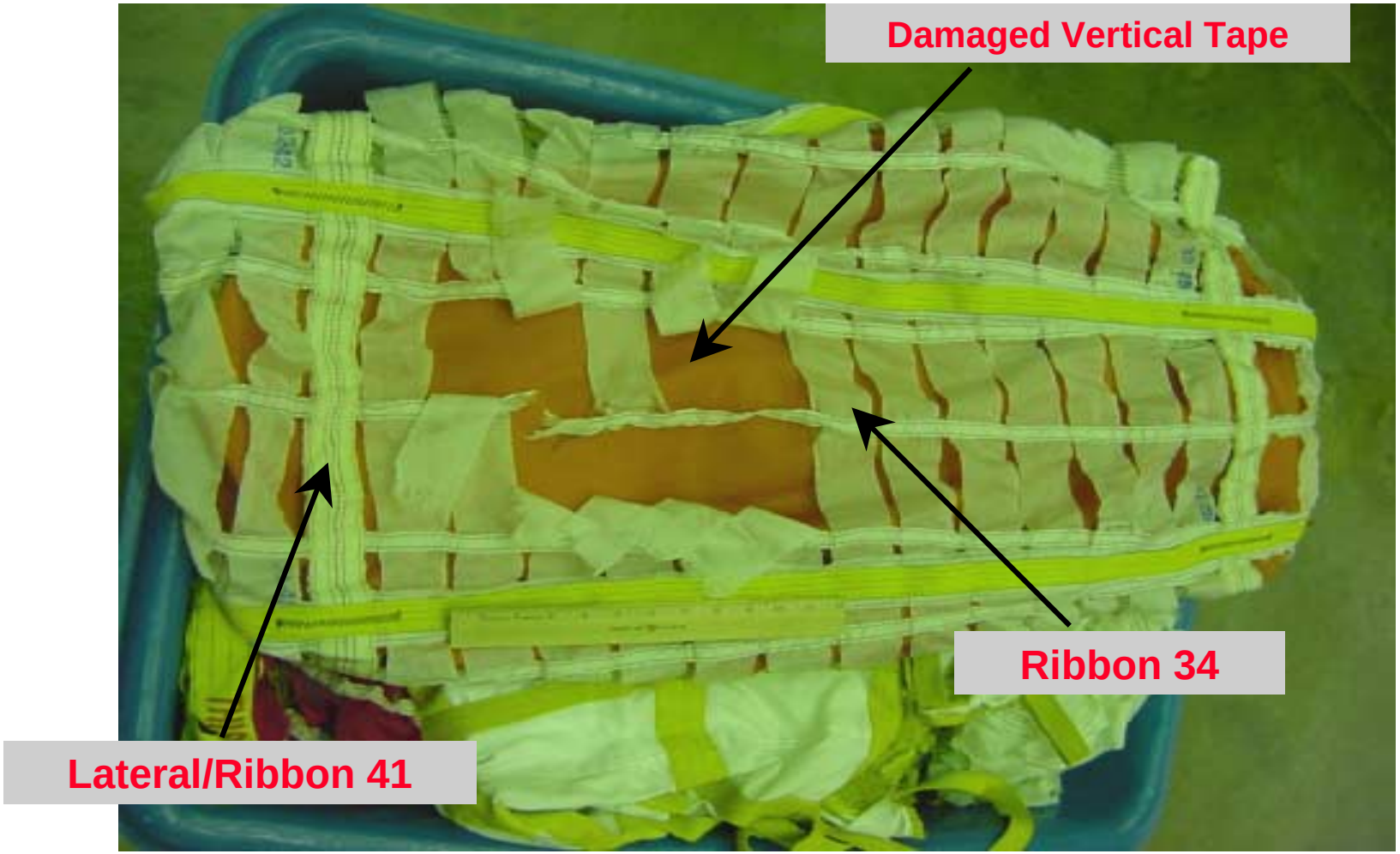
**Organization/Date:**
Orbiter/02-14-02




# STS-108 POST-LANDING DRAG CHUTE DAMAGE OBSERVED

**Presenter:**
Doug White

**Organization/Date:**
Orbiter/02-14-02



# STS-108 POST-LANDING DRAG CHUTE DAMAGE OBSERVED

**Presenter:**
Doug White

**Organization/Date:**
Orbiter/02-14-02

## Discussion:

- 6 lateral bands, also known as “rip stops,” are designed to limit damage to localized areas
- Extensive review of landing rollout video performed by chute experts
  - Vent re-contacts canopy shortly after initial canopy deployment
    - Location of vent re-contact with canopy coincides with hole location
  - No signs of debris, loose objects, or bird strike
  - Drag chute door and sabot deployment show no signs of interfering with chute canopy
  - Past flight videos show dynamic motion of the STS-108 chute was equal to the most severe of 14 other flights reviewed
- NASA JSC M&P confirms majority of damage typical of strain/overload
  - Ribbons show minor friction burning
  - Indicates damage unlikely due to packing process

# STS-108 POST-LANDING DRAG CHUTE DAMAGE OBSERVED

**Presenter:**
Doug White
**Organization/Date:**
Orbiter/02-14-02

## Possible Cause:

- Fault tree developed to identify all possible failure modes
- Most likely cause of damage is vent re-contact with canopy causing vent band/line(s) to damage ribbons

## Risk Assessment and Acceptability for STS-109 Flight:

- Drag parachute system is crit 3/3
- Lateral “rip stop” reinforcements prevent holes from becoming too large
- Very small loss (~0.2%) in drag chute deceleration does not adversely affect drag chute performance
  - No reported problems from pilot which indicate any impact on vehicle control
  - Stopping distance and brake energies nominal

# STS-108 POST-LANDING DRAG CHUTE DAMAGE OBSERVED

**Presenter:**
Doug White
**Organization/Date:**
Orbiter/02-14-02

## Observation #2: Pilot Chute Deployment Bag Damage

- A review of STS-108 drag parachute hardware at PRF identified one of four Kevlar ties that secure the pilot parachute deployment bag to the sabot was loose/untied
  - One of the three remaining deployment bag beckets/loops had completely torn loose from the bag while the two remaining loops have broken stitching
  - Kevlar ties on remaining three beckets/loop attachments to the sabot were intact
  - Remaining knots in loose tie showed evidence of loading prior to/during knot failure

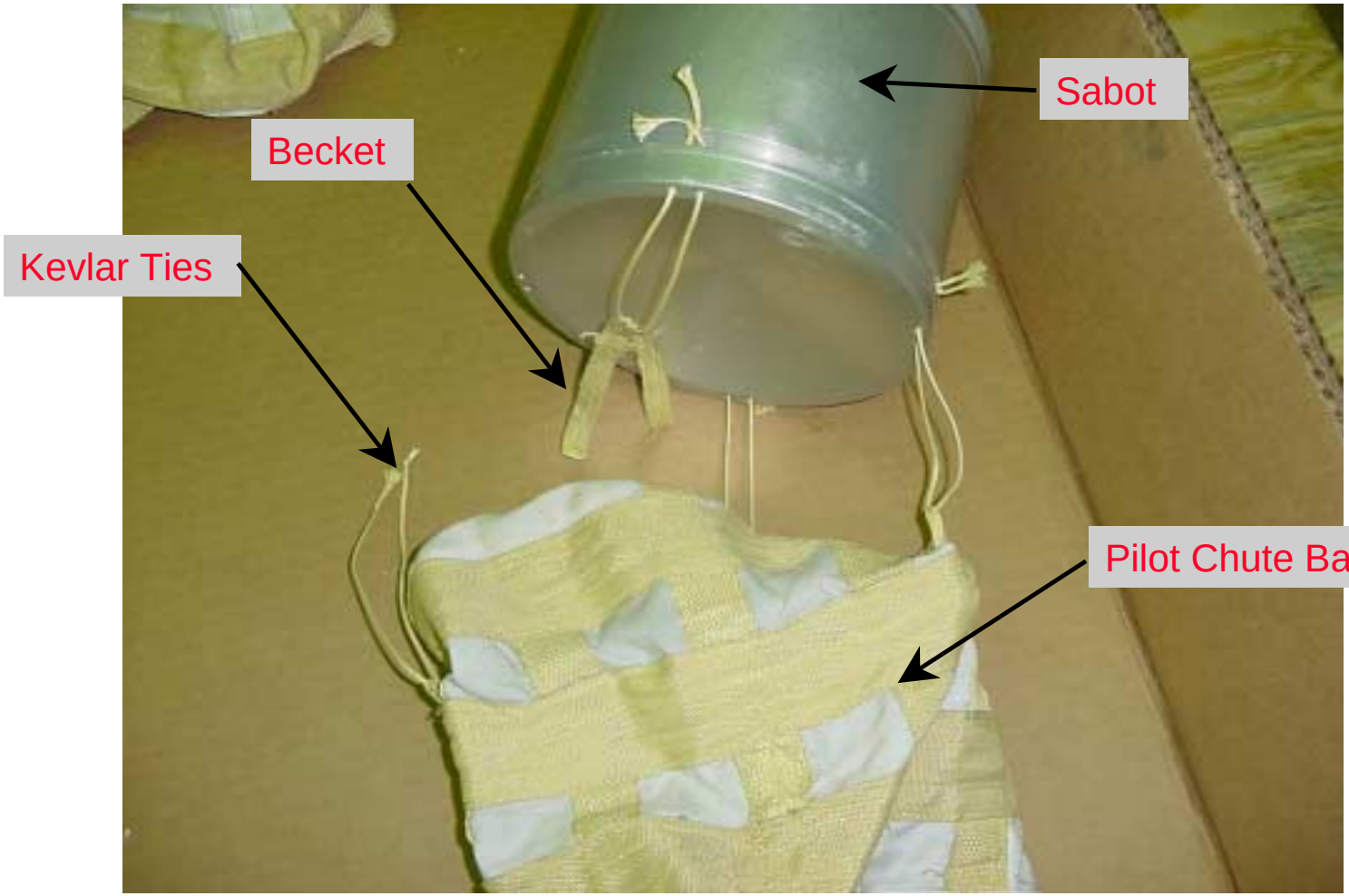
## Concern

- Loose ties holding sabot to deployment bag may result in improper pilot chute bag separation and subsequent failure of main chute to deploy

