VEHICLE ENGINEERING

	Presenter:
	Organization/Date: Orbiter/09-17-02

ORBITER	To Be Presented
GFE	No Constraint
SOFTWARE	No Constraint
FCE	No Constraint
FLIGHT READINESS STATEMENT	To Be Presented
BACKUP	

Orbiter and Flight Software
Boeing Relocation Status

MV/Ralph R. Roe, Jr.

Boeing Orbiter and FSW Relocation Status

	Total	Captured (Existing/Moving)	Replacements Required	Replacements Filled	Incumbents Lost (Boeing/HSF&E)
SSM's	61	12/3	46	45	6/27
OVE Mgmt	13	0/4	9	6	0/4
Orbiter Critical Skills	89	27/9	53	43	5/17
FSW Critical Skills	97	8/13	76	58	5/27
Total	**260**	**47/29**	**184**	**152**	**16/75**

Orbiter STS-112 CoFR

- **Orbiter Critical Skills Transition Process has been assessed for impacts to the near term COFR process**

STS-112	STS-113	STS-107	STS-114

Green: Certified (SSMs)/Qualified (Critical Skills) personnel pr oducing flight products

Yellow: Replacement personnel generating flight products with ap proved work around plan in place

Red: Critical skills unavailable

- **STS-112 is yellow because interim/acting SSM's are delivering flight products in the following subsystems:**
  - EPD&C (H/W), Mass Properties, GN&C Ascent Analysis , KU-Band, EPD&C (Sys), Payload Accomodations, MEC/EMEC/BFC/GCIL, Hydraulics/WSB, Comm & Track (Antennas, Coax), Comm & Track (Audio Sys.), G&N - Star Tracker, Data Processing Sys. (MCDS), Panels & Components, DPS (MDM), DPS (EIU), DPS (MMU), Crew Module, Crew Transfer Structural Subsystems, TCS Hardware, Thermal Analysis, MEDS, Istrumentation (Sensors, Signal Conditioners, …), Mechanisms/Latches/MPM, Data Recorders, New MMU, Navaids,
- **USA oversight in each of these areas has been defined**
- **NASA oversight in each of these areas has been defined**
- **STS-113 and STS-107 are yellow based on training and certification plans and schedules for replacement SSMs.**

Flight Software STS-112 CoFR

- **Flight Software Critical Skills Transition process has been assessed for impacts to the near term COFR process**

STS-112	STS-113	STS-107	STS-114

Green: Qualified personnel producing flight products

Yellow: Replacement personnel generating flight products with approved work around plan in place (if required)

Red: Critical skills unavailable

- **With expected hiring, training and qualification schedules, flights through STS-114 are anticipated to use at least some interim / replacement personnel to produce flight products**
  - **Plan developed to track interim PFO / ILO selections**
  - **Replacement process for final PFO / ILOs has also been defined**
    - **SASCB approval is required for replacement owners**

ORBITER

AGENDA

Presenter:
Doug White
Organization/Date:
Orbiter/09-17-02

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

Special Topics

To Be Presented

- IMU Slip-Ring Failures
- OV-104 MPS LH2 Feedline Flowliner Cracks
- Negative Margin for MPM Liftoff Loads

	Presenter:
	Organization/Date: Orbiter/09-17-02

PREVIOUS FLIGHT ANOMALIES

Presenter:

Organization/Date:
Orbiter/09-17-02

STS-110
IN-FLIGHT ANOMALIES

PREVIOUS IN-FLIGHT ANOMALIES

Presenter:
Doug White

Organization/Date:
Orbiter/09-17-02

STS-110 In-Flight Anomalies, Previous OV-104 Shuttle Mission:

- Four Orbiter in-flight anomalies identified:
  - STS-110-V-04: MEDS IDP2 MSU BITE & FCW Buffer Overflow Error
    - SW change has been incorporated in IDP SW VI 3.01
- **RCS Thrusters**
  - STS-110-V-01: Primary RCS Thruster L1A Failed Off
  - STS-110-V-02: Primary RCS Thruster F1D Low Pc
  - STS-110-V-03: Primary RCS Thruster F3L Low Pc
    - Failed thrusters and other thrusters on the same manifold have been replaced
    - Low Pc Thruster is not a safety of flight concern
    - Existing flight rules contain the required actions

All anomalies and funnies have been reviewed and none constrain STS-112 flight

	Presenter:
	Organization/Date: Orbiter/09-17-02

STS-111
IN-FLIGHT ANOMALIES

PREVIOUS IN-FLIGHT ANOMALIES

Presenter:
Doug White

Organization/Date:
Orbiter/09-17-02

STS-111 In-Flight Anomalies, Previous Shuttle Mission:

- Three Orbiter in-flight anomalies identified:
  - STS-111-V-01: Left OME GN2 Regulator Leakage
  - STS-111-V-02: FES Failure on Primary B Controller
  - STS-111-V-03: Port Aft PLBD Ready-To-Latch Indication Failed On

  - Details presented on following pages

All anomalies and funnies have been reviewed and none constrain STS-112 flight

STS-111-V-01: OMS ENGINE GN2 REGULATOR LEAKAGE

Presenter:
Doug White

Organization/Date:
Orbiter/09-17-02

Observation:

- Left OMS engine GN2 regulator exhibited internal leakage after the prelaunch GN2 activation

Concern:

- Loss of ability to operate OMS engine

Discussion:

- OMS engine GN2 regulator (S/N 109) failed to lockup following activation on first launch attempt (30 May 02)
  - Regulator appeared to have locked up at 349 psia
  - Over 30 seconds, leak rate increased to 32 psi/min
  - Leak observed for ~5 min, at this point the GN2 isolation valve was closed before relief device activation
  - The accumulator was vented and depressurized in an attempt to remove suspected transient contamination
  - Regulator performed nominally for remainder of launch attempt
- Regulator re-exhibited leak during 72-hr scrub turnaround

STS-111-V-01: OMS ENGINE GN2 REGULATOR LEAKAGE

Presenter:
Doug White

Organization/Date:
Orbiter/09-17-02

Actions Taken/In Work:

- Failed regulator was removed and replaced
  - Performed on pad by KSC personnel
- X-ray/CT scan was performed at KSC
  - No anomalies noted
- Reviewed failure history of GN2 regulator
  - 5 instances of internal leakage, all attributed to contamination
- Failed regulator sent to WSTF for TT&E & F/A
  - Preparations for lock-up test in-work
  - TT&E and F/A should be completed by early-October

STS-111-V-01: OMS ENGINE GN2 REGULATOR LEAKAGE

Presenter: Doug White

Organization/Date: Orbiter/09-17-02

Risk Assessment:

- GN2 regulator internal leakage is Crit 1R/3
  - May result in loss of GN2 through relief valve
    - Potential loss of mission objectives for excessive loss
    - Still have at least one start if entire high pressure tank relieves overboard
- Flight rules exist for GN2 regulator internal leakage
  - If leak occurs during ascent, GN2 isolation valve will be closed by moving OMS engine switch from ARM/PRESS to ARM
    - Inhibits engine post-burn purge
      - 10 minute off-time required to avoid risk of off-nominal engine start
    - No purge is Crit 1 for some abort cases – inability to restart engine on abort dumps within required time
      - May result in violation of C.G. and tank landing constraints
    - Lack of purge which may result in off-nominal starts documented in CILs as accepted condition
      - Ascent plume heating minimizes the likelihood of a an off-nominal start
  - On-orbit, GN2 isolation valve is normally closed
    - Minimizes effect of regulator internal leakage

STS-111-V-01: OMS ENGINE GN2 REGULATOR LEAKAGE

Presenter:
Doug White

Organization/Date:
Orbiter/09-17-02

Acceptable for STS-112 Flight:

- OV-104 GN2 regulators had nominal performance during last OMRSD checkout and STS-110
- Flight rules exist for management of leaking regulator
- Relief valve will prevent over-pressurization of downstream components due to internal leakage
  - At least one engine start remains if high pressure GN2 tank vents through the relief valve

STS-111-V-02: FES FAILURE ON PRIMARY B CONTROLLER

Presenter: Doug White
Organization/Date: Orbiter/09-17-02

Observation:

- OV-105 FES failed to come out of standby when operating in the topping mode on the primary B controller at 1:13:22 MET

Concern:

- Loss of one level of FES redundancy

Discussion:

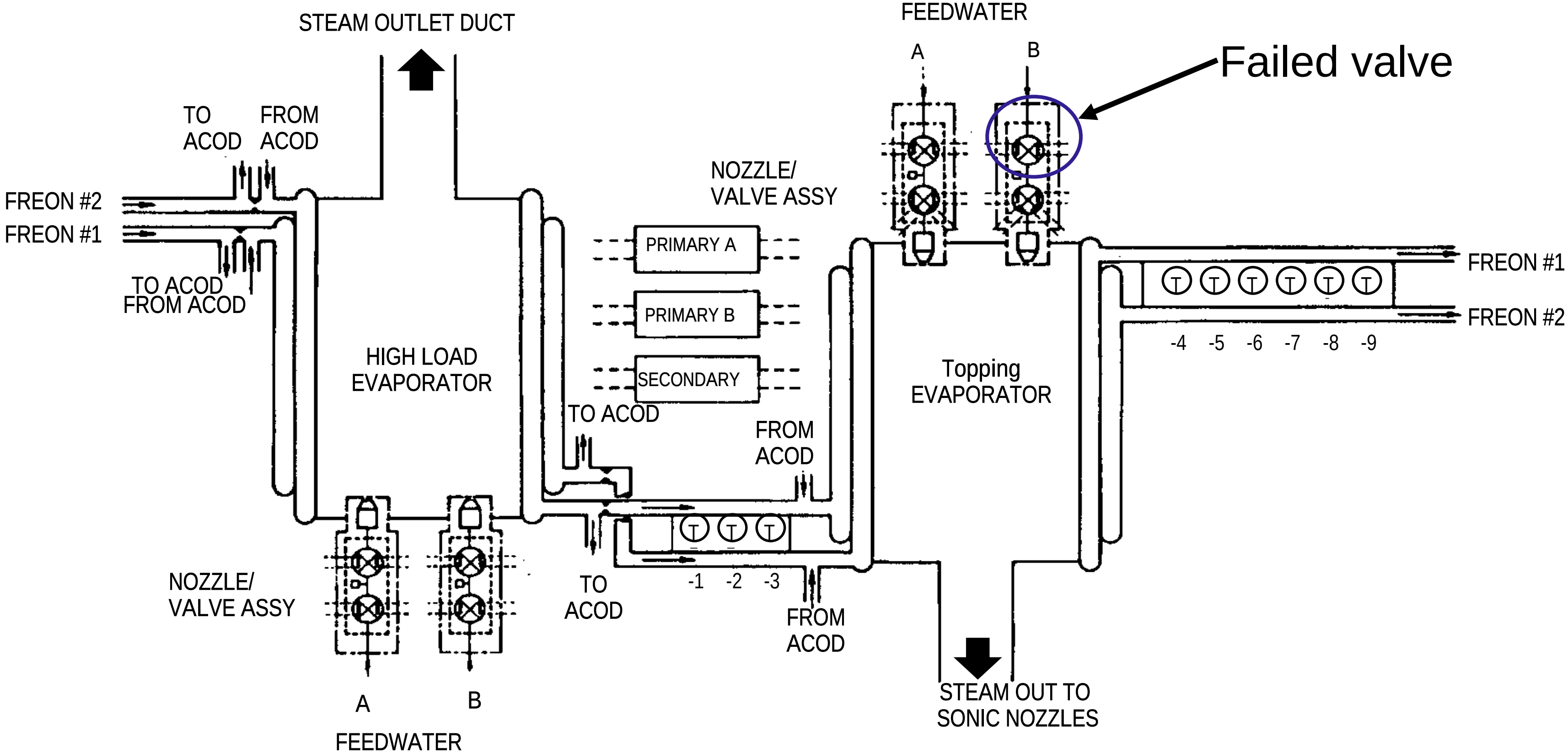
- FES has two cores: high load and topper
- FES high load and topping core required for full up mode during ascent/entry phase -- high heat loads
- FES topper operation supplements cooling performed by radiators on-orbit
- Loss of primary B topping operation equates to loss of full up mode capability for primary B controller

STS-111-V-02: FES FAILURE ON PRIMARY B CONTROLLER

Presenter:
Doug White

Organization/Date:
Orbiter/09-17-02

FLASH EVAPORATOR SUBSYSTEM



STS-111-V-02: FES FAILURE ON PRIMARY B CONTROLLER

Presenter:
Doug White

Organization/Date:
Orbiter/09-17-02

Discussion: cont

- Two attempts to restart the topper in primary B failed
- Core flush using secondary controller was successful, verified that:
  - Feedline B was not obstructed
  - FES B system isolation valve and pulser valve are mechanically sound
  - Primary A and secondary controllers are good

Actions Taken:

- Fault tree was developed and most probable cause was isolated to the primary B control system
- Post-flight troubleshooting showed the FES water system B isolation valve coil to have high resistance
  - Open circuit across the isolation valve
  - Valve was removed and replaced
    - TT&E and FA will be performed

STS-111-V-02: FES FAILURE ON PRIMARY B CONTROLLER

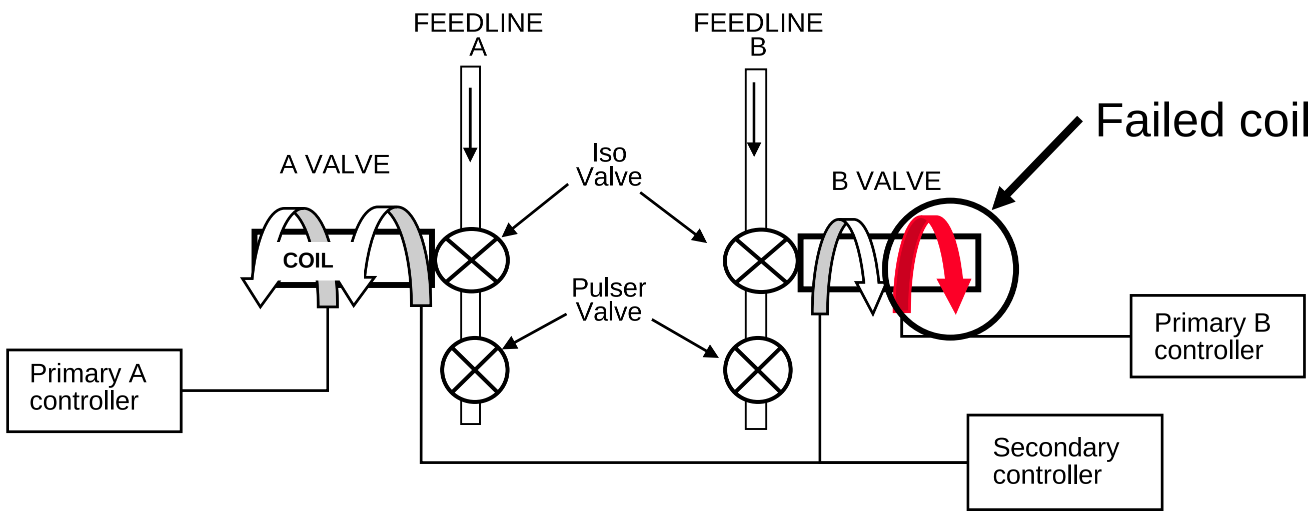
Presenter:
Doug White

Organization/Date:
Orbiter/09-17-02

Action Taken: cont

Controller Valve Coil Redundancy

Controller	High load		Topper	
	System A valves	System B valves	System A valves	System B valves
Primary A	✓		✓	
Primary B		✓		✓
Secondary	✓	✓	✓	✓



STS-111-V-02: FES FAILURE ON PRIMARY B CONTROLLER

Presenter:
Doug White

Organization/Date:
Orbiter/09-17-02

Actions Taken: cont

- Failure history of valves:
  - There have been only two FES valve internal failures, including this STS-111 anomaly, in the shuttle program
    - The other was a high load valve failure during ground testing (~1998)

Risk Assessment

- FES valves/controllers are criticality 1R/3
  - Loss of a topping valve leads to loss of associated controller
  - Primary A and B are redundant
  - Secondary controller provides entry capability at reduced heat loads
    - Contingency procedures are in place and documented in Flight Rules

STS-111-V-02: FES FAILURE ON PRIMARY B CONTROLLER

Presenter: Doug White
Organization/Date: Orbiter/09-17-02

Acceptable for STS-112 Flight:

- Primary controllers/valves are electrically redundant
  - Secondary provides entry capability
- OV-104 satisfied File IX in-flight checkout requirements of STS-110, its previous flight
  - Secondary controller checkout
  - Valve checkout

STS-111-V-03: PAYLOAD BAY DOOR SWITCH MODULE FAILURE DURING DOOR OPENING

Presenter: Doug White

Organization/Date: Orbiter/09-17-02

Observation:

- Three of the payload bay doors (PLBD) ready to latch (RTL) switches on the aft port switch module remained “on” after the port door moved toward the open position following the first and second landing day wave-offs

Concern:

- Switch module RTL indications remaining “on”, requires the PLBD to be closed in manual mode, by the crew, rather than auto mode

STS-111-V-03: PAYLOAD BAY DOOR SWITCH MODULE FAILURE DURING DOOR OPENING

Presenter:
Doug White

Organization/Date:
Orbiter/09-17-02

Discussion:

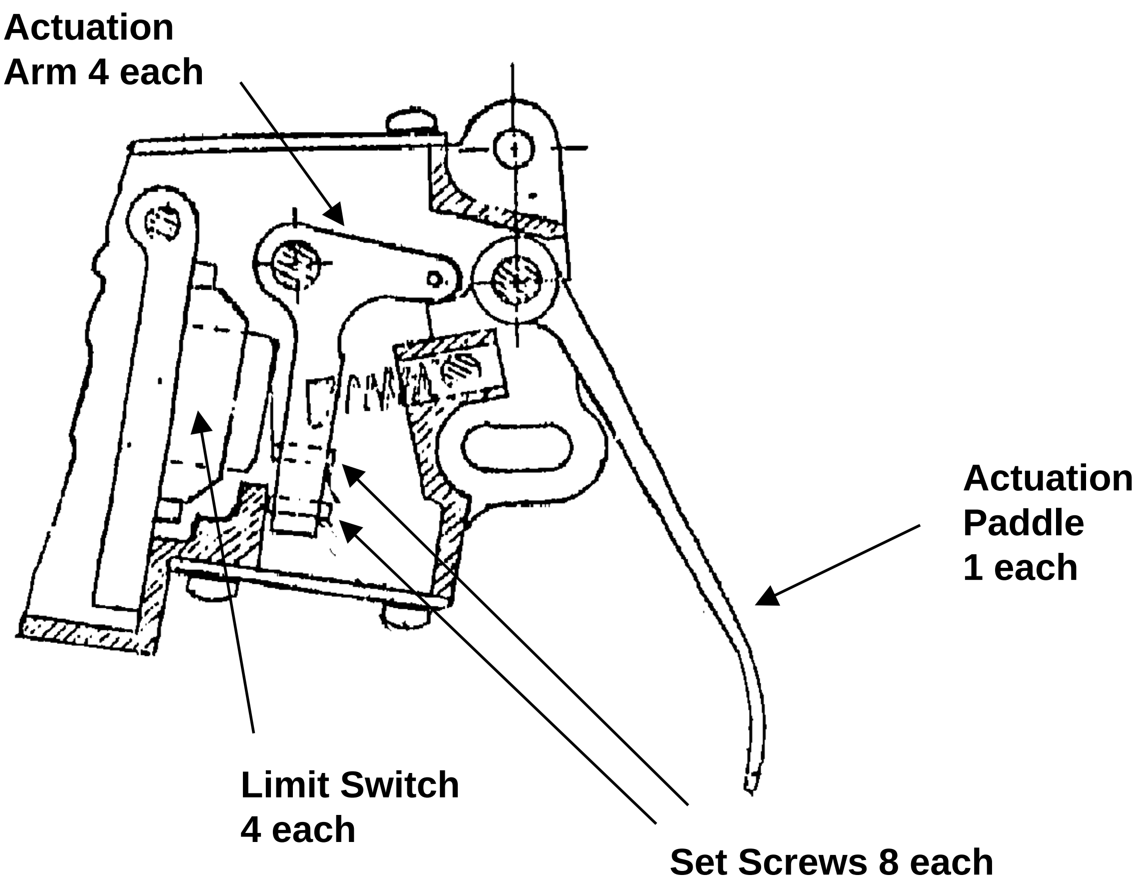
- On first landing wave-off, switches eventually transferred to "off" at approximately 3-1/2 hrs, 6 hours and 9 hours after PLBD opening
- The following day, during the 2nd landing wave-off, the same switches remained "on" in the same port aft switch module
  - Two switches eventually transferred to "off" after approximately 4 hrs, the third transferred after 18 hours
- This anomaly did not affect nominal auto mode PLBD closure for all three cycles during STS-111
- The RTL switches activate the bulkhead actuators, which drive the bulkhead latches to latch the door
  - The switches are actuated by individual "switch levers" that are driven by a single "arm" contacted by the PLBD
  - Two (2) out of three (3) RTL switches in both the forward and aft modules are required before the bulkhead actuators will activate, during auto mode

STS-111-V-03: PAYLOAD BAY DOOR SWITCH MODULE FAILURE DURING DOOR OPENING

Presenter:
Doug White

Organization/Date:
Orbiter/09-17-02

Discussion: cont



PLBD Switch Module Cross Section

STS-111-V-03: PAYLOAD BAY DOOR SWITCH MODULE FAILURE DURING DOOR OPENING	Presenter: Doug White Organization/Date: Orbiter/09-17-02

Actions Taken:

- The switch module was inspected for debris/damage - no visible defects/debris
- A small amount of isopropyl alcohol was used to flush the actuation paddle area to free up any debris - no contamination was found
- The switch module was removed and routed to NSLD for TT&E
- Four previous flight anomalies related to switch module RTL indications remaining “on”
  - All anomalies attributed to either:
    - Thermal conditions affecting the operation of the arm or the individual switch levers
    - Marginal switch rigging
  - Switches re-rigged and returned to the field for unrestricted usage

STS-111-V-03: PAYLOAD BAY DOOR SWITCH MODULE FAILURE DURING DOOR OPENING

Presenter: Doug White

Organization/Date: Orbiter/09-17-02

Risk Assessment:

- Failure mode not documented but failure mode is non-critical
  - Worst case PLBDs would be closed manually
- STS-111 failure was a pre-latch indication, which can be overcome by executing the manual mode door closure procedure

Acceptable for STS-112 Flight:

- All payload bay door switch modules operated correctly on OV-104 STS-110
- Procedure in place to close PLBDs in manual mode for anomalous switch indication
  - On STS-111 if switches had not transferred to “off”, the crew would have closed doors in manual mode
- STS-112 OMRSD testing complete with no anomalies

	Presenter:
	Organization/Date: Orbiter/09-17-02

CRITICAL PROCESS CHANGES

STS-112 CRITICAL PROCESS CHANGE REVIEW SUMMARY

Presenter:
Doug White

Organization/Date:
Orbiter/09-17-02

Item Reviewed	No. of Items Reviewed	Period or Effectivity Covered	No. Found To Be Critical Process Changes
OMRSD Changes (RCNs)	20	STS-112 Specific & Non-Flight Specific Changes Approved 4/9/02 – 8/5/02	1
OMRSD Waivers & Exceptions	3	STS-112 Specific	0
IDMRD Changes (MCNs)	16	Approved 4/9/02 – 8/5/02	3
IDMRD Waivers & Exceptions	4	Approved 4/9/02 – 8/5/02	0
EDCPs	24	Closed 4/9/02 – 8/5/02	1
Boeing Specifications	69	Released 4/9/02 – 8/5/02	0
Boeing Drawings	326	Released 4/9/02 – 8/5/02	0
Material Review	255	Approved 4/9/02 – 8/5/02	5

All process changes were reviewed and none constrain STS-112

CRITICAL PROCESS CHANGES

Presenter:
Doug White
Organization/Date:
Orbiter/09-17-02

OMRSD RCNs

V30 Mid Fuselage & Wing Leading Edge Phase 1 RCM

- This RCN is the initial release of the interval extension review and implements the recommendations of the review for the Mid Fuselage and Wing Leading Edge conducted using the Reliability Centered Maintenance (RCM) process
  - A majority of the V30 structural inspection requirements were extended to an interval of 12 flights. The primary structure requirements were extended with new requirement established for sampling to be performed between flights 4 & 8. NDE inspection of low-life parts will be performed at the specified interval defined

CRITICAL PROCESS CHANGES

Presenter: Doug White
Organization/Date: Orbiter/09-17-02

IDMRD MCNs:

Cleaning of RCS Quad Check valves with HFE 7100 (MCN 3042)

- Implements HFE 7100 as a Freon 113 replacement for precision cleaning and general solvent use during OMS/RCS Quad Check valve repairs
- PCIN S164007B (4/10/02) approved HFE 7100 as a Freon substitute for OMS/RCS system components
  - Material & propellant compatibility determined to be similar to Freon 113
  - No change to cleaning/verification flow rates (similar Freon/HFE densities)
- Implementation of HFE 7100 as a replacement for Freon 113 is a ongoing process
  - 252 documents have been changed to date

CRITICAL PROCESS CHANGES

Presenter: Doug White

Organization/Date: Orbiter/09-17-02

IDMRD MCNs - cont:
Water Storage Tanks Potable & Waste (OM3052)

- There is no OEM fastener installation specification used and/or referenced on the water tank drawings
  - The MA0101-301 processing specification will be added to provide requirements for "how to install" threaded fasteners
  - The applied torque on the fasteners will be per OEM drawing requirements
  - The MA0101-301 processing specification is used on all Orbiter hardware and is commonly used in IDMRDs when OEM doesn't have a controlled specification/document callout

CRITICAL PROCESS CHANGES

Presenter:
Doug White
Organization/Date:
Orbiter/09-17-02

IDMRD MCNs - cont:

Cover Assembly, Water Tanks (OM3053)

- Requirement to apply solid film lubricant per MIL-L-3987 deleted
  - The vendor applies dry film lubricant per a certified process approved by Boeing
- There is no OEM fastener installation specification used and/or referenced on the water tank cover drawing
  - The MA0101-301 processing specification will be added to provide requirements for "how to install" threaded fasteners
  - The applied torque on the fasteners will be per OEM drawing requirements
  - The MA0101-301 processing specification is used on all Orbiter hardware and is commonly used in IDMRDs when OEM doesn't have a controlled specification/document callout

CRITICAL PROCESS CHANGES

Presenter:
Doug White

Organization/Date:
Orbiter/09-17-02

Engineering Design Change Proposals (EDCPs):

Thruster Valve Butyl O-ring is No Longer Commercially Available (EDCP-V0502)

- Allow the use of new O-rings on the General Dynamics fuel and oxidizer valve assemblies
- Parker Hannifin's butyl compound (B591-80) which has been used as O-ring material in the past, is now obsolete
- The Parker Hannifin's replacement product is a butyl compound (B1167-80)
  - The replacement butyl compound has the same or better material properties and similar performance characteristics as the obsolete butyl compound

CRITICAL PROCESS CHANGES

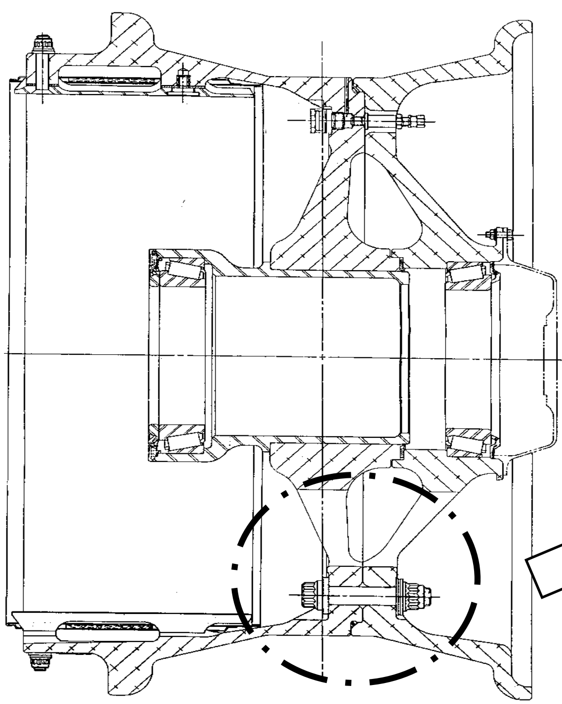
Presenter:
Doug White
Organization/Date:
Orbiter/09-17-02

Material Review (MR) items:

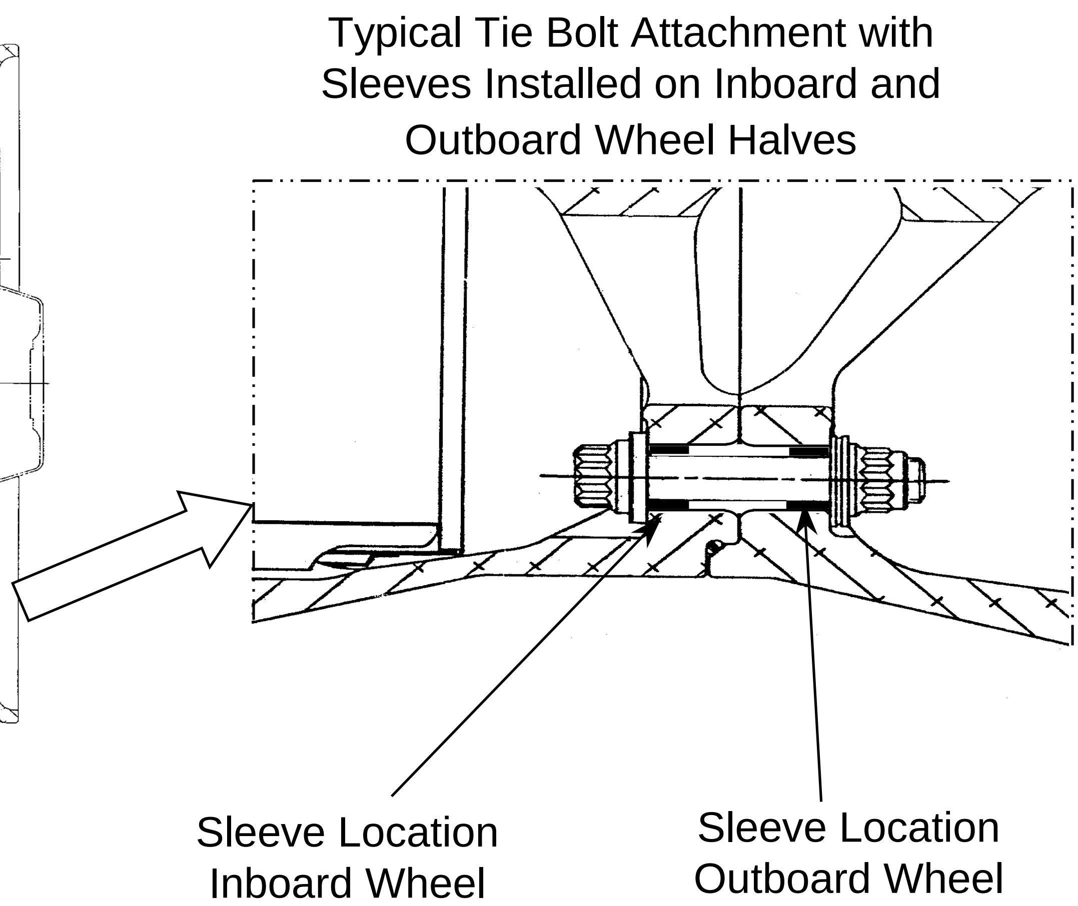
First Flight of Main Landing Gear (MLG) Wheels With MR Sleeve Tie-bolt Hole Repair (4 MRDs on OV-104):

- Repair procedure developed at Goodrich installed sleeves in tie-bolt holes after machining to remove corrosion
  - All 36 holes (18 per wheel half) fitted with sleeves to maintain tie-bolt clearances at assembly
- Fatigue test program completed at WPAFB demonstrated ten-mission life (details in back-up)
- The sleeved test wheel was fluorescent penetrant inspected prior to, during, and after completion of all tests
  - No flaws were detected at any of the sleeved hole locations
- MR dispositions for ten-mission usage of each repaired wheel were processed through PMRB and Fracture Control Board
  - Final MR will be processed for each wheel after the tenth mission for “scrap” disposition

	Presenter:
	Organization/Date: Orbiter/09-17-02



MLG Wheel



CRITICAL PROCESS CHANGES

Presenter:
Doug White
Organization/Date:
Orbiter/09-17-02

Material Review (MR) items:

MPS Flowliner Weld Repair of Cracks

- See special topic section for this topic

	Presenter:
	Organization/Date: Orbiter/09-17-02

CONFIGURATION CHANGES AND CERTIFICATION STATUS

CONFIGURATION CHANGES AND CERTIFICATION STATUS

Presenter:
Doug White

Organization/Date:
Orbiter/09-17-02

- **16 Modifications Incorporated During the STS-112 Processing Flow**
  - Total listing of STS-112 modifications and certification details are in backup
- **4 modifications are flying for the first time on STS-112**
  - MCR 18755 MA9N Frame Modification
  - MCR 19648 FRCS Optional RTV Installation
  - MCR 23070 ET Cavity Ferry Door Attach Fitting Redesign
  - MCR 23077 Forward Orbiter ET Attach Fitting Stud Redesign
  - Summaries to be presented on following pages