# STS-108 POST-LANDING DRAG CHUTE DAMAGE OBSERVED

**Presenter:**
Doug White

**Organization/Date:**
Orbiter/02-14-02



# STS-108 POST-LANDING DRAG CHUTE DAMAGE OBSERVED

**Presenter:**
Doug White

**Organization/Date:**
Orbiter/02-14-02

## Discussion:

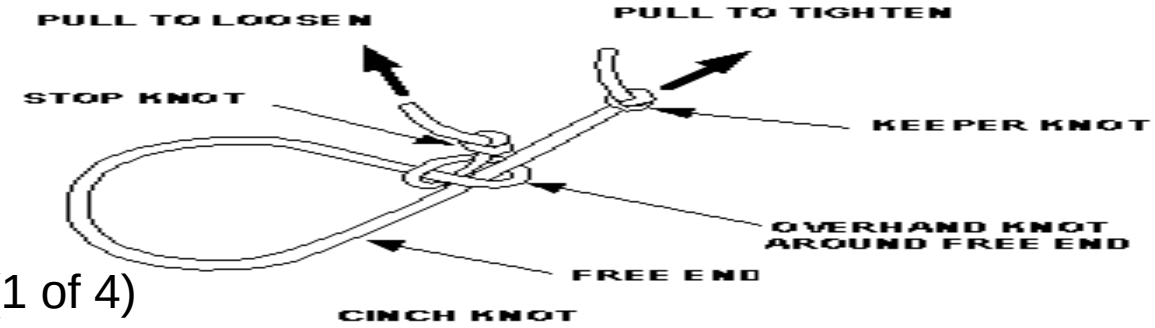
- First time observation of Kevlar ties detached from sabot
  - Kevlar lines are typically found to be intact with occasional signs of minor broken stitching observed on beckets/loops
- Sabot is fired by the mortar cartridge and propels the pilot chute bag out of the mortar tube
- As riser line tension is increased, the sabot aids in pulling the pilot chute bag free via the four Kevlar ties
  - Off-nominal testing has proven that the pilot chute fully deploys even when the sabot completely separates from the pilot chute bag (JSC-26536)
- Sabot attached to pilot pack using combination of cinch knots, stop knots, and keeper knots
- Sabot, pilot chute bag, and riser lines are compressed into mortar tube assembly

# STS-108 POST-LANDING DRAG CHUTE DAMAGE OBSERVED

**Presenter:**
Doug White
**Organization/Date:**
Orbiter/02-14-02

## Possible Causes

- Fault tree developed to identify all possible failure modes
- Most probable cause of the failed line is loss of or a missing stop knot and loosening of the cinch knot allowing the keeper knot to slip through the cinch knot
  - Inspection may have overlooked stop knot since all knots combine into single point
  - Opportunity exists for looseness in knots to occur during insertion or compression of sabot and bag into mortar tube
- First failure of tie likely caused subsequent failure of one becket/loop on deployment bag




Kevlar Tie (1 of 4)

# STS-108 POST-LANDING DRAG CHUTE DAMAGE OBSERVED

**Presenter:**
Doug White

**Organization/Date:**
Orbiter/02-14-02

## Risk Assessment and Acceptability for STS-109 Flight:

- Drag parachute system is crit 3/3
- Loss of attachment redundancy did not affect system operation
  - Remaining Kevlar attachments continued to pull pilot chute bag off of pilot chute
- Off-nominal testing has proven that even when the sabot completely separates from the pilot chute bag, the pilot chute still fully deploys (JSC-26536)

# HYDRAULIC MAIN PUMP MOUNTING FLANGE WASHERS

**Presenter:**
D. White

**Organization/Date:**
Orbiter/02-14-02

## Observation:

- Inspection of removed washers from the OV-102 position 3 hydraulic pump-to-APU mounting studs revealed that they were cupped

## Concern:

- Over time, cupped/bent washers may relax and result in loss of preload

## Discussion:

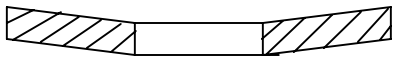
- A design change was made (April 2000) to increase the outside diameter of the washer from .640+/-.010 to .710+.000/-.002 to increase the load distribution area
  - Coining damage to pump mounting flanges had been observed from the smaller diameter washer
  - Larger washers have flown on OV-104 (3 flights) and OV-105 (1 flight)

# HYDRAULIC MAIN PUMP MOUNTING FLANGE WASHERS

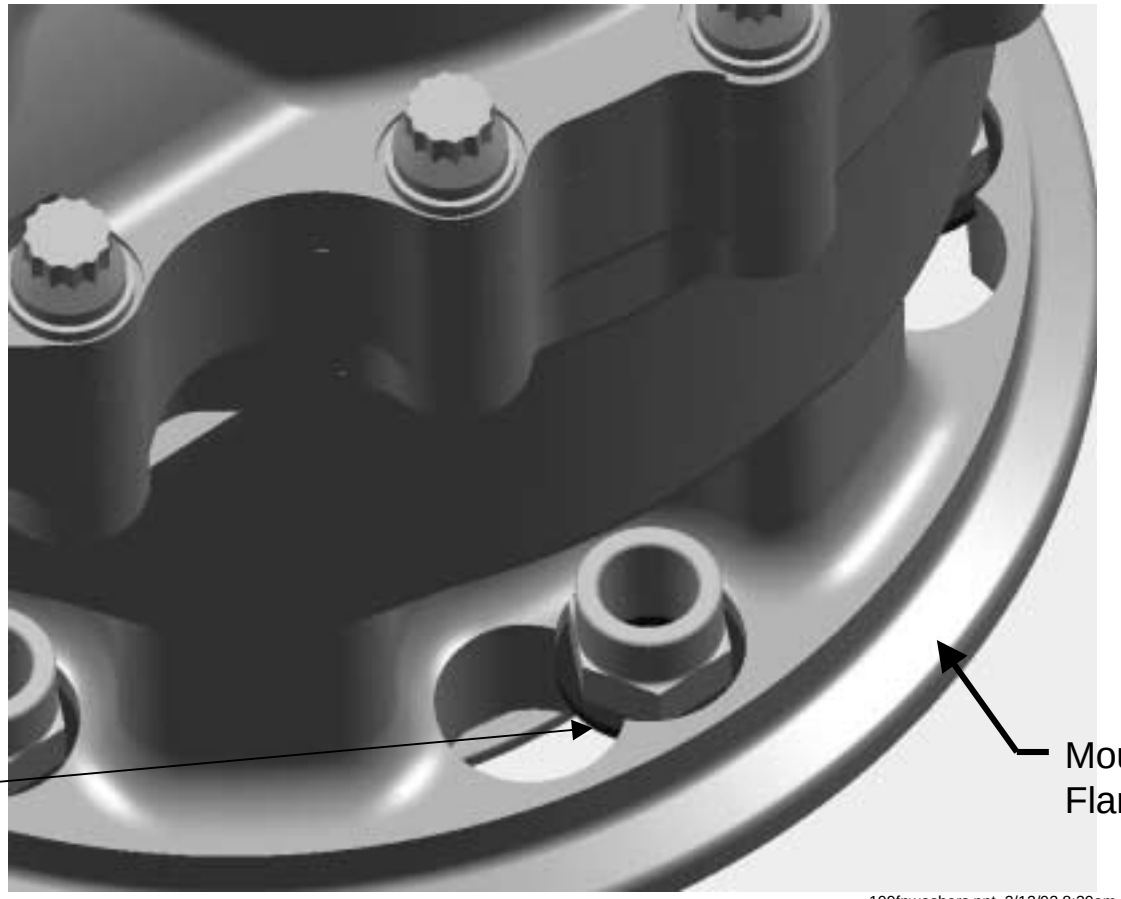
**Presenter:**
D. White

**Organization/Date:**
Orbiter/02-14-02

**Aluminum pump mounting flange is designed with slots to facilitate installation with nuts installed on APU studs**



Cupped washer



# HYDRAULIC MAIN PUMP MOUNTING FLANGE WASHERS

**Presenter:**
D. White

**Organization/Date:**
Orbiter/02-14-02

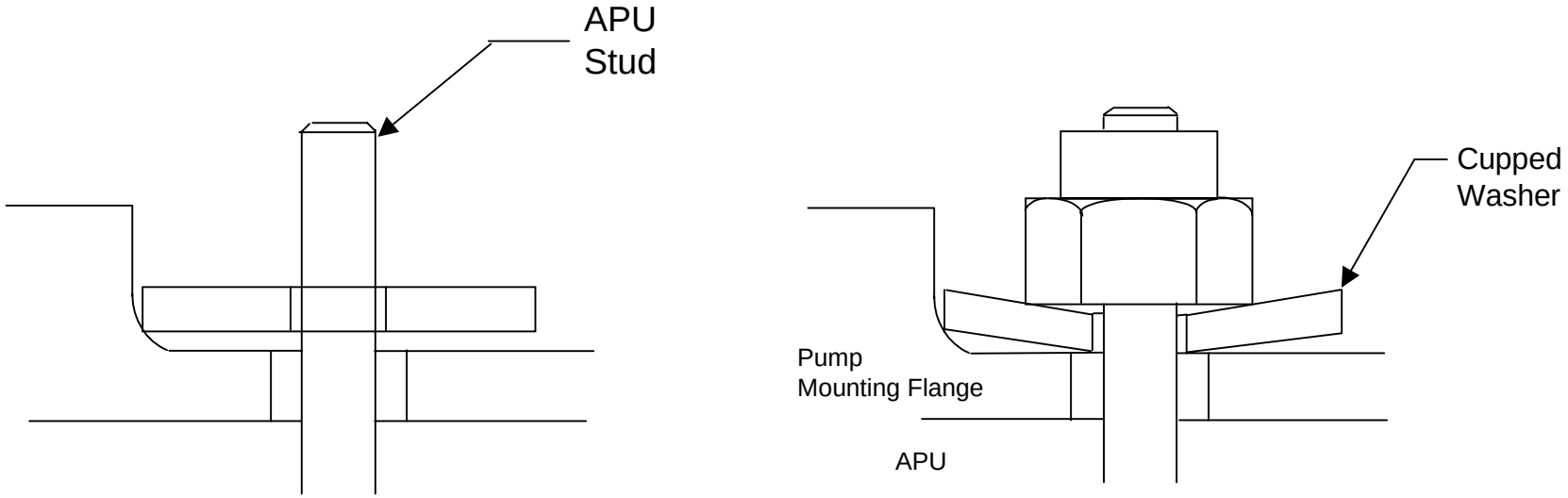
# HYDRAULIC MAIN PUMP MOUNTING FLANGE WASHERS

**Presenter:**
D. White

**Organization/Date:**
Orbiter/02-14-02

## Actions Taken:

- Performed layout analysis of the installation
- Reviewed pump drawings and performed tolerance analysis
  - Determined that under worst case tolerance stack up, the larger diameter washers could interfere with the radius in the spot face
    - Application of torque causes the pump washer to bend
- Performed stress analysis of the installation



# HYDRAULIC MAIN PUMP MOUNTING FLANGE WASHERS

**Presenter:**
D. White

**Organization/Date:**
Orbiter/02-14-02

## Stress Analysis: (cont)

- Preload of current installation is unknown
- Nominal installation procedure results in 8,197 lbs of preload
- With the larger washers, preload on the studs may be reduced due to uneven contact and consequent higher unknown friction
  - Installation with the larger diameter washers results in at least 1,500 lbs of preload (calculated based on loads required to bend washer)
  - Reduced preload can result in higher effect of load cycles and possible reduction of fatigue life of bolt
- Worst case analysis based on 25g flight loads requires 839 lbs of preload
- Current installation is acceptable for one flight
  - Bolt preload is considerably higher than external flight loads (1500/839 = 1.78)

# HYDRAULIC MAIN PUMP MOUNTING FLANGE WASHERS

**Presenter:**
D. White

**Organization/Date:**
Orbiter/02-14-02

## Actions In Work:

- Design and Stress engineering are evaluating a change to a smaller diameter washer with lower installation torque value
  - Smaller diameter washer to preclude interference with pump flange fillet radius may result in recurrence of coining problem
  - Evaluating washer thickness requirement to preclude cupping and provide more predictable friction coefficient
  - Evaluating acceptable reduction of installation torque to preclude or reduce potential coining with modified (smaller) washer

# HYDRAULIC MAIN PUMP MOUNTING FLANGE WASHERS

**Presenter:**
D. White

**Organization/Date:**
Orbiter/02-14-02

## Acceptable For STS-109 Flight:

- Stress analysis indicates sufficient margin of safety with bent washers
  - OV-102 pumps have not experienced flight loads
- No history of failure of the APU/pump joint
- Pump operation is verified pre-launch (APU hot-fire)
- Redundant capability exists
  - Hydraulic system is criticality 1R/2

# HYDRAULIC MAIN PUMP PORT CAP BOLTS

**Presenter:**
D. White
**Organization/Date:**
Orbiter/02-14-02

## Observation:

- Bolts at the port cap / front housing interface on the OV-102 hydraulic pumps are dry film lubricated (DFL); should be passivated
  - Inspection of OV-102 pumps revealed all 6 bolts on all three pumps are DFL

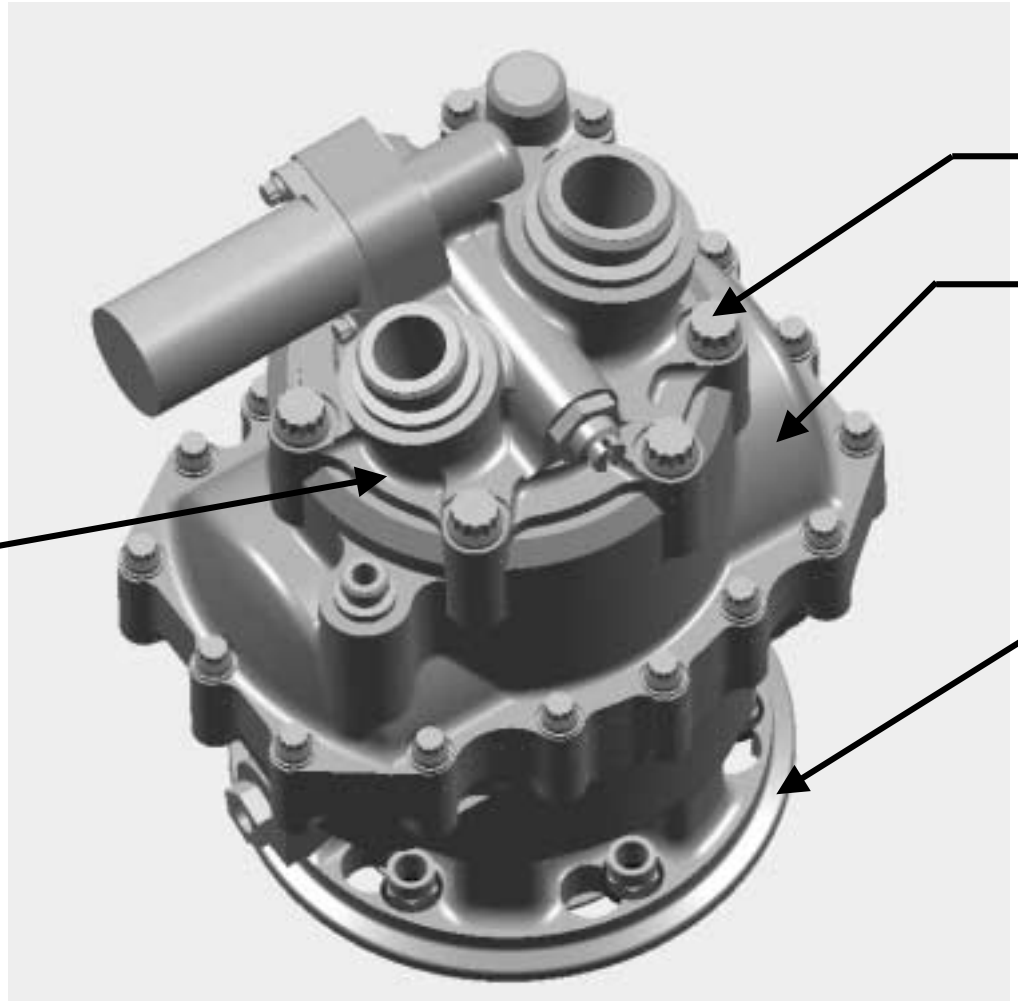
## Concern:

- Possible insert pull-out due to higher preload resulting from lower coefficient of friction for the DFL bolts
  - Potential hydraulic pump port cap separation and hydraulic fluid leak, resulting in loss of hydraulic system (criticality 1R2)