CONFIGURATION CHANGES AND CERTIFICATION STATUS

Presenter:
Doug White

Organization/Date:
Orbiter/09-17-02

MCR 18755 MA9N Frame Modification

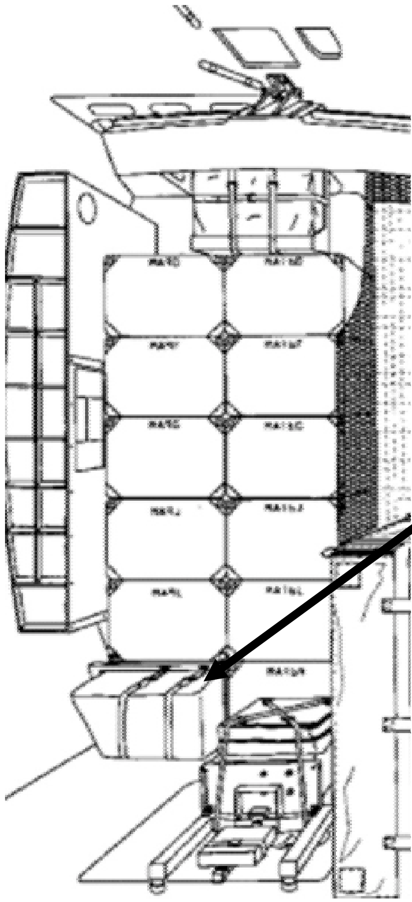
- MA9N soft stowage frame interfered with MA16N locker door operation
- Fabricated new MA9N frame increasing the clearance 3/16 inch
- Additionally changed the attach points from the locker above (MA9L) to the vehicle structural panel
  - Ease of installation
  - Increase strength
  - Change installation sequence

CONFIGURATION CHANGES AND CERTIFICATION STATUS

Presenter:
Doug White

Organization/Date:
Orbiter/09-17-02

MCR 18755 MA9N Interference



MA9N BAG AND FRAME LOCATION

VIEW LOOKING AFT

VIEW LOOKING OUTBOARD STARBOARD SIDE (MID-DECK)

TWO BRACES ADDED

INTERFERENCE LOCATION

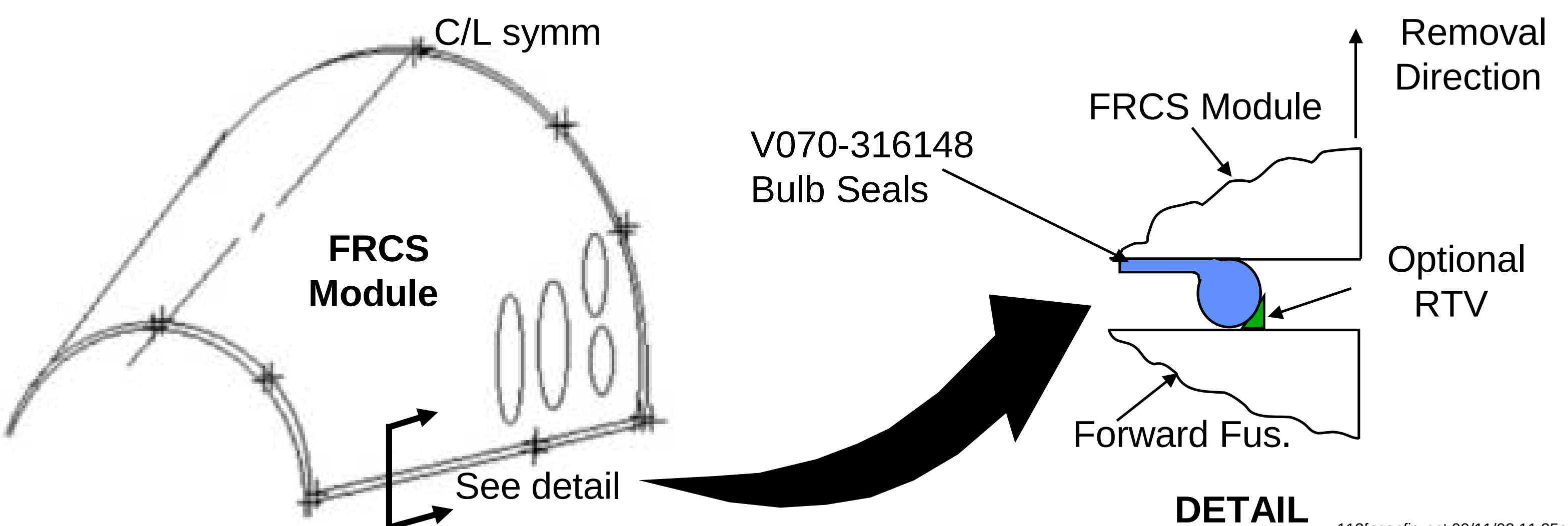
CONFIGURATION CHANGES AND CERTIFICATION STATUS

Presenter: Doug White

Organization/Date: Orbiter/09-17-02

MCR 19648 FRCS Optional RTV Installation

- The requirement to apply an RTV seal around the FRCS perimeter is optional if a successful leak check is performed with no RTV seal in place
  - Bulb seal remains as primary seal
  - Thermal analysis determined bulb seal adequate as only seal
- The elimination/reduction of the RTV seal results in significant savings during turn around processing when an FRCS is removed
  - Change allows use of RTV as required to assure seal



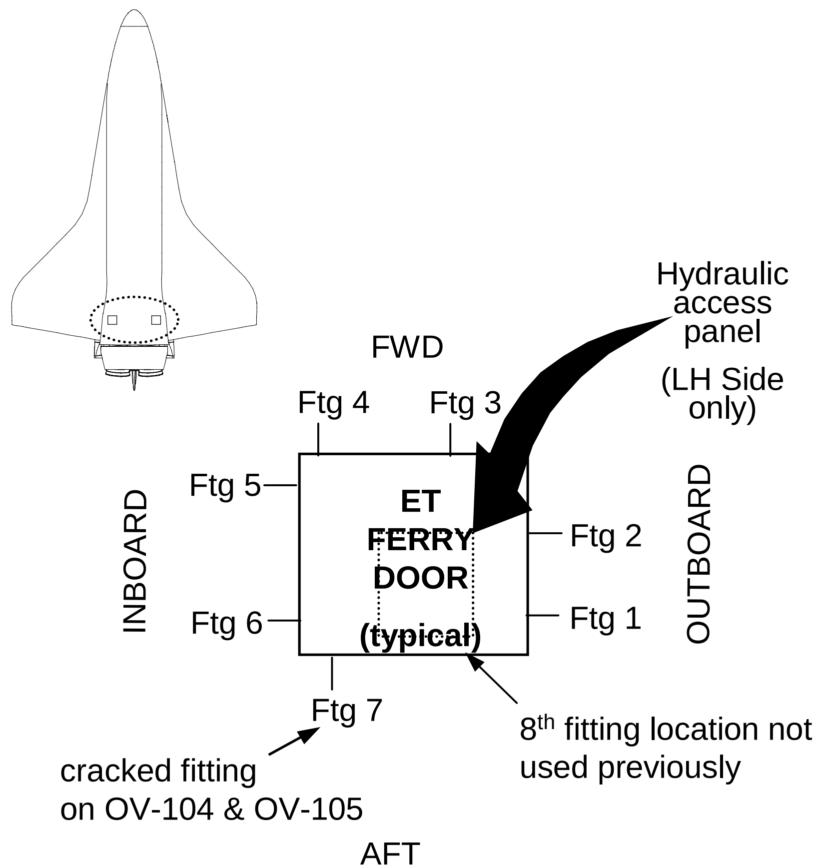
CONFIGURATION CHANGES AND CERTIFICATION STATUS

Presenter:
Doug White

Organization/Date:
Orbiter/09-17-02

MCR 23070 ET Cavity Ferry Door Attach Fitting Redesign

- STS-98 post-flight inspection found a fatigue crack on the ferry door at attach point #7
  - Modification installs a fitting at the unused location, attach point #8 (LH & RH)
    - Reduces unsupported span of the ferry door
    - Reduces stress levels at attach point #7
  - Also adds a hydraulic access panel in the LH ferry door



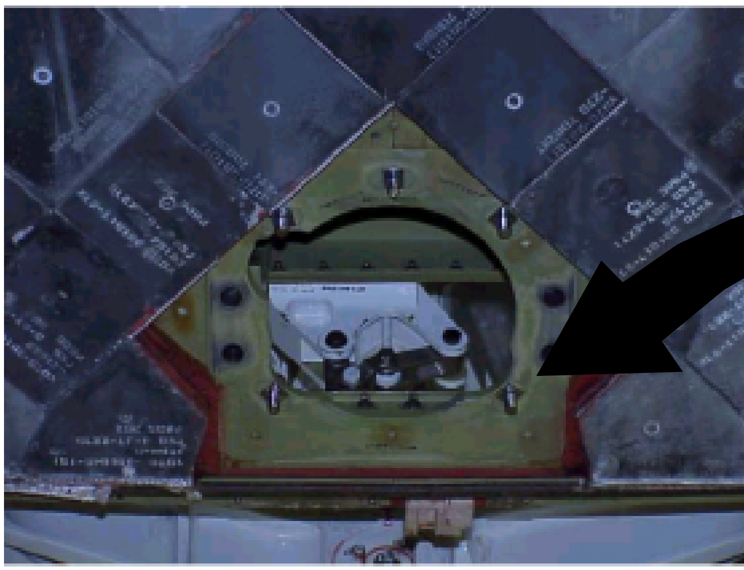
CONFIGURATION CHANGES AND CERTIFICATION STATUS

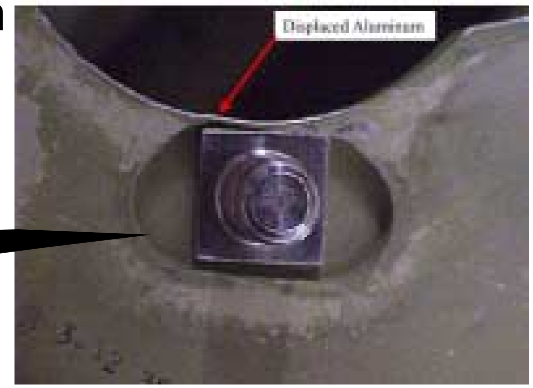
Presenter:
Doug White

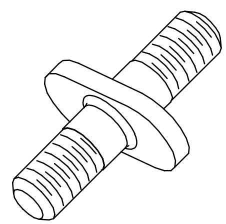
Organization/Date:
Orbiter/09-17-02

MCR 23077 Forward Orbiter ET Attach Fitting Stud Redesign

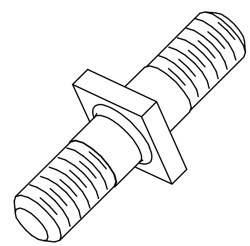
- STS-102 on OV-103 post-flight inspection found a crack in the attach fitting of the forward ET attach point
  - Current design can result in cracking during ground installation
  - Stud redesigned to alleviate concern







New Design



Old Design

	Presenter:
	Organization/Date: Orbiter/09-17-02

SPECIAL TOPICS

SPECIAL TOPICS FOR THE STS-112 FLIGHT READINESS

Presenter:

Organization/Date:
Orbiter/09-17-02

Topic	Presenter
IMU Slip-Ring Failures	Doug White
OV-104 LH2 Feedline Flowliner Cracks	Doug White
Negative Margin for MPM Liftoff Loads	Doug White

IMU SLIP-RING FAILURES	Presenter: Doug White
	Organization/Date: Orbiter/09-17-02

Observation:

- During the STS-108 mission, inertial measurement unit (IMU) -2 exhibited platform fail and redundant rate fail BITEs along with excessive Z-axis gyro drift for 45 minutes before clearing

Concern:

- Loss of one level of IMU subsystem redundancy

Discussion:

- Azimuth Gyro drift rate exceeded 100 sigma (0.7 degrees/hour vs. 0.006 degrees/hour one sigma)
- Upon recovery of IMU-2, the unit was realigned and nominal operation resumed for the next 108 hours through landing

IMU SLIP-RING FAILURES	Presenter: Doug White
	Organization/Date: Orbiter/09-17-02

Discussion:

- Post-flight analysis discovered two anomalous conditions with s/n 207, both of which were required to create the IFA
  - The circuit supplying power to one phase of the two-phase azimuth gyro motor was observed to be opened between 50 degrees and 250 degrees azimuth at the slip ring
  - The vertical gyro intermittently lost sync (rotation speed measured out of spec)
    - Caused gyro wheel supply BITE (the root cause of the platform failure BITE)
- The vertical gyro loss of sync caused the slowing of azimuth gyro
- The azimuth gyro could not resume normal speed with only one phase of its two-phase motor available and eventually resulted in a high drift rate

IMU SLIP-RING FAILURES

Presenter: Doug White
Organization/Date: Orbiter/09-17-02

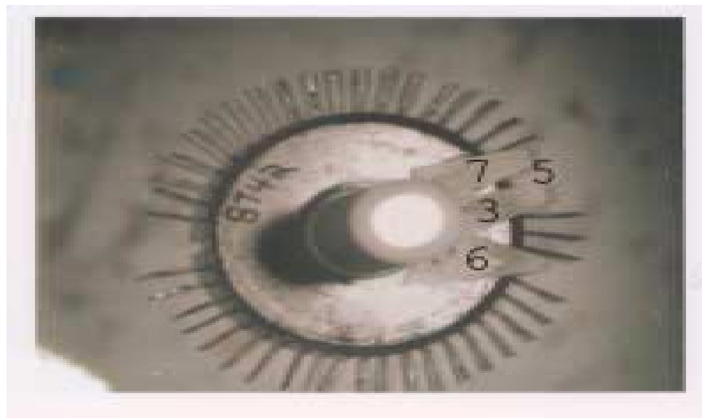
Discussion:

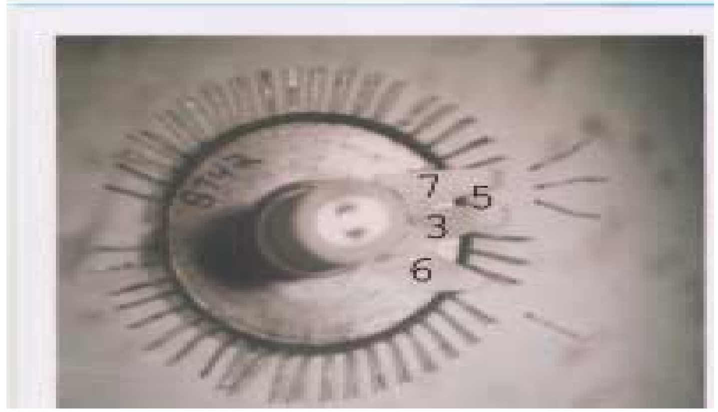
- X-ray analysis of the 42-wire azimuth slip ring found breaks in fan-out wires 3, 5, 6 & 7
  - Wire 3 carried the 90 degree phase of the azimuth gyro motor power
- SEM analysis indicates fatigue failure from up/down flexure
- Slip ring misalignment is a phenomenon observed to be present and variable between IMUs
  - A side load on the slip ring shaft from the brush block tape cable is the major contributor to slip ring misalignment
  - Slip ring misalignment varies among IMUs

Most probable cause of wire failures appears to be a combination of the degree of slip ring misalignment and the number of times it is flexed (usage related)

IMU SLIP-RING FAILURES	Presenter: Doug White
	Organization/Date: Orbiter/09-17-02

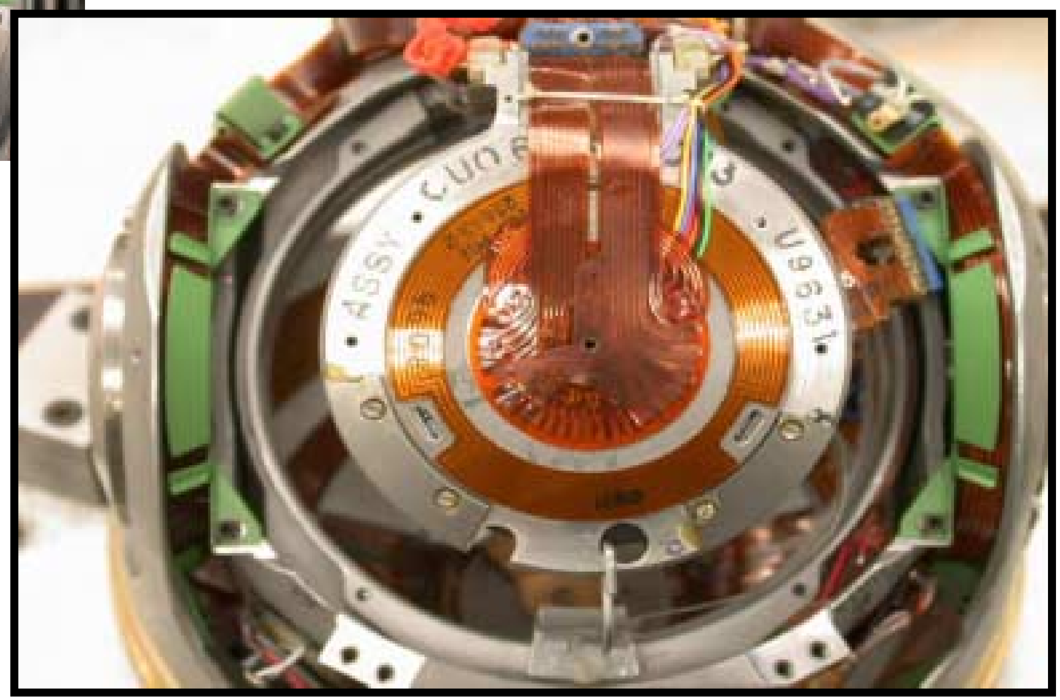
Photos of HAINS S/N 207 Broken Slip Ring Wires





IMU SLIP-RING FAILURES	Presenter: Doug White
	Organization/Date: Orbiter/09-17-02

Inertial Platform with Slip Ring Fan-Out Exposed

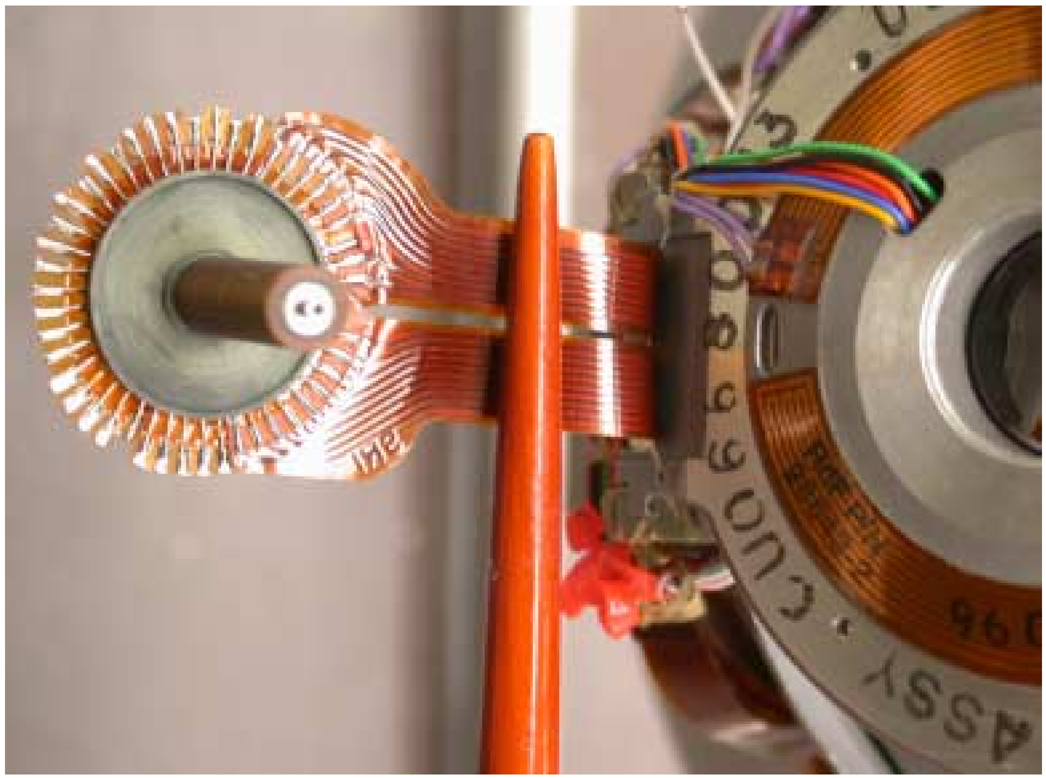


IMU SLIP-RING FAILURES

Presenter:
Doug White

Organization/Date:
Orbiter/09-17-02

Slip Ring Fan-Out Removed from Coordinate Resolver

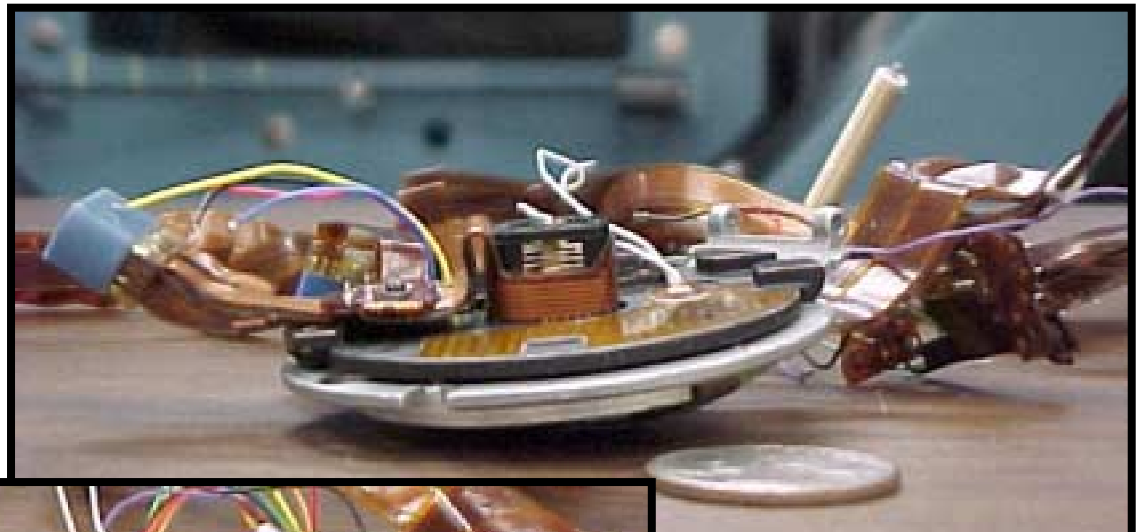


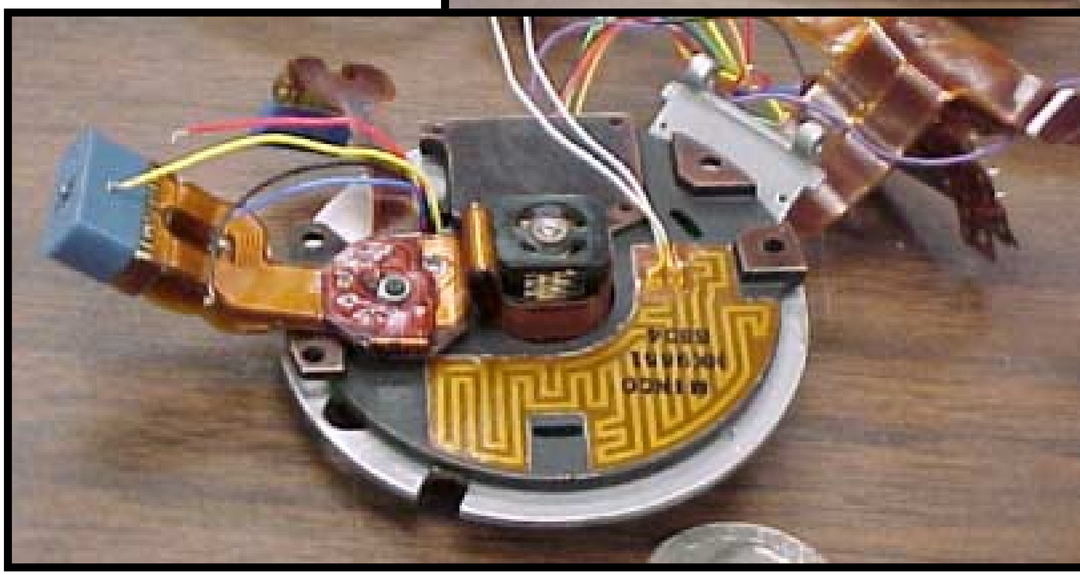
IMU SLIP-RING FAILURES

Presenter:
Doug White

Organization/Date:
Orbiter/09-17-02

Brush Block Assembly in Place

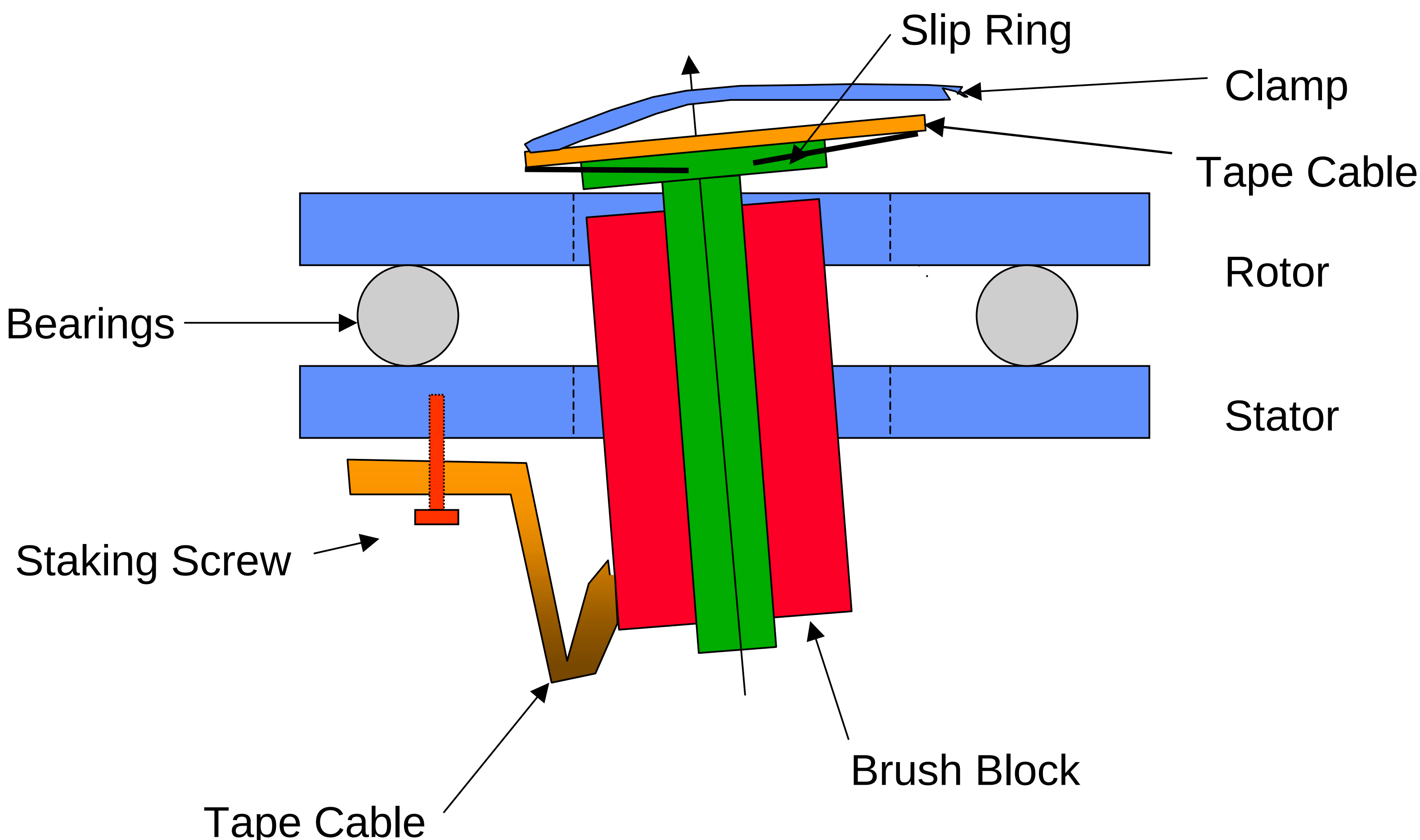




IMU SLIP-RING FAILURES

Presenter:
Doug White
Organization/Date:
Orbiter/09-17-02

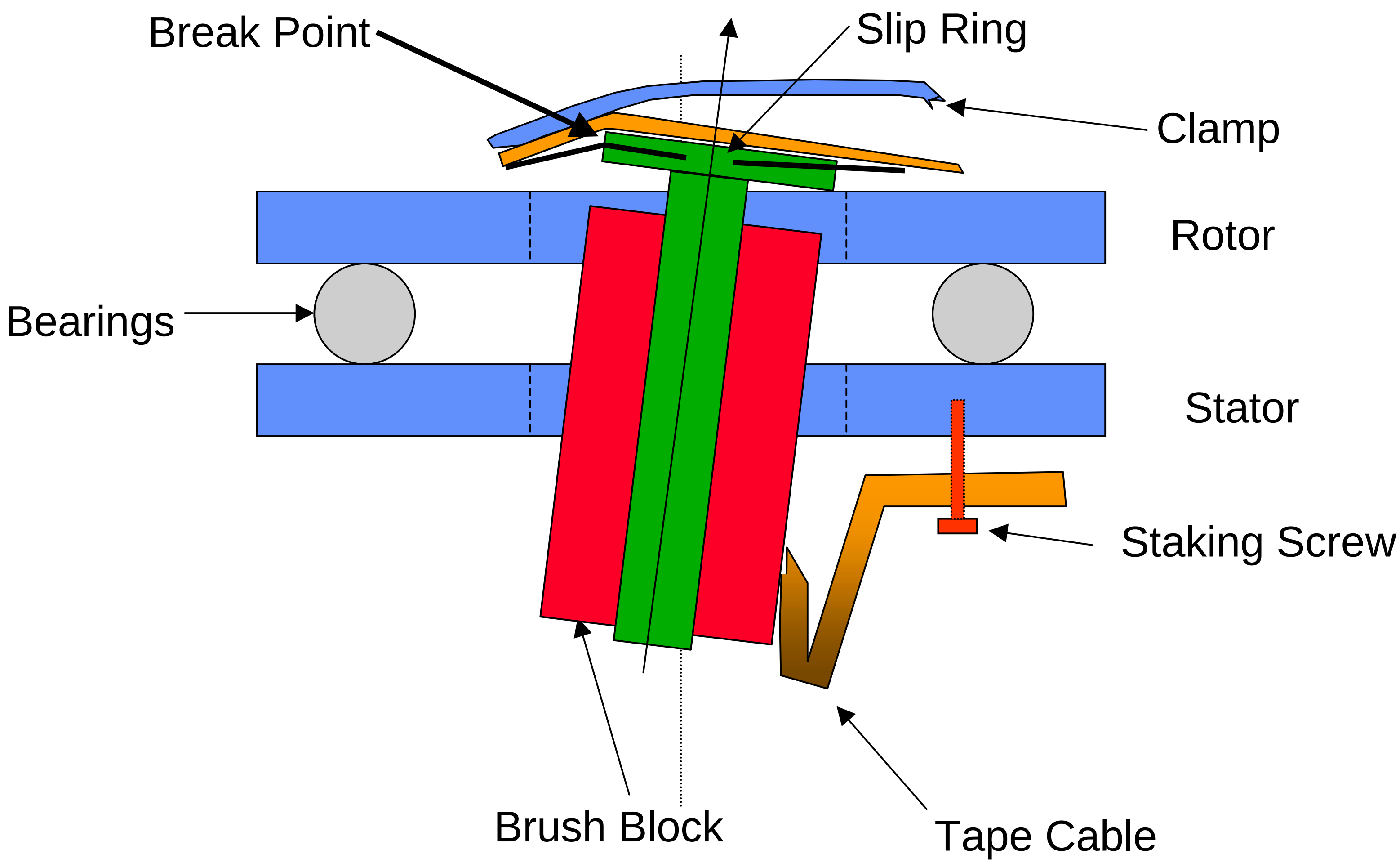
Slip Ring in Place w/ Clamp & Staking Screw - Simplified



IMU SLIP-RING FAILURES

Presenter:
Doug White
Organization/Date:
Orbiter/09-17-02

Coordinate Resolver Rotated 180 Degrees



IMU SLIP-RING FAILURES

Presenter:
Doug White

Organization/Date:
Orbiter/09-17-02

Discussion:

- IMU S/N 210 (platform S/N 119) was removed from OV-104 to measure wobble because of previous failure (1997) of its slip ring at 2500 hours

Slip Ring/Brush Block Wobble Data

IMU/Platform	Hours	Wobble	Comments
198/102	2700	None	X-ray found no breaks
Spare/104	2300	0.005 in.	X-ray found no breaks
204/109	7000	0.005 in.	X-ray found no breaks
207/114	4500	TBD	Wires 3, 5, 6, & 7 broken
210/119	~2500	Not measured in 1997	Wires 6, 11, & 15 broken
210/119	2100	0.016 in.	X-ray found no breaks
202/120	3800	0.010 in.	Manufacturing defect on wire #44, no sign of breaks on other wires