# HYDRAULIC MAIN PUMP PORT CAP BOLTS

**Presenter:**
D. White

**Organization/Date:**
Orbiter/02-14-02



# HYDRAULIC MAIN PUMP PORT CAP BOLTS

**Presenter:**
D. White

**Organization/Date:**
Orbiter/02-14-02

## Discussion:

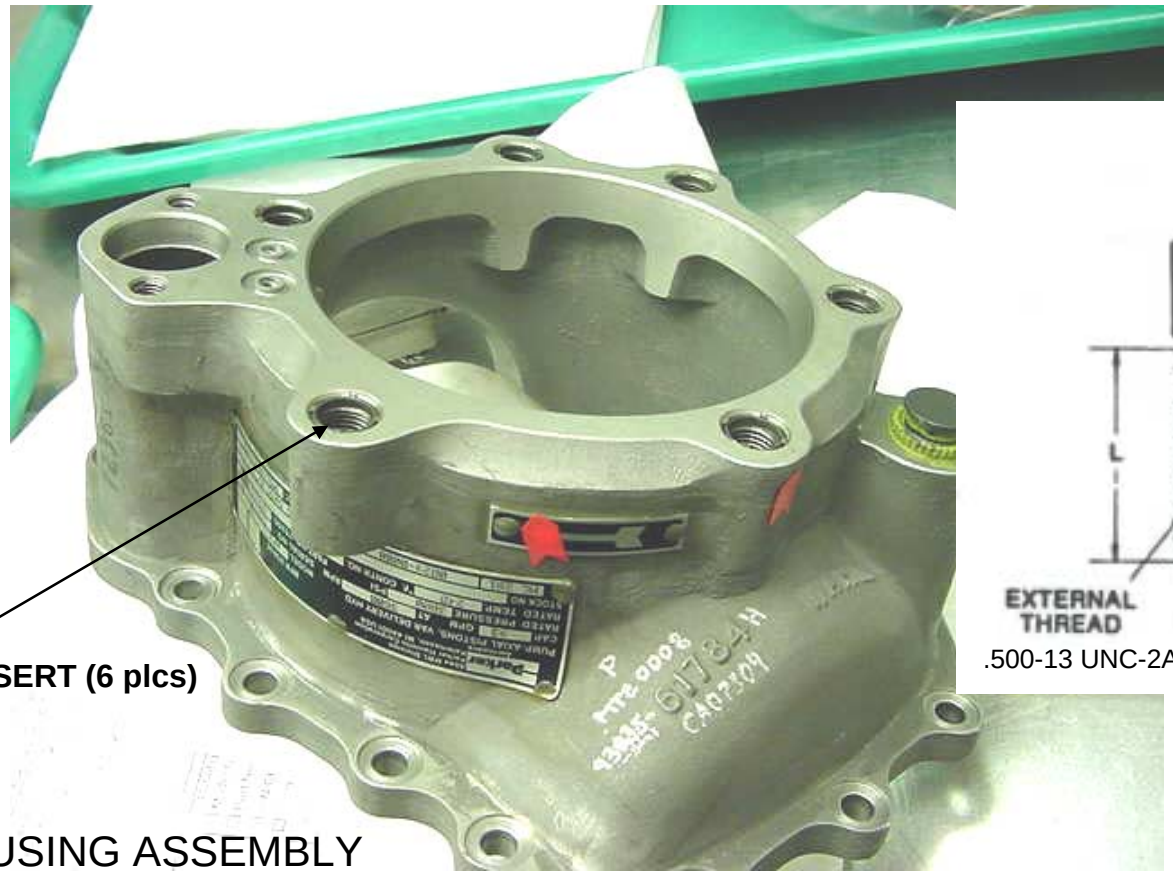
- During drawing review for a port cap/check valve modification, it was noted that the supplier drawing called out DFL bolts (P/N RD111-4009-6606) on the port cap versus passivated bolts (P/N RD111-4009-0606)
  - Pump was certified in 1975 utilizing passivated bolts
  - Supplier made drawing change to DFL bolts approximately 1975 to 1977 without program approval
  - Recent update to the pump procurement specification to identify the bolt part numbers allowed detection of this discrepancy
- Both bolts are A-286
  - Original bolt is passivated per MIL-S-5002
  - DFL bolt is entirely coated with moly-disulfide dry film lubricant

# HYDRAULIC MAIN PUMP PORT CAP BOLTS

**Presenter:**
D. White

**Organization/Date:**
Orbiter/02-14-02

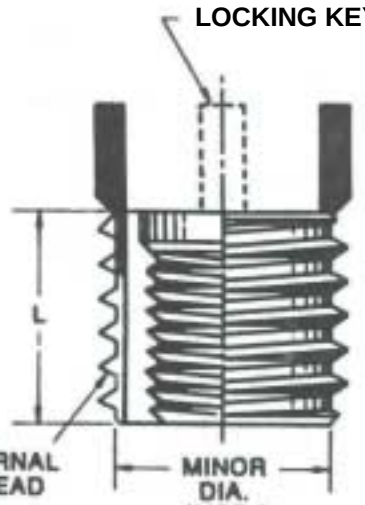
## Port cap / front housing interface utilizes dry film lubricated threaded key locked inserts



KEY LOCKED INSERT (6 plcs)

FRONT HOUSING ASSEMBLY

**INSERT (UNINSTALLED)**




.500-13 UNC-2A

# HYDRAULIC MAIN PUMP PORT CAP BOLTS

**Presenter:**
D. White
**Organization/Date:**
Orbiter/02-14-02

## Discussion: (Cont)

- Inspection at supplier facility and in spares revealed that 6 of 8 pumps have DFL bolts
  - 4 pumps with all DFL bolts
  - 2 pumps with mix of DFL and passivated bolts
- SRB pump uses DFL bolt along with a corrosion inhibiting compound (Braycote-137) at this interface
- Failure history investigation of Orbiter and SRB pumps shows no pump failures due to insert pull-out
  - Potential incident of stripped threads on SRB pump documented in 1999
    - No evidence of external leakage or performance degradation

# HYDRAULIC MAIN PUMP PORT CAP BOLTS

**Presenter:**
D. White
**Organization/Date:**
Orbiter/02-14-02

## Discussion: (Cont)

- Review of main hydraulic pumps installed in OV-102 revealed system #1 pump has 6 inserts that have been replaced
  - Insert replacement results in re-clocking to ensure proper key staking ➔ Reduces shear area and insert ultimate pull-out strength
  - Preliminary analysis indicated a negative margin for a pump with re-clocked inserts

# HYDRAULIC MAIN PUMP PORT CAP BOLTS

**Presenter:**
D. White
**Organization/Date:**
Orbiter/02-14-02

## Discussion: (Cont)

- Developed plan to refine analysis and verify margin
  - Performed tests on pump housing to define contribution of key staking and last half-thread to refine effective shear area
    - Measured housing thread and insert dimensions
    - Actual insert ultimate pull-out strength for re-clocked inserts
    - Performed shear and tensile tests to determine actual housing material properties
  - Test data used to define factor to ratio calculated minimum shear area (based on worst case drawing dimensions)

# HYDRAULIC MAIN PUMP PORT CAP BOLTS

**Presenter:**
D. White
**Organization/Date:**
Orbiter/02-14-02

## Discussion: (Cont)

- Additional actions performed to validate analysis results
  - Performed torque-tension test to determine actual friction factor for A286 DFL bolts in aluminum housing with inserts
    - Test performed using DFL bolts without and with Braycote-137 corrosion inhibitor
      - Lowest friction factor was 0.08
  - Performed data pack review to determine previous flight experience of flight pumps with re-clocked inserts
    - Three pumps on OV-104 and two pumps (system 2 & 3) on OV-105 have also had inserts replaced
      - OV-104 system 3 pump reported to have DFL bolts – flown four times
      - Bolt type on remaining pumps is unknown
  - SRB pumps have flown with re-clocked inserts with no history of leakage

# HYDRAULIC MAIN PUMP PORT CAP BOLTS

Presenter: D. White

Organization/Date: Orbiter/02-14-02

## Discussion: (Cont)

- Additional actions are being performed to validate analysis results
  - Values for shear area and coefficient of friction are being finalized
    - Technical community meeting in Huntington Beach to finalize values

# HYDRAULIC MAIN PUMP PORT CAP BOLTS

**Presenter:**
D. White
**Organization/Date:**
Orbiter/02-14-02

## Risk Assessment:

- ATP includes multiple functional checks of the port cap / front housing interface
  - Outlet port proof pressure test performed at 4500 psi
  - Extensive run time, full hydraulic load transients, high temperature (240 °F), multiple leak checks
  - Normal flight operating conditions: 3050-3150 psi, 210 °F max
- Pump operation is verified pre-launch during APU hot fire
- Worst case effect is loss of associated APU/hydraulic system due to external leakage
  - Hydraulic system is certified for entry with 2 of 3 systems available (criticality 1R2)

# HYDRAULIC MAIN PUMP PORT CAP BOLTS

**Presenter:**
D. White

**Organization/Date:**
Orbiter/02-14-02

## This Issue Is Presently Considered A Constraint To Flight For STS-109:

- Discussion on values for shear area and coefficient of friction is continuing
  - Technical community meeting in Huntington Beach to finalize values

# INVESTIGATION OF DSC TRANSISTOR FAILURES

**Presenter:**
Doug White
**Organization/Date:**
Orbiter/02-14-02

## Observations:

- TT&E of a Dedicated Signal Conditioner (DSC) which had failed during the STS-92 mission (Oct. '00) found two defective Raytheon transistors (P/N JANTXV2N3019, Lot Date Code 7525)

## Concern:

- These transistor failures may be indicative of a problem specific to the 7525 LDC
- Due to their extensive usage throughout the vehicle, these failures could have a significant impact on the fleet if determined to be lot related

## Discussion:

- The DSC CVRD module Q503 transistor failures (detached base and emitter bond wires) are illustrated in Figures 1 through 4