IMU SLIP-RING FAILURES

Presenter:
Doug White

Organization/Date:
Orbiter/09-17-02

Discussion:

- The large wobble measurement for IMU S/N 210 fits with failure hypothesis
- All other IMU measurements/observations indicate no fatigue failures among those with low wobble measurements
- Among IMUs measured, percentage of large slip ring misalignment is low
- There are 9 IMUs with over 4500 hours and no slip ring failures
- Review of PRACA failure history data showed that STS-108 IMU IFA represented the third slip ring related failure during the HAINS IMU's 12-year life (approx 80,900 operate hours)

IMU SLIP-RING FAILURES

Presenter: Doug White	**Organization/Date:** Orbiter/09-17-02

Discussion:

- Kearfott searched IMU platform build records
  - One assembly technician built all but two platforms
  - There is no pattern in build dates of failed IMUs
- Kearfott is actively developing a re-design of azimuth slip ring mounting to prevent fracture of fan-out wires
  - Replacement slip rings are on order
  - IMU PRT developing fleet-wide retrofit plan
- As for the vertical gyro lubrication problem, this was recognized early in the HAINS program
  - Sufficient spare gyros (without this problem) are on the shelf
  - Gyros replaced when platform opened for repairs
  - Impending gyro failure has been identified by high gyro drift rates that can be compensated

IMU SLIP-RING FAILURES	Presenter: Doug White
	Organization/Date: Orbiter/09-17-02

Observation:

- Recently, during OV-104 IMU calibrations in preparation for the STS-112 mission, IMU-1 (HAINS s/n 202) annunciated platform fail BITEs
  - There were two separate BITE occurrences: 25 seconds and 12 seconds
  - Once beyond the BITE flags, the IMU pre-flight calibration and three pre-flight alignments were performed successfully

IMU SLIP-RING FAILURES

Presenter: Doug White	
Organization/Date: Orbiter/09-17-02	

Actions Taken/In-Work:

- IMU S/N 202 was removed and replaced
  - S/N 202 was shipped to the Kearfott for TT&E
  - Gyro health signals showed significant degradation from azimuth 318 degrees through zero to 79 degrees
  - Break-out box measurements found the common ground for gyro motor power was opening at the same angles
    - This ground runs through wire #44 of the slip ring
    - X-rays and visual inspection verified broken wire #44
    - Kearfott M&P found material on the broken face of the wire that indicates this wire had a 50% to 75% fracture introduced during manufacturing
    - All slip rings are subjected to 100% inspection – this appears to be a rare QA escape
  - From all indications, this failure is not in the same category as previous slip ring failures

IMU SLIP-RING FAILURES

Presenter:
Doug White

Organization/Date:
Orbiter/09-17-02

Discussion:

- Reviewed pedigree of OV-104 IMU ship-set
  - HAINS S/N 203 has ~3700 Operate hours
    - Original Slip Rings
    - Original configuration gyros
  - HAINS S/N 208 has ~5600 hours
    - New Slip Rings with ~2300 hours
    - New gyros
  - HAINS S/N 215 has ~5000 Operate hours
    - Original Slip Rings
    - New gyros

IMU SLIP-RING FAILURES	Presenter: Doug White
	Organization/Date: Orbiter/09-17-02

Risk Assessment:

- The IMU subsystem is Crit 1R3 for loss of output, Crit 1R2 for erroneous output
  - Any failure of the 16 slip ring wires in the hypothesized wear-out zone will result in an IMU BITE and not in an RM dilemma
  - Failure mode effects analyses of all other slip ring wires (not in the hypothesized wear-out zone) found three wires that, if broken, could cause erroneous output without a BITE indication
- Per the flight rules, first IMU failure results in NEOM, second failure invokes next PLS
  - Flight rule allows assessment of risk for IMU failures that may result in early flight termination

IMU SLIP-RING FAILURES

Presenter:
Doug White
Organization/Date:
Orbiter/09-17-02

Acceptable for STS-112 Flight:

- The IMUs will be subjected to planned, comprehensive vehicle-level tests
  - TCDT, hanger calibration and three gyro-compass tests
  - On launch day, another three gyro-compass tests and a pre-flight calibration are performed
  - Three of four failures were found during these tests on the ground
- The IMU slip ring failure rate is low (i.e., only four confirmed failures during 12-year life of HAINS program)
  - Probability of an IMU failure during STS-112 is low
- Flight rules allow for real-time risk assessment
- Adequate subsystem redundancy is in place

OV-104 MPS LH2 FEEDLINE FLOWLINER CRACKS	Presenter: Doug White Organization/Date: Orbiter/09-17-02

Observation:

- Inspections of MPS LH2 engine feedline flowliners found cracks in the gimbal assembly flowliners near the SSME interface

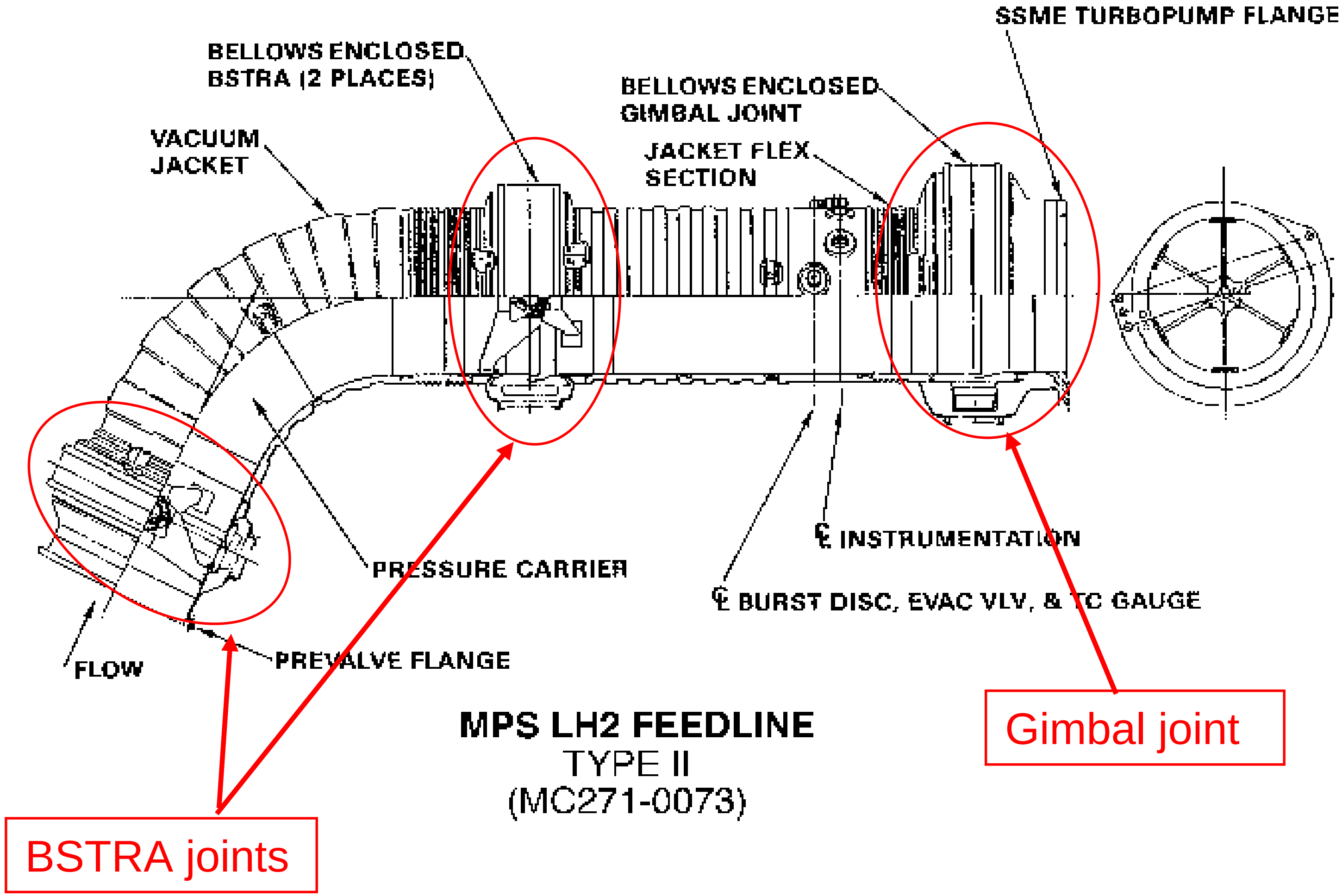
Concerns:

- Crack propagation resulting in possible:
  - Metallic FOD ingestion by SSME
  - Loss of flowliner integrity
  - Disruption of flow field leading to LPFTP cavitation

OV-104 MPS LH2 FEEDLINE FLOWLINER CRACKS

Presenter:
Doug White

Organization/Date:
Orbiter/09-17-02

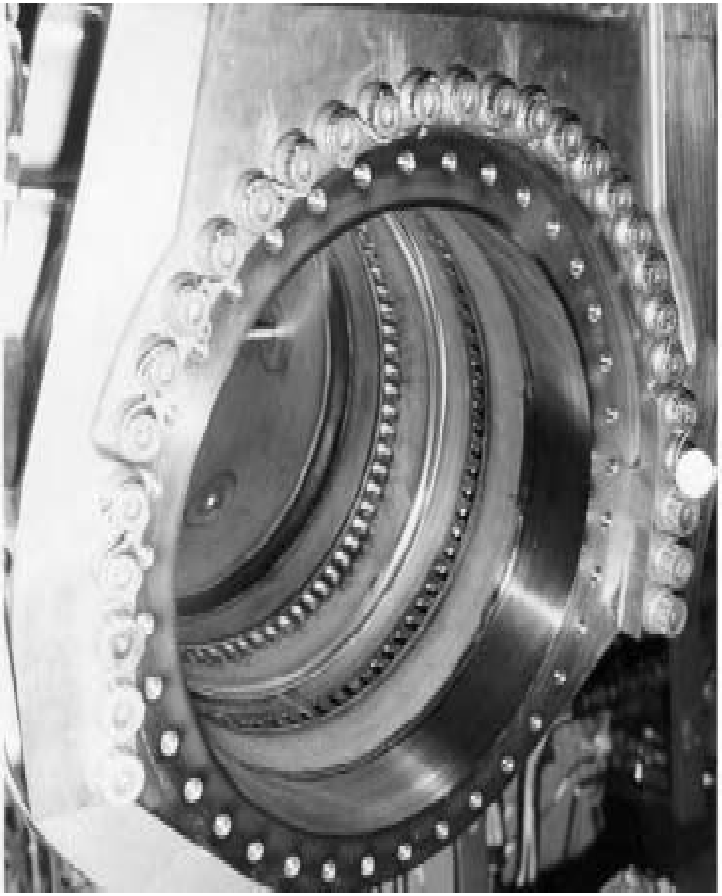


OV-104 MPS LH2 FEEDLINE FLOWLINER CRACKS

Presenter:
Doug White

Organization/Date:
Orbiter/09-17-02

OV-102

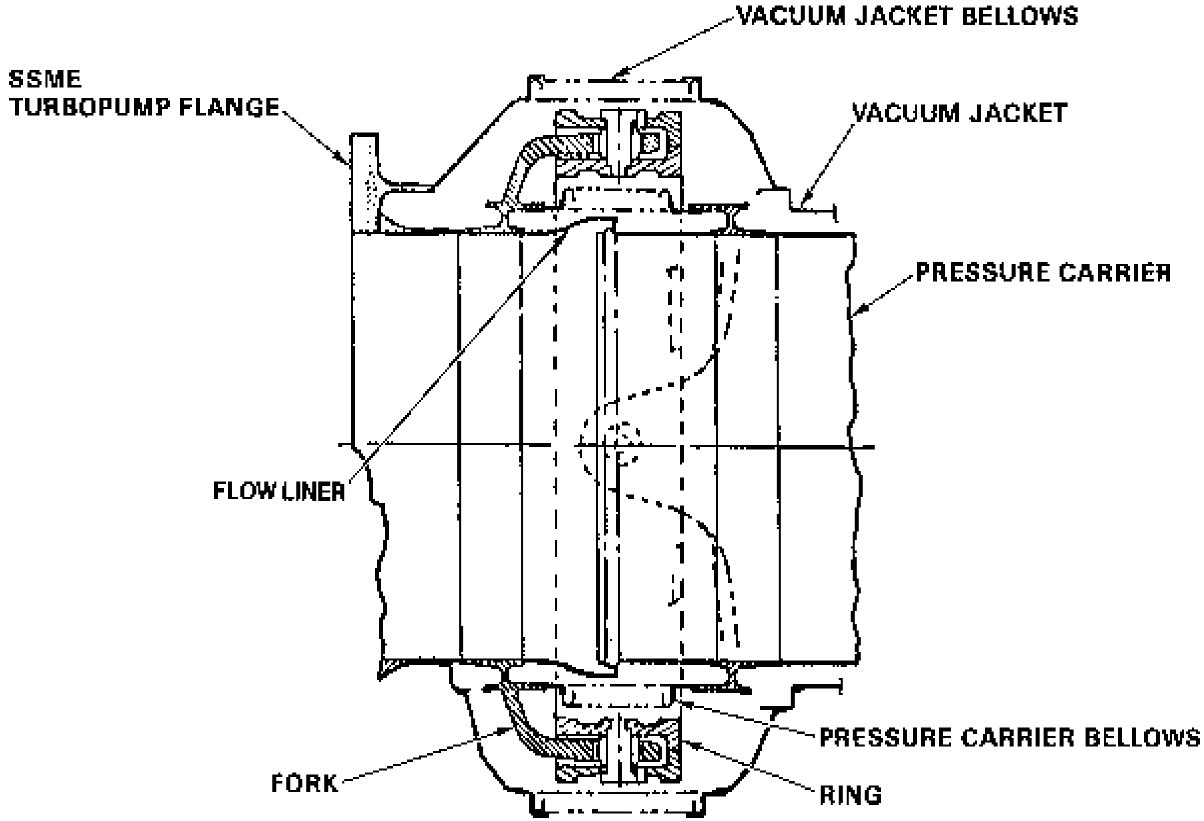


OV-103 AND SUBS

OV-104 MPS LH2 FEEDLINE FLOWLINER CRACKS

Presenter:
Doug White

Organization/Date:
Orbiter/09-17-02

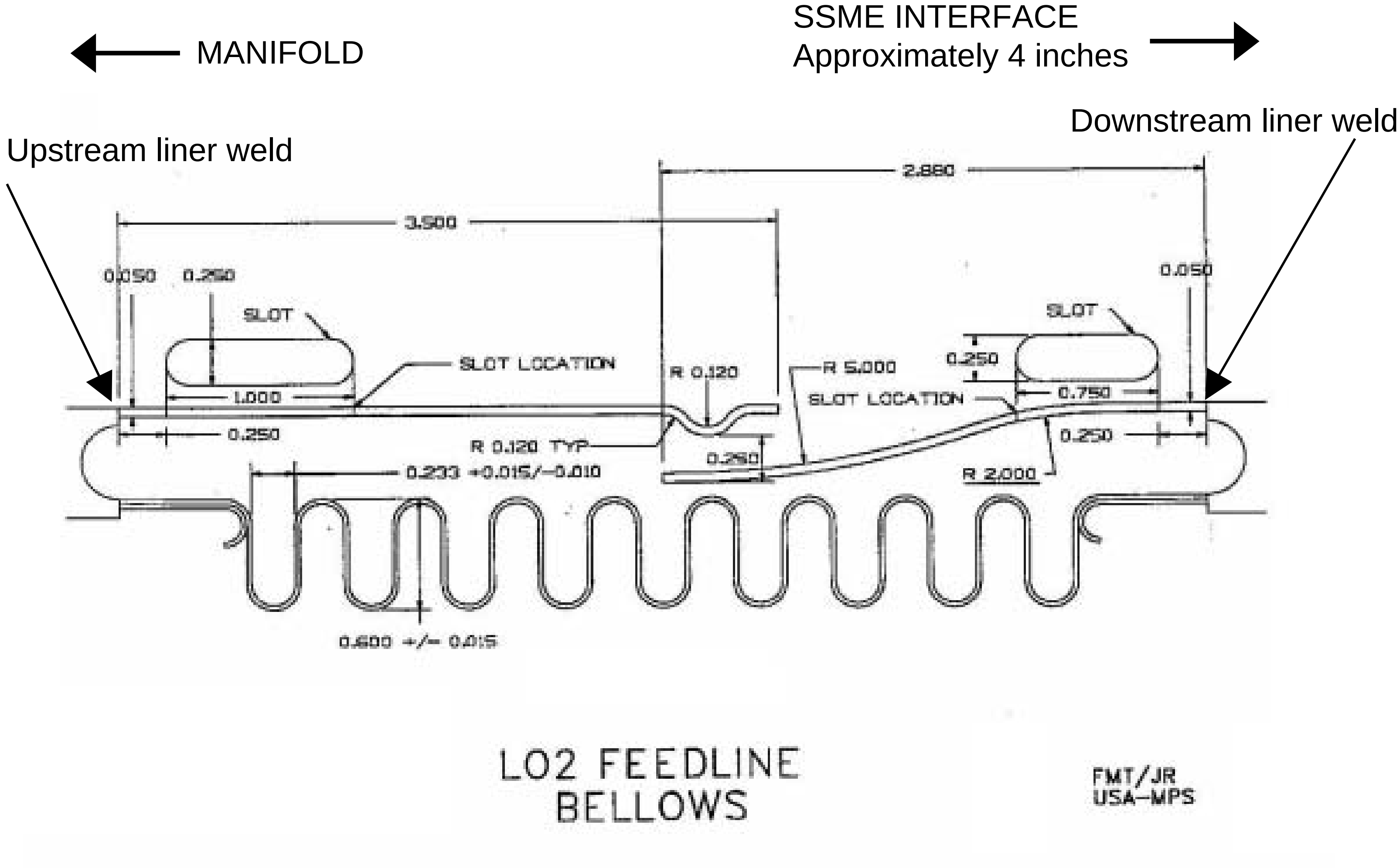


MPS LH2 & LO2 FEEDLINE GIMBAL JOINT

TYPES II, III, & IV

OV-104 MPS LH2 FEEDLINE FLOWLINER CRACKS

Presenter:
Doug White
Organization/Date:
Orbiter/09-17-02



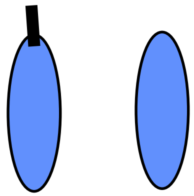
OV-104 MPS LH2 FEEDLINE FLOWLINER CRACKS