# INVESTIGATION OF DSC TRANSISTOR FAILURES

**Presenter:**
Doug White
**Organization/Date:**
Orbiter/02-14-02

## Discussion: (cont)

Bond Wires Appear to be Attached to Die

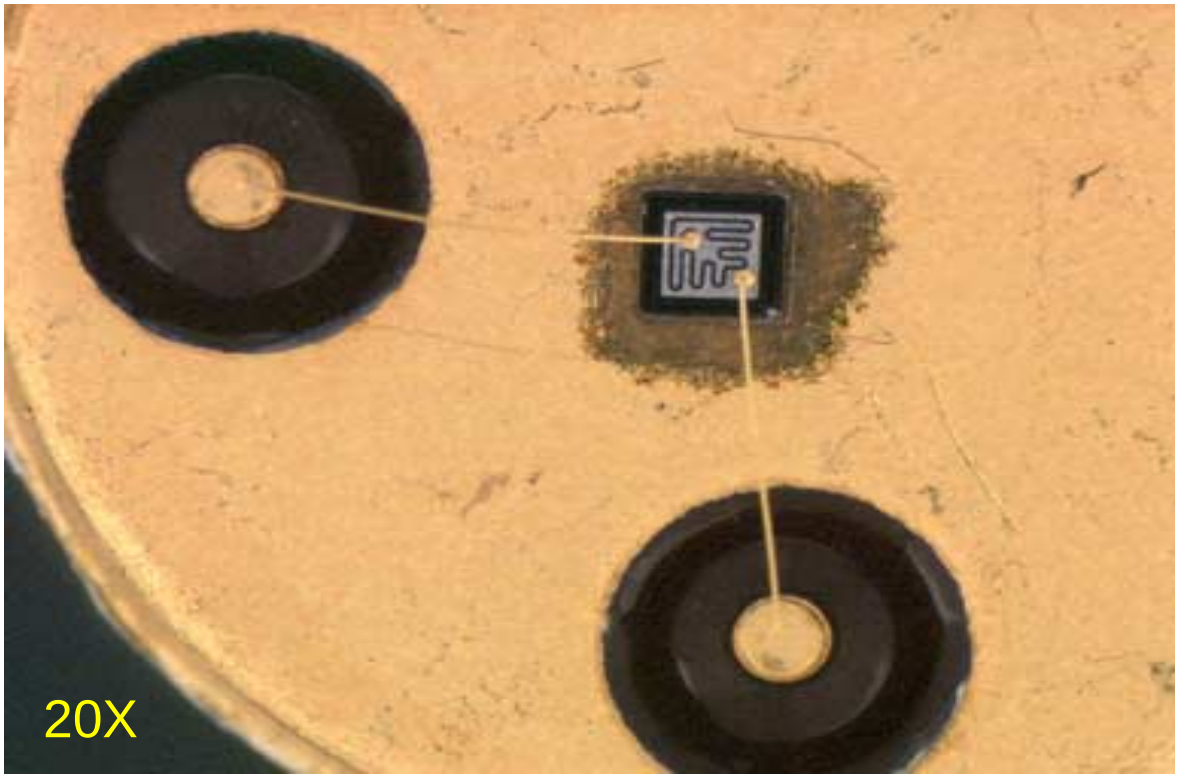



Figure 1

# INVESTIGATION OF DSC TRANSISTOR FAILURES

**Presenter:**
Doug White
**Organization/Date:**
Orbiter/02-14-02

## Discussion: (cont)

**Closer Examination Shows Bond Wires Are Actually Detached**

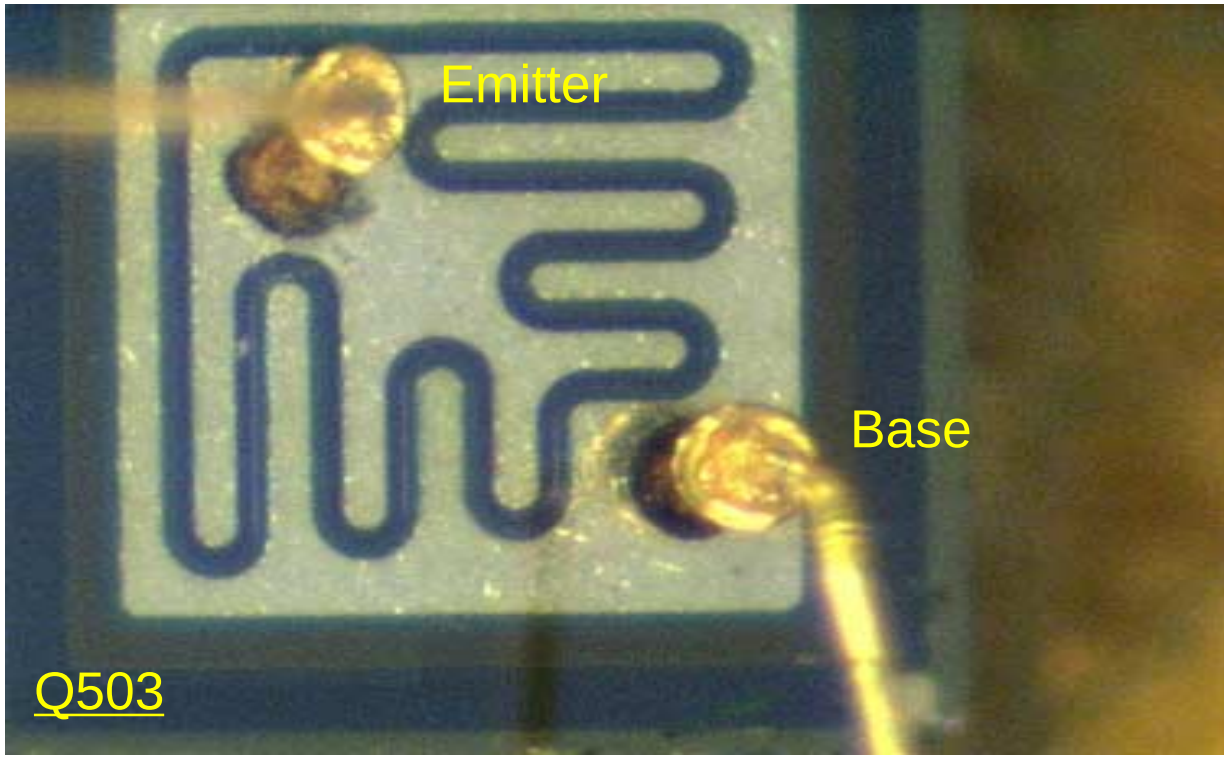



Figure 2

# INVESTIGATION OF DSC TRANSISTOR FAILURES

**Presenter:**
Doug White
**Organization/Date:**
Orbiter/02-14-02

## Discussion: (cont)

SEM of Detached Base and Emitter Bond Wires

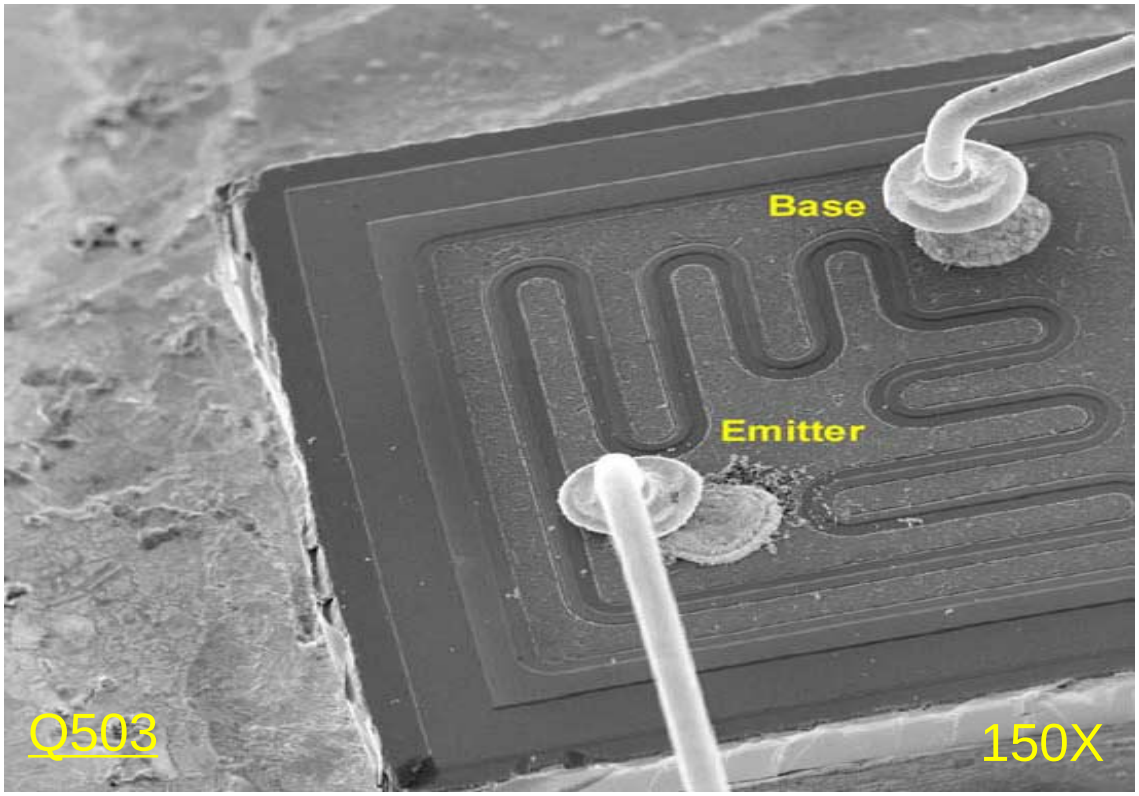



Figure 3

# INVESTIGATION OF DSC TRANSISTOR FAILURES

**Presenter:**
Doug White
**Organization/Date:**
Orbiter/02-14-02

## Discussion: (cont)

SEM Showing Intermetallics In Bond Region

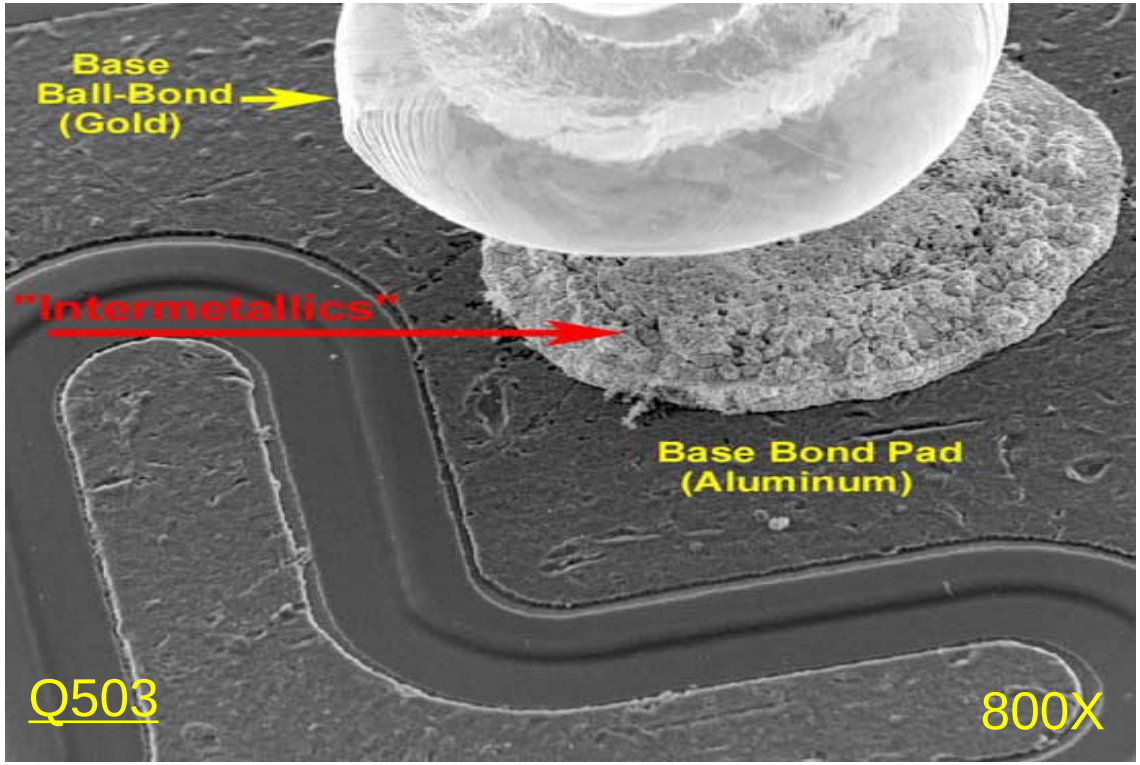



Figure 4

# INVESTIGATION OF DSC TRANSISTOR FAILURES

**Presenter:**
Doug White
**Organization/Date:**
Orbiter/02-14-02

## Discussion: (cont)

- The 2N3019 transistor design employs gold bond wires attached (via thermal compression) to an aluminum die substrate forming a strong intermetallic bond
- Diffusion of aluminum into gold results in the formation of an intermetallic compound which tends to exhibit a purple coloration, at and around the periphery of the aluminum-to-gold interface
  - The presence of this material is not, in and of itself, an indication of an inferior mechanical connection
  - However, if the intermetallic compound progresses to develop Kirkendall voids, the integrity of the mechanical connection may be undermined
    - The potential for void formation is accelerated in the presence of certain contaminants (i.e., chlorine, bromine, fluorine, etc.)

# INVESTIGATION OF DSC TRANSISTOR FAILURES

**Presenter:**
Doug White
**Organization/Date:**
Orbiter/02-14-02

## Actions Taken/In-Work:

- Conducted PRACA history search to identify all 2N3019 transistor failures (refer to Figure 5)
  - Identified 16 CARs documenting 19 transistor failures (various manufacturers)
  - Due to incomplete documentation, only 8 CARs confirmed to involve Raytheon transistors
  - No records contained information regarding destructive failure analysis