Presenter:
Doug White

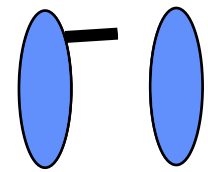
Organization/Date:
Orbiter/09-17-02

Crack Inspection Summary

Axial Cracks



Circumferential Cracks



	Engine 1 LH2	Engine 2 LH2
MPTA	1 Circumferential, Downstream	None
OV-102	None	3 Circumferential, Downstream
OV-103	1 Axial, Upstream 2 Axial, Downstream	None
OV-104	1 Axial, Downstream 2 Circumferential, Downstream	None
OV-105	1 Axial, Downstream	1 Axial, Upstream

OV-104 MPS LH2 FEEDLINE FLOWLINER CRACKS

Presenter: Doug White

Organization/Date: Orbiter/09-17-02

Weld Repair Option Had the Fewest Unknowns and Could Be Bounded by Analysis

Comparison of Critical Parameters Before and After Repair				
Configuration	**Environment**	**Structural Response**	**Material Properties**	**Mission Life**
Weld				
Circumferential or Axial Cracks	No Change	No Change	Material properties may be reduced, but can be measured through test	Can be predicted based on fatigue life of bench test specimens
Slots				
Circumferential				
Large	Unknown effect on delta P across liner	Unpredictable shift in stress distribution	No Change	Fatigue life prediction requires high-fidelity test environment
Super	Unknown effect on delta P across liner	Unpredictable shift in stress distribution	No Change	Fatigue life prediction requires high-fidelity test environment
Axial				
Elongated	Unknown effect on delta P across liner	TBD	No Change	Fatigue life prediction requires high-fidelity test environment
Stop Drill				
Circumferential	Unknown effect on delta P across liner	Unpredictable shift in stress distribution	No Change	Fatigue life prediction requires high-fidelity test environment
Axial	Unknown effect on delta P across liner	Unpredictable shift in stress distribution	No Change	Fatigue life prediction requires high-fidelity test environment
Fly As Is				
Circumferential	Unpredictable effect of flow induced loads on crack growth	Unpredictable behavior at resonant frequencies	No Change	Fatigue life prediction requires high-fidelity test environment
Axial	Unpredictable effect of flow induced loads on crack growth	Unpredictable behavior at resonant frequencies	No Change	Fatigue life prediction requires high-fidelity test environment

OV-104 MPS LH2 FEEDLINE FLOWLINER CRACKS

Presenter: Doug White

Organization/Date: Orbiter/09-17-02

Approach to Clear Flowliner Repair for 1 Mission

- Weld all detectible cracks and polish slots
  - Complete
- Test coupons to crack initiation
  - Plot test data
  - Evaluate for scatter
- Determine minimum weld life relative to parent material (i.e., knockdown factor)
- Use reverse fracture bounding analysis to estimate:
  - Equivalent damage, constant amplitude stress level
  - Life to “initiation”
  - Life to critical length - i.e., slot-to-slot crack (circumferential), detrimental length (axial)
  - Apply appropriate scatter factors
    - 4 for crack initiation in weld repaired area
    - 2 for crack growth from undetected damage

OV-104 MPS LH2 FEEDLINE FLOWLINER CRACKS

Presenter:
Doug White

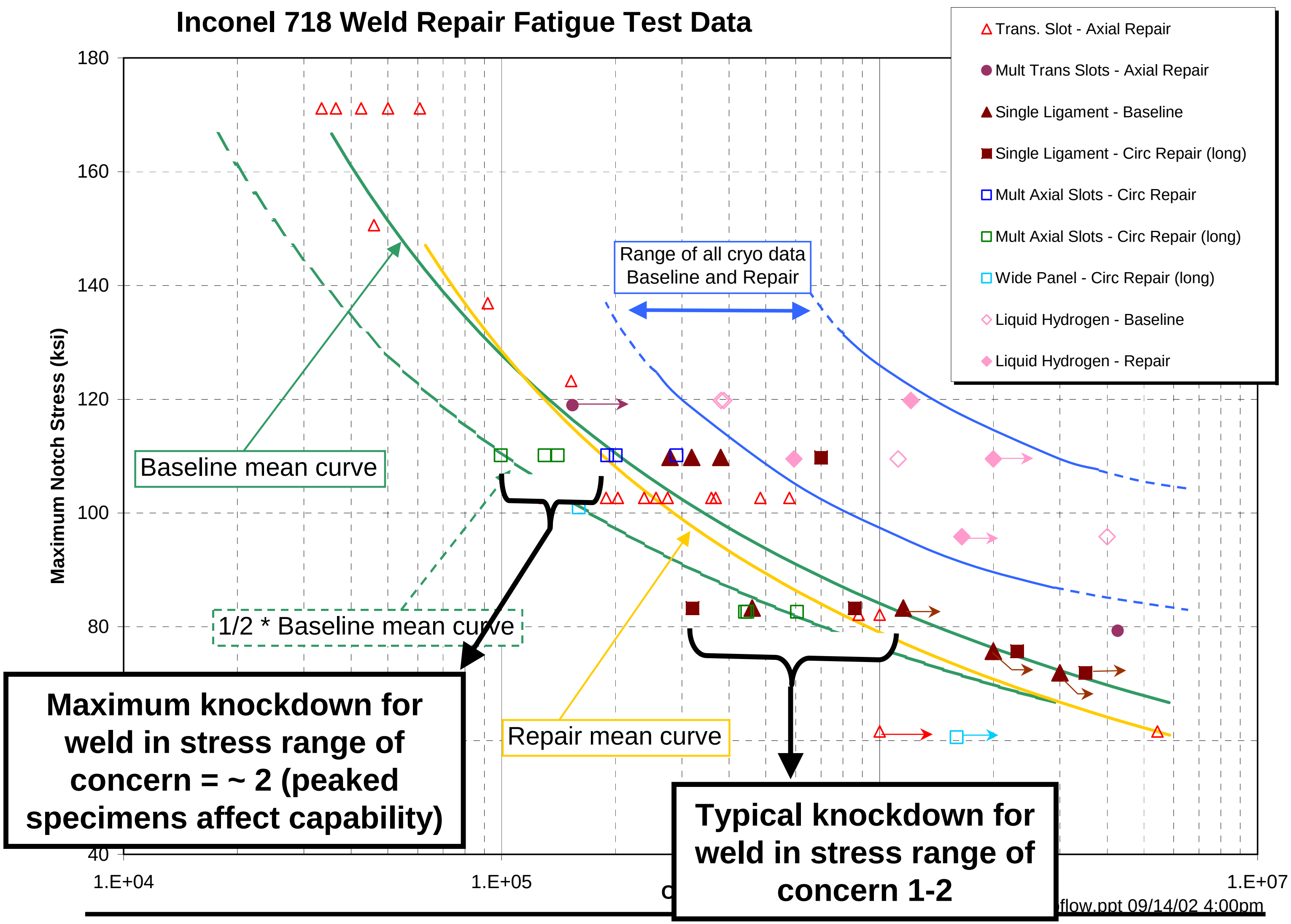
Organization/Date:
Orbiter/09-17-02

Repair area

OV-104 MPS LH2 FEEDLINE FLOWLINER CRACKS

Presenter:
Doug White

Organization/Date:
Orbiter/09-17-02



OV-104 MPS LH2 FEEDLINE FLOWLINER CRACKS

Presenter:
Doug White
Organization/Date:
Orbiter/09-17-02

Reverse Fracture Analysis[1]

- Final flaw size and missions (time) are known
  - 1 mission = ~ 500 seconds
- Fracture properties of material were estimated
- Chose a fracture model which best reflects hardware geometry and stress gradient
- Made realistic assumptions for critical parameters:
  - Initial flaw size[2] (a_i) – 0.005 in.
  - Stress ratio (R) – 0.7
  - Frequency (f) – 1000 hz
- Iterated to constant amplitude stress spectra which produces equivalent damage in hardware (i.e., matches what we see in crack data from vehicles)
- Critical assumption is that crack driving mechanisms remain the same as crack grows
  - No significant changes in resonant frequencies of hardware
  - No significant changes in spectra mission to mission

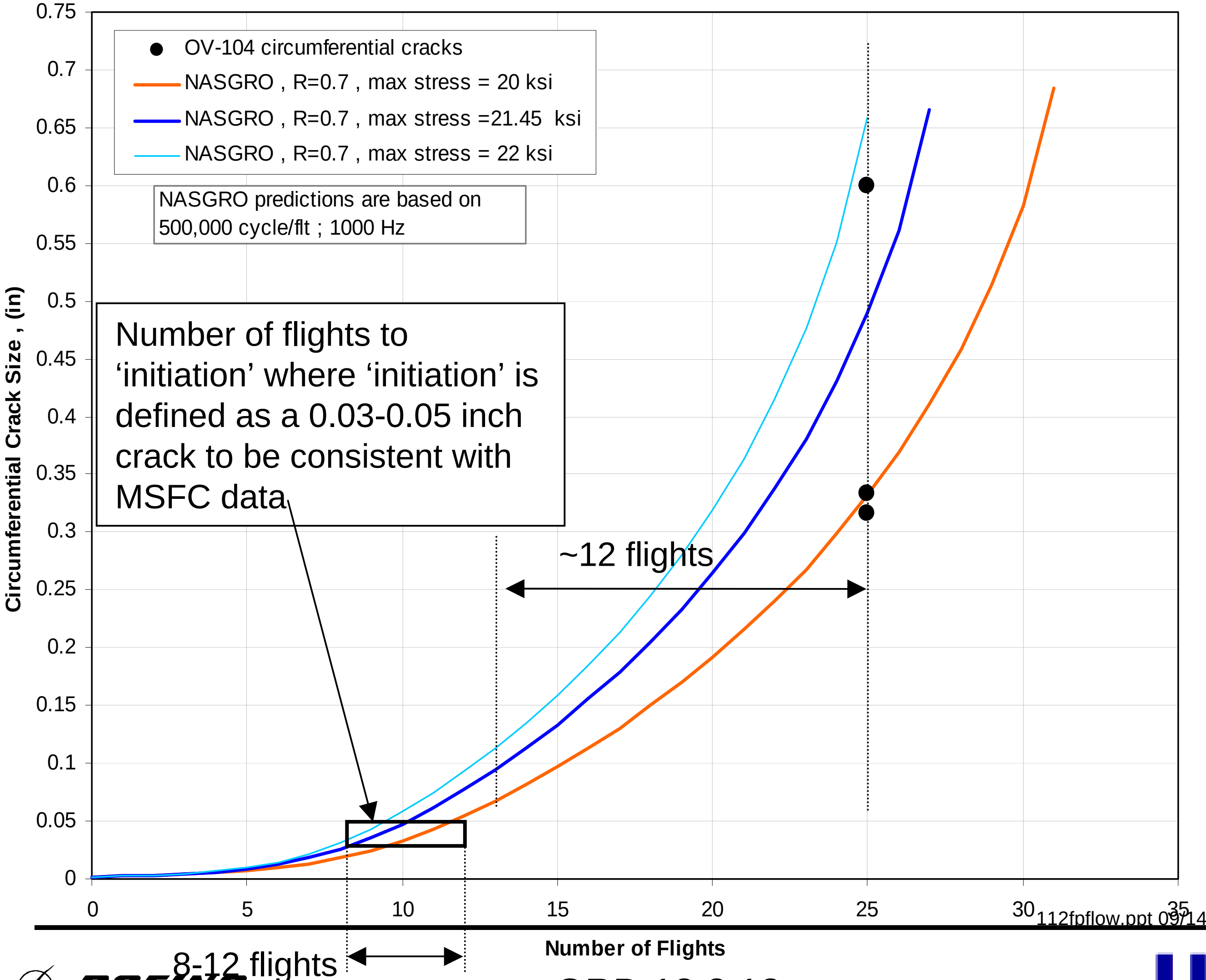
[1]R. Patin," Service Life Assessment of the Inconel Flowliners"

OV-104 MPS LH2 FEEDLINE FLOWLINER CRACKS

Presenter:
Doug White

Organization/Date:
Orbiter/09-17-02

Circumferential Crack Assessment – 0.33 vs. 0.6 inch

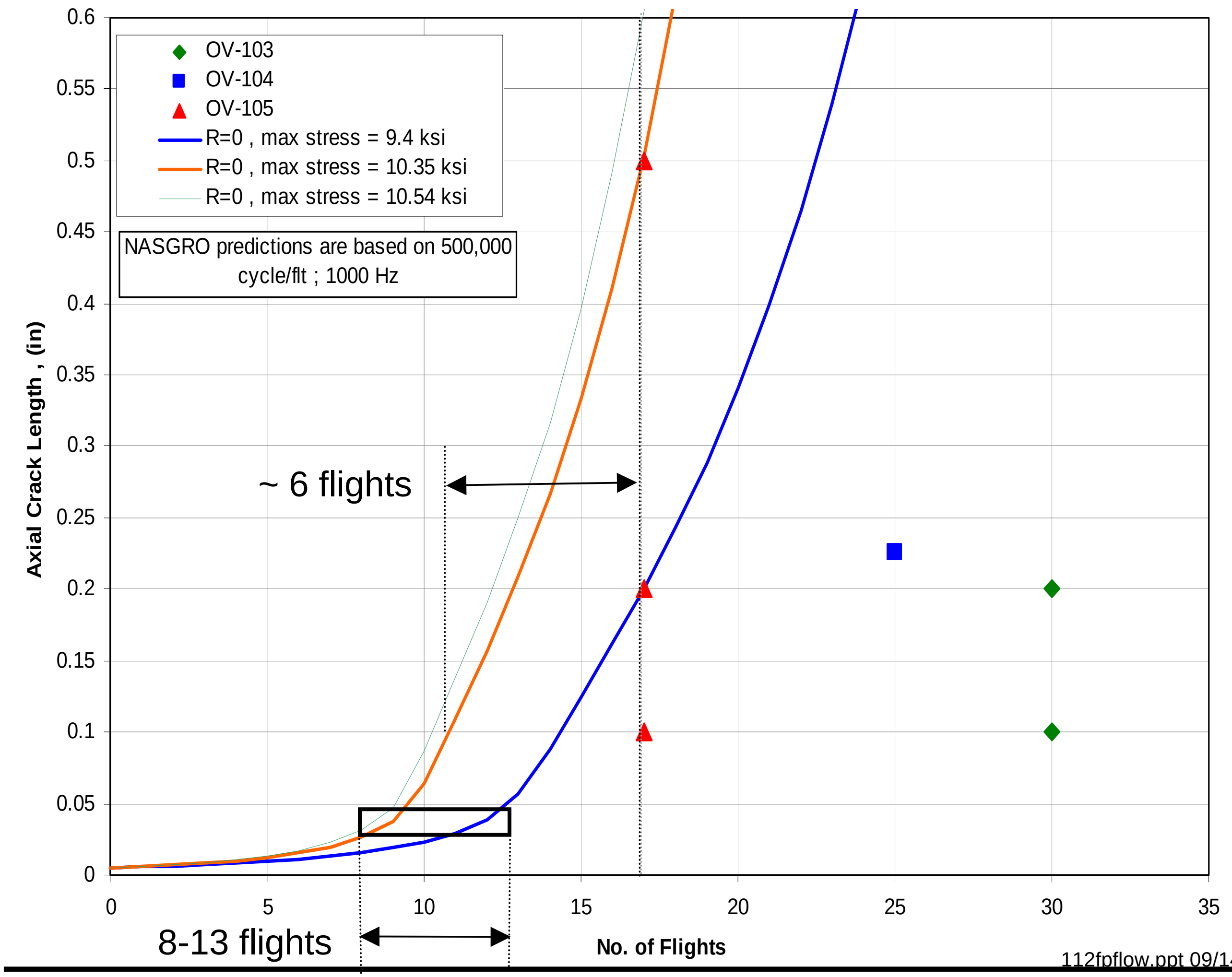


OV-104 MPS LH2 FEEDLINE FLOWLINER CRACKS

Presenter:
Doug White

Organization/Date:
Orbiter/09-17-02

Axial Crack Assessment – 0.2 vs. 0.5 inches



OV-104 MPS LH2 FEEDLINE FLOWLINER CRACKS

Presenter:
Doug White
Organization/Date:
Orbiter/09-17-02

Interpretation of Data

- For weld repaired areas:
  - Life to "initiation" = ~ 8 - 12 missions
  - Knockdown factor = ~ 2
  - Estimated life to "initiation" = ~ 4 - 6 missions
  - Application of required scatter factor = ~ 1 mission to "re-initiation" of cracks
- For undetected damage areas in parent material at circumferential crack locations (existing flaws below probability of detection threshold)
  - Life remaining to critical length = ~ 12 missions
  - Application of required scatter factor = ~ 6 missions of stable growth
- For undetected damage in parent material areas at axial crack locations
  - Life remaining to reach 0.5 (historical maximum) = ~ 6 mission
  - Application of required scatter factor = ~ 3 missions of stable growth