    - One record indicated that transistor was de-lidded and photographed, but in most cases transistors were simply R&R'd
- Four recent failures led us to investigate LDC 7525 as a potential lot problem
  - Aerospace Corporation failure database
  - GIDEPs
  - Additional failure analysis at NSLD
  - Destructive testing of randomly selected parts at Hi-Rel

# INVESTIGATION OF DSC TRANSISTOR FAILURES

**Presenter:**
Doug White
**Organization/Date:**
Orbiter/02-14-02

## Actions Taken/In-Work: (cont)

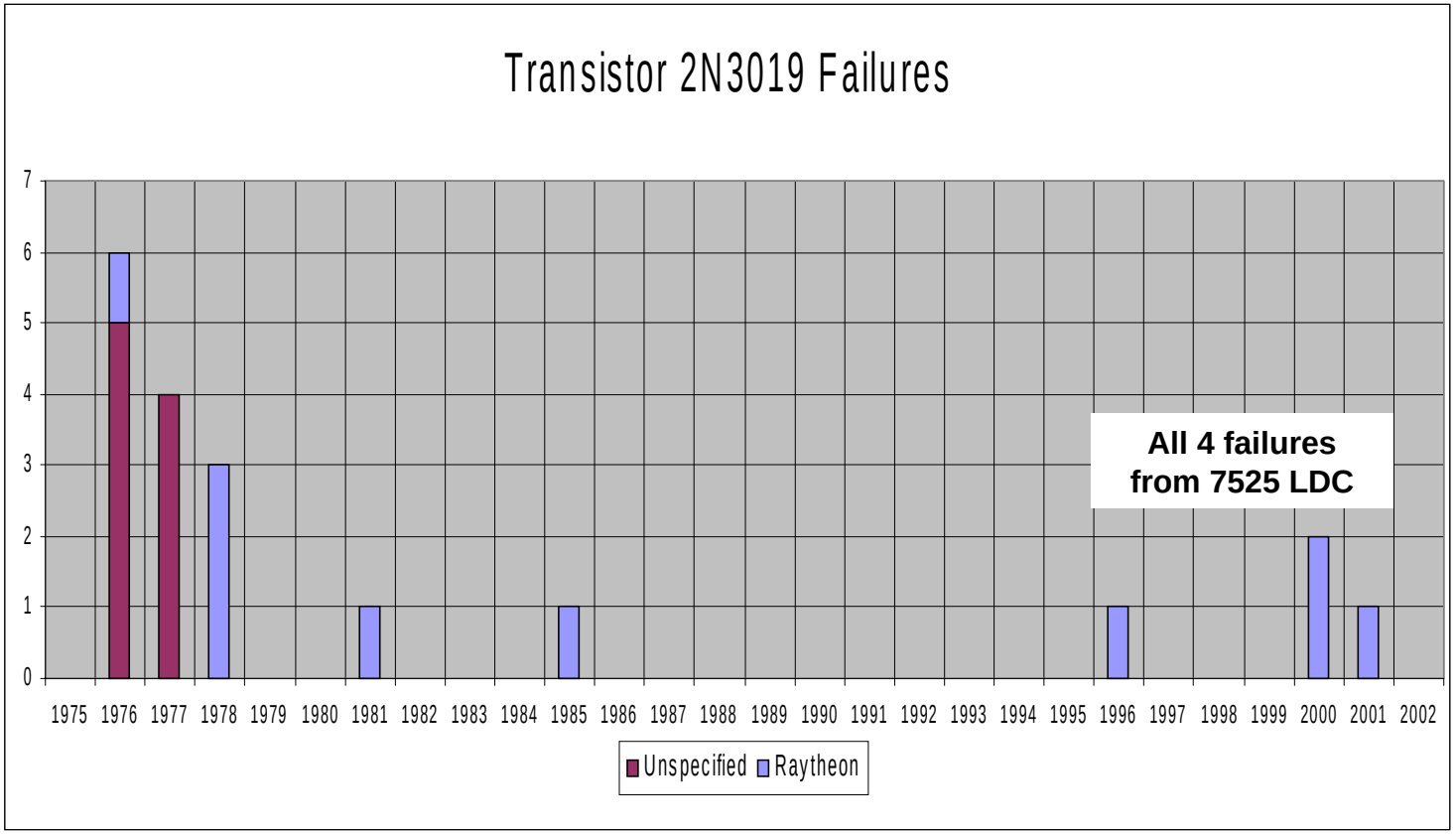



Figure 5

# INVESTIGATION OF DSC TRANSISTOR FAILURES

**Presenter:**
Doug White
**Organization/Date:**
Orbiter/02-14-02

## Actions Taken/In-Work: (cont)

- The Aerospace Corporation parts history database was queried for failure information on 2N3019 transistors and other related parts
  - The resultant data indicate that the semiconductor industry process control was not idealized during the era in question
  - The data showed infrequent occurrences of contamination at the lot level with parts manufactured by Raytheon and Motorola
    - The contamination events seemed to be clustered sporadically in the late 1960s through the mid 1970s, then briefly recurred in the early 1980s
    - No specific part numbers or lot numbers could be identified having more failures than any other group

# INVESTIGATION OF DSC TRANSISTOR FAILURES

**Presenter:**
Doug White
**Organization/Date:**
Orbiter/02-14-02

## Actions Taken/In-Work: (cont)

- GIDEP search of 2N3019 transistors found 5 records
  - One record related to lifted bond wires but problem was attributed to insufficient bonding (i.e., improper melt)
- Expanded GIDEP search to all JANTX(V) transistors identifying one record that dealt specifically with intermetallic growth (refer to Table 1)
  - GIDEP report T9-A-78-02 issued 10/78 in response to failures of transistors utilizing gold ball bonds on aluminum die metallization
    - Failures isolated to lifted lead bonds primarily caused by intermetallic growth
  - Upon further investigation, determined that failed parts were re-screened in accordance with MIL-STD-975 without limiting the maximum junction temperature to 175 deg. C
    - MIL-STD-975 does not take into consideration the fact that bimetallic bonding systems may be subjected to multiple high temperature excursions which are detrimental to bonding integrity

# INVESTIGATION OF DSC TRANSISTOR FAILURES

**Presenter:**
Doug White
**Organization/Date:**
Orbiter/02-14-02

## Actions Taken/In-Work: (cont)

GIDEP Search Summary

| Doc. # | Date | Mfg | Part Number | LDC | Problem Description |
|---|---|---|---|---|---|
| T9-A-78-02 | 10/78 | Various | JANTX(V) | Various | Detailed discussion on prior page |
| R1-A-79-02A | 2/80 | Motorola<br>Raytheon | JANTXV2N3019 | 7848<br>? | Shorter than required external leads |
| EA-F-80-08 | 12/80 | Fairchild | JANTXV2NXXXX | Various | General audit (unspecified findings) |
| BZ-A-80-01D | 3/81 | Fairchild | JANTX | 7701 thru 8032 | Certain transistors may not meet burn-in reqt's per MIL-S-19500 |
| Z4-A-81-01 | 3/81 | Raytheon | JTX2N3019 | 7840<br>7848 | Failed lead bonds due to underbonding (improper melt) |
| R4-A-91-01 | 8/91 | Raytheon | JANTXV2N3019(s) | 8735<br>8748 | Internally shorted due to loose metallic particles |

Table 1

# INVESTIGATION OF DSC TRANSISTOR FAILURES

**Presenter:**
Doug White
**Organization/Date:**
Orbiter/02-14-02

## Actions Taken/In-Work: (cont)

- In an effort to isolate the transistor problem to a particular manufacturer or LDC, NSLD performed additional failure analysis
  - Three of 4 failed parts showed signs of chlorine contamination
  - No human trace elements were found

NSLD Failure Analysis Summary

| Ref. Des. | Mfg. | LDC | Curve Tracer | PIND | Leads Visually Intact | Chlorine | Human Contaminants |
|---|---|---|---|---|---|---|---|
| Q503 | Raytheon | CRP 7525 | Failed | Failed | No-Both | Yes | No |
| Q504 | Raytheon | CRP 7525 | Failed | Passed | No-Emitter | No | No |
| | | | | | | | |
| Q701 | Raytheon | CRP 7525 | Failed | N/A | No-Both | Yes | No |
| | | | | | | | |
| Q503 | Raytheon | CRP 7525 | Failed | N/A | No-Both | Yes | No |
| | | | | | | | |
| Q503 | Raytheon | CRP 7403 | Passed | N/A | Yes-Both | Yes | Yes |
| Q504 | Raytheon | CRP 7403 | Passed | N/A | Yes-Both | Yes | Yes |

Table 2

# INVESTIGATION OF DSC TRANSISTOR FAILURES

**Presenter:**
Doug White
**Organization/Date:**
Orbiter/02-14-02

## Actions Taken/In-Work: (cont)

- To obtain more data, located additional 2N3019 transistors (with various LDCs) were shipped to Hi-Rel Laboratories, Inc. for comprehensive Destructive Physical Analysis (refer to Table 3)
  - Of particular interest are the results of bond wire strength tests (i.e., pull tests) since that is the only conclusive method of determining the integrity of the gold-to-aluminum bonds
  - Hi-Rel results showed that transistors with “abundant” quantities of chlorine contamination failed bond wire strength testing
    - The 7525 LDC transistors showed what appears to be process induced chlorine contamination (i.e., non-human)

# INVESTIGATION OF DSC TRANSISTOR FAILURES

**Presenter:**
Doug White
**Organization/Date:**
Orbiter/02-14-02

## Actions Taken/In-Work: (cont)

### Hi-Rel Labs. Failure Analysis Summary

| Q | LDC | Manufacturer | Transistor | SRU P/N | SRU S/N | N.D. Pull to 4 gm | Chlorine | Human Contaminants | Comments |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | |
| tbd | CRP 7525 | RAYTHEON | JANTXV2N3019 | tbd | tbd | FAILED | ABUNDANT | NO | BASE BALL BOND LIFTED @ 0.2 GM |
| tbd | CRP 7525 | RAYTHEON | JANTXV2N3019 | tbd | tbd | FAILED | ABUNDANT | NO | BASE BALL BOND LIFTED BEFORE PULL TEST |
| tbd | CRP 7525 | RAYTHEON | JANTXV2N3019 | tbd | tbd | PASS | NO | NO | |
| tbd | CRP 7525 | RAYTHEON | JANTXV2N3019 | tbd | tbd | PASS | NO | NO | |
| tbd | CRP 7525 | RAYTHEON | JANTXV2N3019 | tbd | tbd | PASS | NO | NO | |
| tbd | CRP 7525 | RAYTHEON | JANTXV2N3019 | tbd | tbd | PASS | NO | NO | |
| Q503 | CRP 7525 | RAYTHEON | JANTXV2N3019 | MC473-0110-0008 | 165A | PASS | NO | NO | WIRE BROKE AT TOP OF BALL |
| Q504 | CRP 7525 | RAYTHEON | JANTXV2N3019 | MC473-0110-0008 | 165A | PASS | NO | NO | |
| Q504 | CRP 7831 | RAYTHEON | JANTXV2N3019 | MC473-0110-0005 | 53A | FAILED | ABUNDANT | ABUNDANT | EMITTER BALL BOND LIFTED @ 1.3 GM |
| Q503 | CRP 8118 | RAYTHEON | JANTXV2N3019 | MC450-0034-0043 | 148A | PASS | NO | NO | |
| Q504 | CRP 8118 | RAYTHEON | JANTXV2N3019 | MC450-0034-0043 | 148A | PASS | NO | NO | WIRE BROKE AT TOP OF BALL |
| Q503 | CRP 7429 | RAYTHEON | JANTXV2N3019 | MC473-0110-1008 | P6 | PASS | NO | NO | |
| Q503 | CRP 7927 | RAYTHEON | JANTXV2N3019 | MC473-0110-0005 | 53A | PASS | SLIGHT | | WIRE BROKE AT TOP OF BALL |
| Q503 | CRP 7927 | RAYTHEON | JANTXV2N3019 | MC473-0110-0005 | 51A | PASS | SLIGHT | | NO BREAK |
| Q504 | CRP 7927 | RAYTHEON | JANTXV2N3019 | MC473-0110-0005 | 51A | PASS | SLIGHT | | NO BREAK |
| Q503 | CRP 7706 | RAYTHEON | JANTXV2N3019 | MC473-0110-0005 | 69A | PASS | NO | NO | |
| Q504 | CRP 7706 | RAYTHEON | JANTXV2N3019 | MC473-0110-0005 | 69A | PASS | NO | NO | WIRE BROKE @ TOP OF BALL (NICKED WIRE) |
| Q503 | CRP 7612 | RAYTHEON | JANTXV2N3019 | MC473-0110-0005 | 40A | PASS | SLIGHT | SLIGHT | NO BREAK |
| Q504 | CRP 7612 | RAYTHEON | JANTXV2N3019 | MC473-0110-0005 | 40A | PASS | SLIGHT | SLIGHT | NO BREAK |
| Q503 | CCXP 7638A | NATIONAL | JANTXV2N3019 | MC473-0110-0005 | 42A | PASS | NO | NO | NO BREAK |
| Q504 | CCXP 7638A | NATIONAL | JANTXV2N3019 | MC473-0110-0005 | 42A | PASS | NO | NO | NO BREAK |
| Q503 | CCABT7506 | TRANSITRON | JANTXV2N3019 | MC473-0110-0005 | 16A | PASS | MODERATE | MODERATE | AL WIRE ON GOLD POST |
| Q504 | CCABT7506 | TRANSITRON | JANTXV2N3019 | MC473-0110-0005 | 16A | PASS | MODERATE | MODERATE | AL WIRE ON GOLD POST |

Table 3

# INVESTIGATION OF DSC TRANSISTOR FAILURES

**Presenter:**
Doug White
**Organization/Date:**
Orbiter/02-14-02

## Actions Taken/In-Work: (cont)

- Destructive Physical Analysis conducted at both NSLD and Hi-Rel indicates that the Raytheon 2N3019 transistors still deliver excellent performance unless there is evidence of abundant chlorine contamination
  - Contaminants introduced during the manufacturing process tend to accelerate intermetallic growth and may contribute to reduced reliability (as evidenced by bond pull test results)
- Limited data available to date points strongly to process induced chlorine contamination of the Raytheon 2N3019 7525 LDC transistors
- The Orbiter investigating team has notified the other Shuttle elements so they may determine their usage (if any) of the 2N3019 transistor
  - Preparation of GIDEP Advisory is in-work

# INVESTIGATION OF DSC TRANSISTOR FAILURES

**Presenter:**
Doug White
**Organization/Date:**
Orbiter/02-14-02

## Actions Taken/In-Work: (cont)

- Configuration management records indicate that up to 19.4% (191/982) of all 2N3019 transistors installed in OV-102 are from the 7525 LDC

| Description | Number in DSCs | Number in Other H/W | Total |
|---|---|---|---|
| 2N3019 Raytheon transistors with 7525 LDC | 152 | 0 | 152 |
| 2N3019 Raytheon transistors with unknown LDC | 16 | 0 | 16 |
| 2N3019 transistors with unknown manufacturer/LDC | 10 | 13 | 23 |
| Total | 178 | 13 | 191 |
| | | | |
| Total 2N3019 transistors (Raytheon, others & unknowns) in OV-102 | | | 982 |