OV-104 MPS LH2 FEEDLINE FLOWLINER CRACKS

Presenter:
Doug White

Organization/Date:
Orbiter/09-17-02

Rationale Developed to Clear Other MPS Feedline Hardware:

- Flight rationale based on environment derived from Stennis test data and CFD analysis
  - Environment jointly agreed to by Engine and Orbiter Projects will be formalized in an ICD when it reaches maturity
- BSTRA Joint
  - All other load sources (vibration, thermal, pressure) give lower stresses in BSTRA flow liner than in gimbal flow liner – Lower loads and better load path
  - No significant flow effects from, or on BSTRA hardware
- Bellows to Gimbal weld
  - Detailed finite element analysis by Arrowhead Products included full range of gimbal rotations and internal 126 psig proof pressure obtained conservative M.S. = +0.54

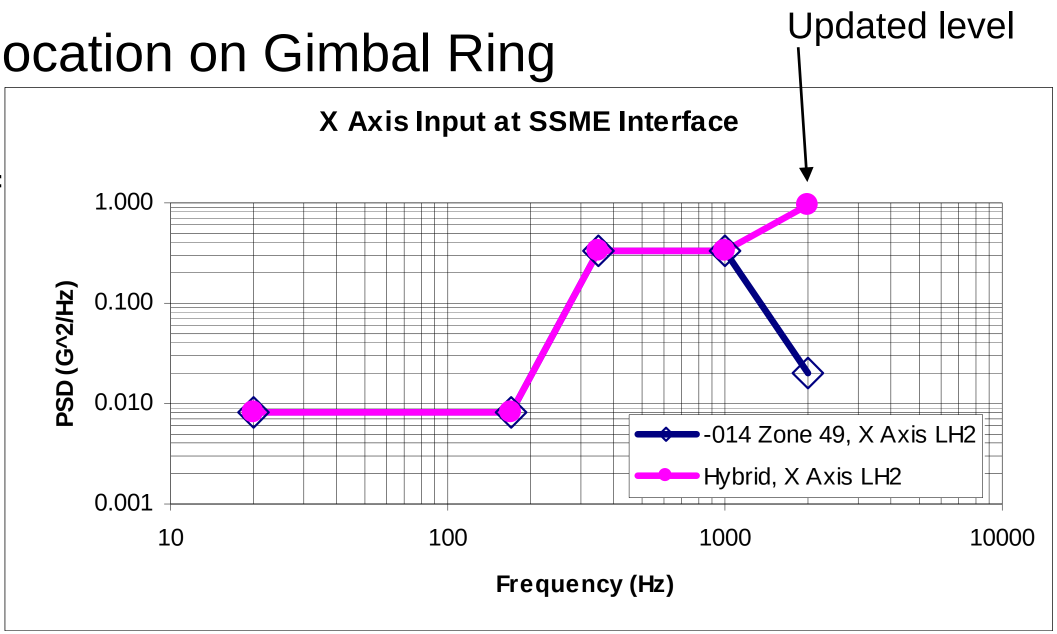
OV-104 MPS LH2 FEEDLINE FLOWLINER CRACKS

Presenter:
Doug White

Organization/Date:
Orbiter/09-17-02

Rationale Developed to Clear Other MPS Feedline Hardware:

- Fatigue Critical Location on Gimbal Ring
  - Updated to model based of latest test data and updated environment based on review of flight data



  - Feedline dynamic loads re-run using adjusted input levels for axial direction
  - Found significant increase in response
    - Axial loads up by a factor of 2.5
    - Primary frequency doubled, more cycles

OV-104 MPS LH2 FEEDLINE FLOWLINER CRACKS

Presenter: Doug White

Organization/Date: Orbiter/09-17-02

Rationale Developed to Clear Other MPS Feedline Hardware:

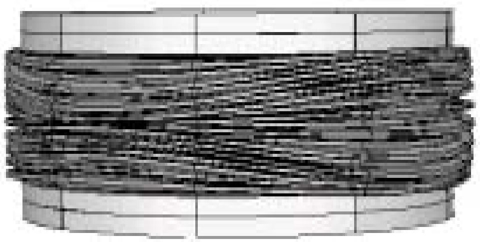
- Fatigue Critical Location on Gimbal Ring
  - Preliminary analysis cleared static margin by including plasticity effects but fracture analysis found less than 1 mission on ring or yoke
  - Analysis results inconsistent with observed flight data
  - Effort underway to reconcile the differences between the model and the real world

OV-104 MPS LH2 FEEDLINE FLOWLINER CRACKS

Presenter:
Doug White

Organization/Date:
Orbiter/09-17-02

Rationale Developed to Clear Other MPS Feedline Hardware:



2nd Vibration Mode of Bellows

- Bellows
  - Performed dynamic response analysis with pressure fields tuned to vibration modes
  - Fatigue analysis resulted in 51 missions of life with a scatter factor of 4

OV-104 MPS LH2 FEEDLINE FLOWLINER CRACKS	Presenter: Doug White
	Organization/Date: Orbiter/09-17-02

Rationale for STS-112 Flight:

- Repair welds return flowliners to near-print configuration
- Material coupon tests and bounding analysis provide >1 mission life to crack initiation with a scatter factor of 4
- Material coupon tests and bounding analysis provide ~6 missions of stable crack growth for undetectable cracks with a scatter factor of 2
- Most other components in the MPS feedline system potentially susceptible to combined environments loads have been reviewed/inspected and cleared for flight

Successful Completion of the Gimbal Ring and Yoke Analysis Is a Constraint to Flight

OV-104 MPS LH2 FEEDLINE FLOWLINER CRACKS

Presenter:
Doug White

Organization/Date:
Orbiter/09-17-02

Open Work for STS-114 Flight

- Flowliner NDE inspections following STS-112
- Fracture analysis development and / or stress analysis refinement to show acceptable life beyond a single mission

STS-112 NEGATIVE MARGIN FOR MPM LIFTOFF LOADS

Presenter:
Doug White
Organization/Date:
Orbiter/09-17-02

Observation:

- Analysis of STS-112 Lift-off Loads shows negative margin of safety for Manipulator Positioning Mechanism (MPM) Torsion Rod

Concern:

- Potential loss of ability to stow or deploy RMS for duration of mission
- Potential loss of arm restraint, permitting the arm to impact the radiator

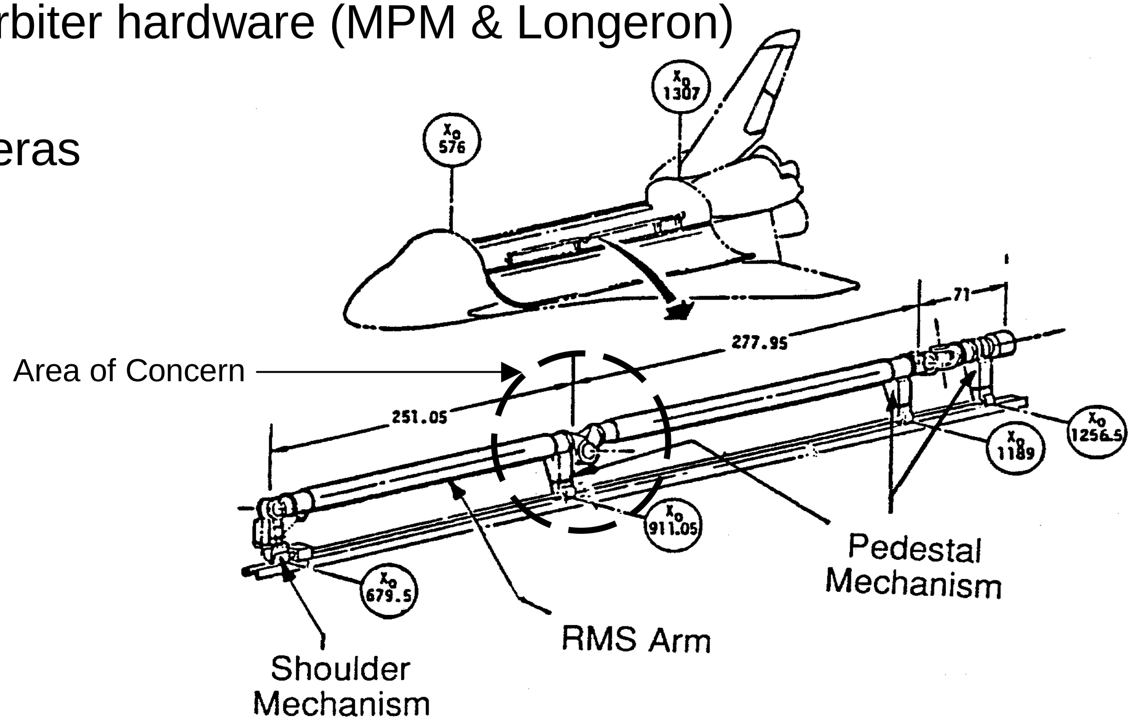
Discussion:

- Lift-off Loads are developed by Systems Integration as part of the Flight Margins Assessment (FMA) process to assess flight specific payload configurations
  - 800 case Monte Carlo set used to develop three sigma case
- Exceedances of Element-defined redlines are presented to Loads Panel for disposition
  - Redlines developed during Performance Enhancement certification

STS-112 NEGATIVE MARGIN FOR MPM LIFTOFF LOADS	Presenter: Doug White
	Organization/Date: Orbiter/09-17-02

Discussion: cont

- STS-112 analysis identified exceedances for MPM pedestal 1 +Mx (Xo 911)
- Dynamic base drive analysis performed to produce high fidelity loads for RMS and its attachments
  - Affected Orbiter hardware (MPM & Longeron)
  - RMS
  - RMS Cameras



STS-112 NEGATIVE MARGIN FOR MPM LIFTOFF LOADS

Presenter:
Doug White
Organization/Date:
Orbiter/09-17-02

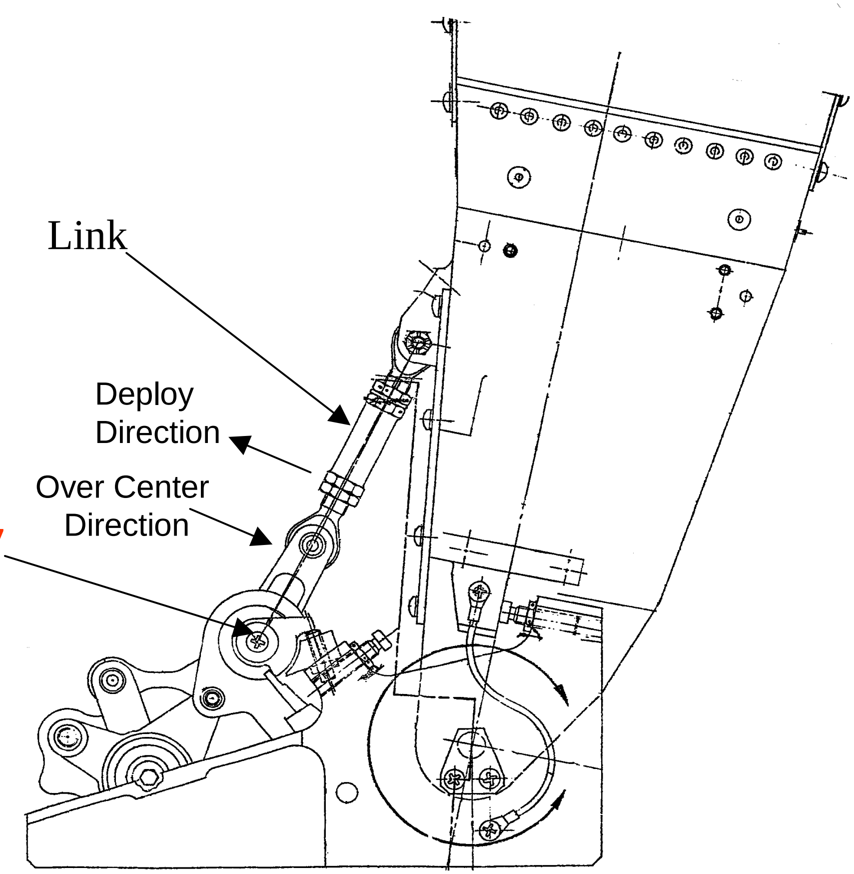
Discussion: cont

- Original stress analysis was refined in an attempt to clear all negative parts
  - Cleared negative margin on torque stop
  - Negative 7% margin identified for MPM torsion rod remained
  - RMS and RMS camera both have positive margin (NASA GFE evaluation)

STS-112 NEGATIVE MARGIN FOR MPM LIFTOFF LOADS

Presenter:
Doug White

Organization/Date:
Orbiter/09-17-02



STS-112 NEGATIVE MARGIN FOR MPM LIFTOFF LOADS

Presenter:
Doug White
Organization/Date:
Orbiter/09-17-02

Discussion: cont

- Researched stress analysis assumptions
  - Reviewed MPM static test report from 1983
    - Report showed that MPM test article failed after 14 seconds at 1.4 times the design load (passed test)
    - Failure occurred in the torsion rod (lowest-predicted-margin part)
  - Evaluated the analytical techniques
    - Found to be too aggressive and based on an erroneous assumption
- Based on the evidence above, the refined analysis indicated that the torsion rod negative margin grew from negative 7% to negative 21%
- Additionally, nonlinear deflection in the over-center mechanism will cause other parts (link, pins and bellcrank) to have negative margins
  - Over-center deflection is the most critical parameter

STS-112 NEGATIVE MARGIN FOR MPM LIFTOFF LOADS

Presenter:
Doug White
Organization/Date:
Orbiter/09-17-02

Discussion: cont

- Several options were considered:
  - Set up the MPM with an initial over-center on the low end of the spec (30mil +/-10)
  - Replace Inconel 718 torsion rod with one made of a stronger material (MP35N)
  - Reduce input loads (Loads Panel action)
  - Use a block/stop to limit the over-center deflection
- Reducing the initial over-center dimension to the lower end of the tolerance (30mil +/-10) to .020 regains a positive margin for the torsion rod
  - Margin for the link remains negative even with smaller initial over-center
- Changing torsion rod material to MP35N does not provide the strength for positive margin if over-center deflection is not limited

STS-112 NEGATIVE MARGIN FOR MPM LIFTOFF LOADS

Presenter: Doug White	
Organization/Date: Orbiter/09-17-02	

Discussion: cont

- Loads Panel reviewed loads for possible reduction in magnitude
  - Used increased damping profile previously defined for calculating RMS loads
  - Refined definition of three sigma load condition by increasing Monte Carlo case size from 800 to 3200
    - Resulted in a 1% reduction in load
  - Identified primary driver for MPM loads to be SRB Ignition Over Pressure (IOP) coupled with payload modes
  - Reviewed SRB IOP flight data since 1994 baseline
    - Addition of new flight data did not change 3 sigma IOP level
- Additional scrubbing did not produce a significant reduction in loads

STS-112 NEGATIVE MARGIN FOR MPM LIFTOFF LOADS	Presenter: Doug White Organization/Date: Orbiter/09-17-02