- Configuration Management is aggressively working to characterize usage of the 2N3019 transistors in the remaining Orbiter vehicles

# INVESTIGATION OF DSC TRANSISTOR FAILURES

**Presenter:**
Doug White
**Organization/Date:**
Orbiter/02-14-02

## Risk Assessment:

- Likelihood of lot related contamination issue increases potential for transistor failure
- In most instances, failure impact is minimized by subsystem redundancy
- SSMs have identified criticality of all circuits and measurements containing 2N3019 LDC 7525 transistors or those with unknown LDCs
- One measurement, MPS GH2 pressurization disc pressure, is crit 1R2
  - Used by flight controllers to decide proper abort scenario in the event of a low ET hydrogen tank ullage pressure
  - Very low probability of a plugged GH2 filter or a hole in the tank make this an acceptable risk

# INVESTIGATION OF DSC TRANSISTOR FAILURES

**Presenter:**
Doug White
**Organization/Date:**
Orbiter/02-14-02

## Risk Assessment: (cont)

- Three (3) measurements are 1 of 1 in the LCC and failure of any one would cause a launch scrub
  - APU 3 gas generator chamber pressure
  - APU 2 and APU 3 turbine speed
- Thirty-three (33) measurements are 1 of 2 in the LCC
  - Failure of any one of these and the redundant measurement would cause a launch scrub

# INVESTIGATION OF DSC TRANSISTOR FAILURES

**Presenter:**
Doug White
**Organization/Date:**
Orbiter/02-14-02

## Usage of 2N3019 LDC 7525 in Other SSVEO/USA Elements

- SSVEO
  - EMU and GFE—none
  - RMS—none
    - Three assemblies contain similar part number transistors from 1977 and 1978
    - Consequences of failures in these transistors have been evaluated and are not a concern
- SRB
  - No suspect parts in crit 1 or 1R circuits
  - Possibly installed in crit 3 circuits of IEAs
    - Manufacturer information not available for all part installations
  - Worst case failure identified as a launch abort

# INVESTIGATION OF DSC TRANSISTOR FAILURES

**Presenter:**
Doug White
**Organization/Date:**
Orbiter/02-14-02

## Usage of 2N3019 LDC 7525 in Other SSVEO/USA Elements

- KSC Ground equipment evaluation performed
  - Launch Processing System (LPS)
  - Ground Support Equipment (GSE)
- Ground equipment configuration traceability is not maintained to the transistor level
  - Not feasible to determine usage to a particular manufacturer/LDC
- No reason to suspect transistor failure based on ground equipment failure history
- Critical ground equipment has system redundancy

# INVESTIGATION OF DSC TRANSISTOR FAILURES

**Presenter:**
Doug White
**Organization/Date:**
Orbiter/02-14-02

## Acceptable for STS-109 Flight:

- Available failure history data do not show an identifiable increasing failure trend for 2N3019 transistors
- Testing does not show a general end-of-life concern for 2N3019 transistors from any manufacturer or lot
- Recent failure history and our small sample of test data do show that LDC 7525 has a higher-than-expected rate of failure due to non-human chlorine contamination
- Most failure impacts limited to loss of measurements
- System redundancy mitigates failure impacts
  - One crit 1R2 measurement has a very low probability of second failure
  - Slightly increased risk of launch scrub

# UNEXPECTED GPC SYNCHRONIZATION FAILURE

**Presenter:**
Patti Thornton

**Organization/Date:**
Flight Software/02-14-02

## Observation:

- An unexpected GPC Fail-to-Sync (FTS) during ascent was observed in the SMS using STS-110 (OI-29) software
  - Occurred following an intentionally induced FTS of another GPC
- Root cause traced to a timing sensitivity in FTS processing resulting in inconsistent input data being used in remaining Redundant Set (RS) GPCs following the first FTS
  - Inconsistent data caused GPCs to take divergent processing paths through new code added on OI-29 resulting in second FTS

## Concern:

- Exposure exists to inconsistent input data without error indication for one pass following a FTS on STS-109 (OI-28)
  - Violates basic design assumption of uniform data across RS
  - Potential exists for inconsistent GPC commanding and additional FTS

# UNEXPECTED GPC SYNCHRONIZATION FAILURE

**Presenter:**
Patti Thornton

**Organization/Date:**
Flight Software/02-14-02

## Discussion:

- One basic function of FTS processing is to cease further communication on data buses commanded by the failing GPC
  - If I/O is in progress on one of those buses at that time, it is possible to sliver the halt of I/O by up to 66 usec such that some GPCs receive 2-4 more words of new data than others
  - When halted, buses do not set error indicators used by software I/O completion processing to inform applications of suspect data

## Actions Taken or in Work:

- DR 110884 submitted to document and track issue
- Set of input data with potential exposure to inconsistency across the RS following a FTS has been identified
  - Detailed analysis is in progress to identify potential downstream effects and required conditions to the extent possible
  - Target completion by 02-18-02

# UNEXPECTED GPC SYNCHRONIZATION FAILURE

**Presenter:**
Patti Thornton

**Organization/Date:**
Flight Software/02-14-02

## Actions Taken or in Work: (cont)

- Software solution identified which would preclude any downstream effects if this situation were to occur
  - Being worked in parallel with code analysis to preserve Program options in the event a fix is deemed necessary for flight

## Exceptions:

- CoFR Exception filed pending successful resolution of STS-109 impacts/risks and disposition of DR 110884 for flight
  - Analysis being tracked by the SASCB
  - Target resolution with Program for flight by 02-20-02
  - Results to be presented at L-2

## Risk Assessment:

- Loss of multiple GPCs can result in reduced command authority and loss of critical system redundancy

# UNEXPECTED GPC SYNCHRONIZATION FAILURE

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Patti Thornton

**Organization/Date:**
Flight Software/02-14-02

## Risk Assessment: (cont)

- Likelihood of encountering this problem appears to be very low requiring all of the following conditions to occur:
  - A failure condition resulting in a FTS
    - 2 in-flight in >12,000 est. hrs of in-flight RS execution using AP-101S GPCs (Moding to STBY excluded)
  - FTS must occur in very specific timing line-up with active I/O
  - Sliver of I/O halt between GPCs must occur and result in inconsistent input data
  - One 40 msec pass of different data must result in sufficient divergent processing between GPCs to cause downstream effects
    - Additional timing conditions and/or error conditions may be required, further decreasing likelihood of occurrence
- Problem scenario has not been recreated on STS-109 (OI-28)

# UNEXPECTED GPC SYNCHRONIZATION FAILURE

**Presenter:**
Patti Thornton
**Organization/Date:**
Flight Software/02-14-02

## Risk Assessment: (cont)

- No known occurrences of secondary FTS due to problem scenario in history of program prior to OI-29
  - Inducing FTS's for training and testing purposes is long standing practice
- Final risk assessment pending further analysis of potential effects and required conditions on STS-109 (OI-28)
  - Target resolution with Program for flight by 02-20-02
  - Results to be presented at L-2

| | |
|---|---|
| | **Presenter:** |
| | **Organization/Date:** Orbiter/02-14-02 |

# FLIGHT READINESS STATEMENT

SPACE SHUTTLE VEHICLE ENGINEERING OFFICE

**STS-109 (OV-102)** ☐ **ORR** ☒ **FRR** ☐ **Prelaunch MMT**

Pending completion of scheduled open work, the Orbiter vehicle, support hardware, flight crew equipment, and software are certified and ready to support. For United Space Alliance accountable functions, insight, audit, and surveillance activities have been reviewed, and there are no constraints to flight.

ORBITER / FLIGHT SOFTWARE / FLIGHT CREW EQUIPMENT

P. E. Shack, Manager, Shuttle Engineering Office

F. A. Oullette, Manager, Flight Crew Equipment Management Office

D. E. Stamper, TMR, Software

P.A. Petete, Acting TMR, Orbiter and Flight Crew Equipment

REMOTE MANIPULATOR SYSTEM

S. Higson, Program Director, SRMS
McDonald Dettwiler and
Advanced Robotics Limited

R. Allison, RMS Project Manager

SPACE VISION SYSTEM

N/A

L. Beach, Program Manager, SVS
NEPTEC

N/A

D.S. Moyer, SVS Integration Office

FERRY FLIGHT PLANNING

D. L. McCormack, Ferry Flight Manager 2/1/02

Ralph R. Roe, Manager
Space Shuttle Vehicle Engineering

ORB-RRS 2

# USA SSVEO Functions

## STS-109 (OV-102) FLIGHT READINESS STATEMENT

☐ ORR ☒ FRR ☐ Prelaunch MMT

**PENDING COMPLETION OF SCHEDULED OPEN WORK, THE ORBITER VEHICLE, SUPPORT HARDWARE, FLIGHT CREW EQUIPMENT, AND SOFTWARE ARE CERTIFIED AND READY TO SUPPORT.**

**ORBITER / FLIGHT SOFTWARE**

B. I. Bejmuk, Program Director, Orbiter
Human Space Flight and Exploration
The Boeing Company

J. Wilder, Associate Program Manager
Orbiter Element
United Space Alliance

T. F. Peterson, Associate Program Manager
Flight Software Element
United Space Alliance

**FLIGHT CREW EQUIPMENT**

E. L. Young, FCE/EVA Associate Program Manager
United Space Alliance

ORB-RRS 3