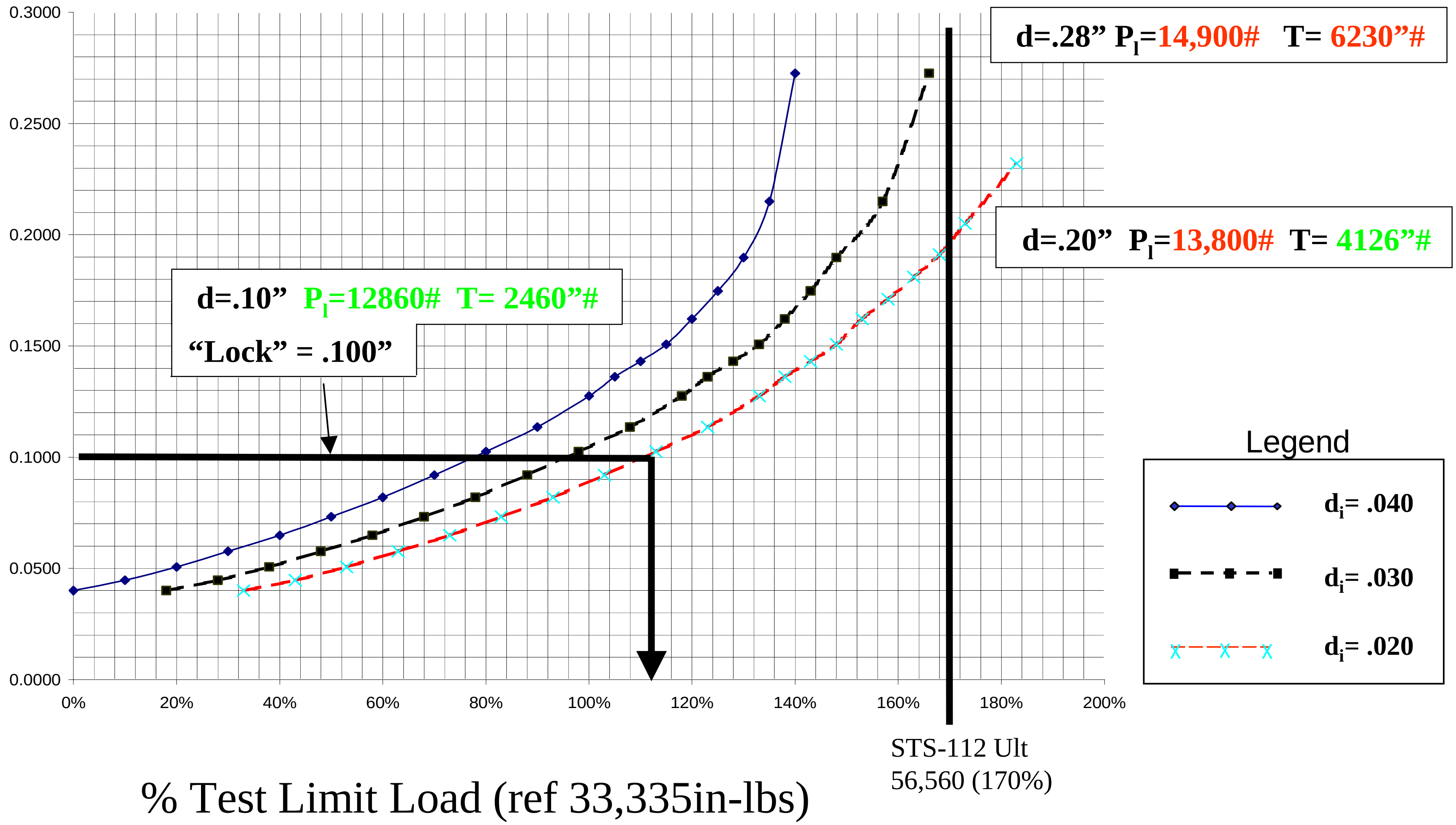
Discussion: cont

- Designing a block/stop to limit the over-center deflection (d) under liftoff loads became the only viable solution
- Limiting the total over-center deflection under load to 0.100" regains positive margins for all parts
  - Testing for SPIFEX payload established link allowable (P_l) of 13,400 lbs
  - Testing of MPM hardware in 1983 (STS84-0167) established torsion rod/stop allowable (T) of 4940 in-lbs (ultimate)
  - 1983 tests also established relationship of load to deflection in over-center direction (.040" initial)
    - Link loads also measured during test

STS-112 NEGATIVE MARGIN FOR MPM LIFTOFF LOADS

Presenter:
Doug White

Organization/Date:
Orbiter/09-17-02



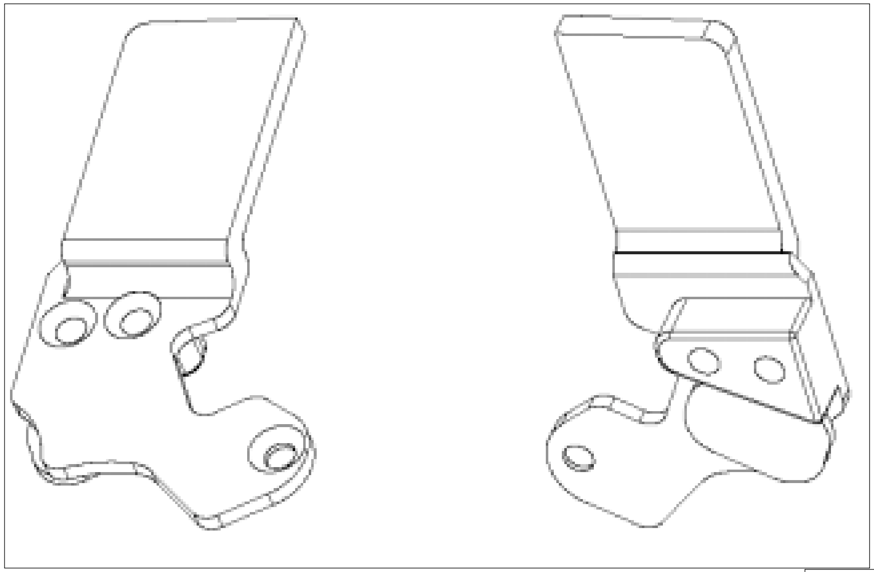
STS-112 NEGATIVE MARGIN FOR MPM LIFTOFF LOADS	Presenter: Doug White Organization/Date: Orbiter/09-17-02

Discussion: cont

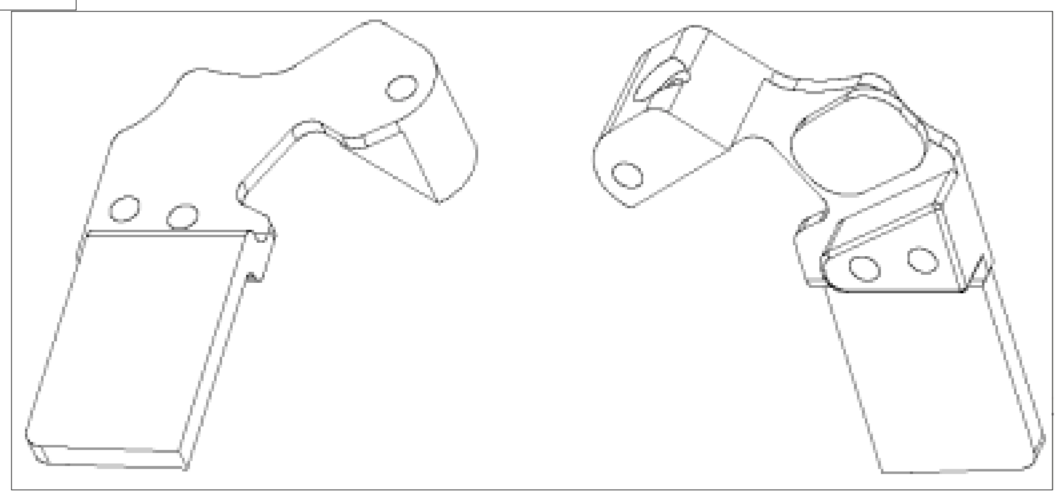
- Developed a block/stop to limit over-center deflection with the following features
  - Limits over-center travel
  - Does not interfere with any MPM motion
  - Does not require EVA to remove
  - Does not put a side load on link
  - Carries a 600 pound load
  - Able to install in vertical
  - Will not require MPM re-rigging or disassembly
- Team developed a Pro-Engineer CAD model with full, simulated MPM motion capabilities to develop and initially test the block/stop design
- Produced a plastic model to fit check on an MPM
  - Tested on MPM engineering unit and OV-105

STS-112 NEGATIVE MARGIN FOR MPM LIFTOFF LOADS

Presenter:
Doug White
Organization/Date:
Orbiter/09-17-02



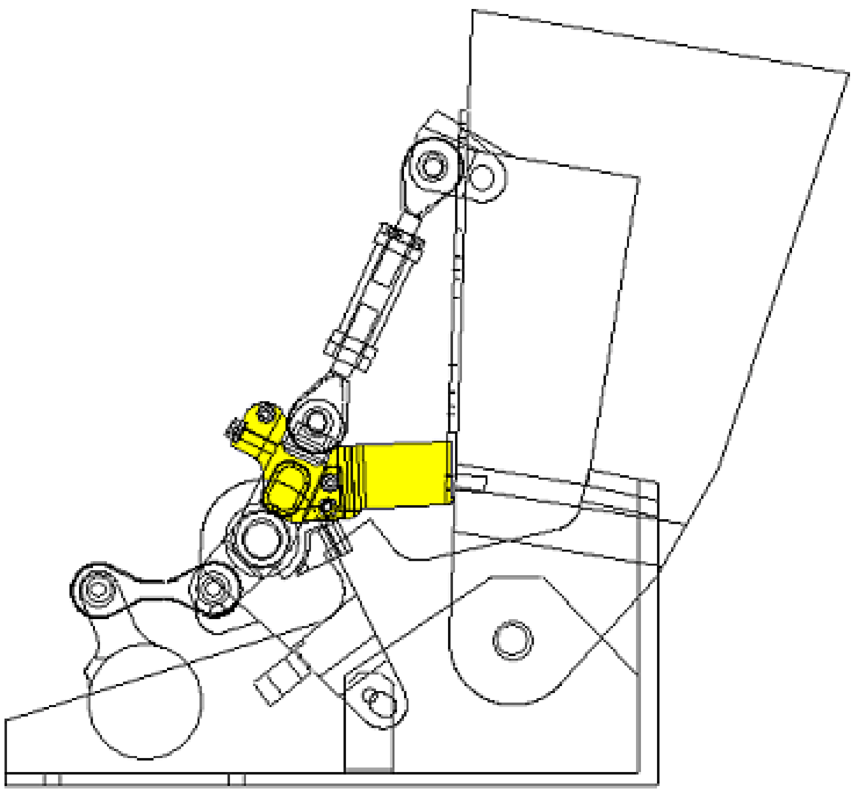
- Aluminum
- Size approx. 1.5" x 3.5" x 0.5"
- Mass 0.1lbm./per half



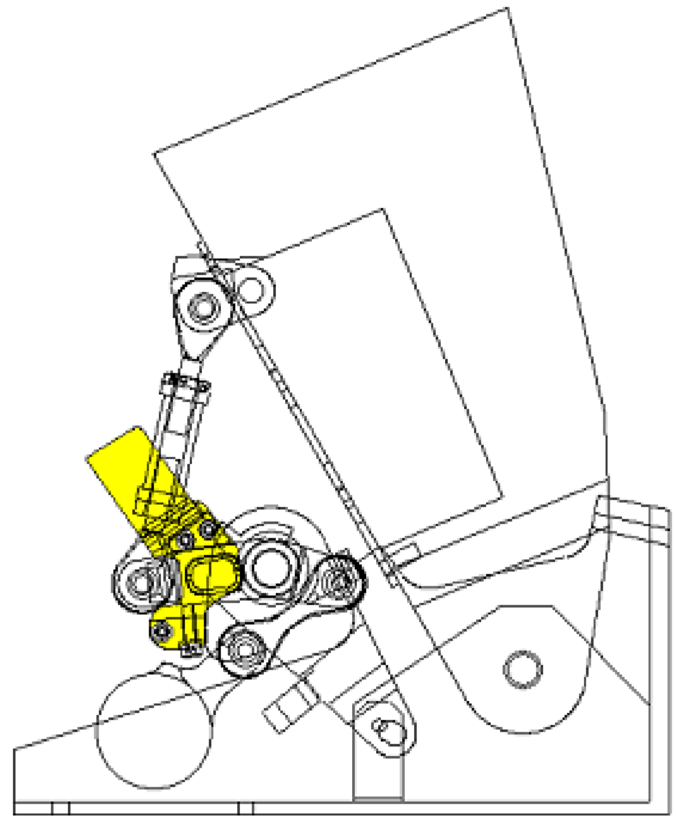
STS-112 NEGATIVE MARGIN FOR MPM LIFTOFF LOADS

Presenter:
Doug White
Organization/Date:
Orbiter/09-17-02

.2



.20” over center installation/launch configuration



Position with MPM Fully Deployed

STS-112 NEGATIVE MARGIN FOR MPM LIFTOFF LOADS	**Presenter:** Doug White
	Organization/Date: Orbiter/09-17-02

Discussion: cont

- MR certification by test and analysis
  - Fit and form demonstrated by test
    - Plastic part fit checked in lab and on OV-105
    - Functionally checked with 3 deploy/stow cycles after installation on pad
  - 1.4 factor of safety demonstrated by analysis
    - New assembly and affected load path (link, pins, bellcrank, torsion rod, and stop) are complete with +MS
- New assembly is designed for single flight use
  - Bellcrank will be inspected after flight for damage from set screw

STS-112 NEGATIVE MARGIN FOR MPM LIFTOFF LOADS

Presenter:
Doug White
Organization/Date:
Orbiter/09-17-02

- **Risk Assessment/Acceptability for STS-112 Flight:**
  - No flight or mission risk
  - New block/stop limits over-center deflection to control stresses and provides positive margin
    - Standard 1.4 factor of safety maintained for new part and existing parts in the MPM assembly
    - Requires no changes to operational procedures

	Presenter:
	Organization/Date: Orbiter/09-17-02

FLIGHT READINESS STATEMENT

SSVEO is Ready to fly STS-112

ORBITER
FLIGHT SOFTWARE
FLIGHT CREW
EQUIPMENT

____
P.E. Shack, Manager
Shuttle Engineering Office

s/D. Stamper
D. E. Stamper, TMR
Software

s/N. Cerna
N. Cerna, Manager
Flight Crew Equipment Management Office

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

ORBITER/FLIGHT SOFTWARE

s/B. Bemuk
B. I. Bejmuk, Program Director, Orbiter
NASA Systems
The Boeing Company

s/J. Wilder
J. Wilder, Associate Program Manager
Orbiter ElementUnited Space Alliance

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

FLIGHT CREW EQUIPMENT

s/J.F.Buchli
J.F.Buchli, FCE/EVA Associate
Program Manager
United Space Alliance

RMS

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

s/R. Allison
R. Allison, RMS Project Manager

SVS

s/L. Beach
L. Beach, Program Manager, SVS
NEPTEC

s/D.Moyer
D. S. Moyer, SVS Integration Office

FERRY FLIGHT PLANNING

s/D. McCormack
D. L. McCormack, Ferry Flight Manager

____
Ralph R. Roe, Manager
Space Shuttle Vehicle Engineering

	Presenter:
	Organization/Date: Orbiter/09-17-02

BACKUP INFORMATION

	Presenter:
	Organization/Date: Orbiter/09-17-02

STS-110
IN-FLIGHT ANOMALIES
BACKUP

STS-110-V-04: MEDS IDP 2 MSU BITE AND FCW BUFFER OVERFLOW ERROR

Presenter:

Organization/Date:
Orbiter/09-17-02

Observation:

- An FCW BUFFER OVERFLOW error was seen in MEDS downlist for IDP2 18 seconds after the crew powered off MDU PLT2
- Downlist data also showed that the FREEZE BIT in the IDP status response header word was set ON intermittently for the subsequent 33 seconds, and this was followed immediately by an “MSU FAILURE” error

Concern:

- Frozen (i.e., stale or erroneous) data on DPS display could lead to loss of vehicle – (ref. CIL 05-3A-IDP-02)

STS-110-V-04: MEDS IDP 2 MSU BITE AND FCW BUFFER OVERFLOW ERROR

Presenter:
Organization/Date: Orbiter/09-17-02

Discussion:

- Analysis revealed that the FCW BUFFER OVERFLOW error and the frozen DPS display were a result of how the IDP SW responds to this MSU FAILURE error
  - Data retrieved post flight
    - MSU FAILURE was a "Status Phase Error"
    - Indicates communication between the IDP SW and the MSU was "hung", i.e., both were waiting for response from the other
  - Present MSU communications is an intermediate task
    - Between foreground tasks run cyclically every 40 milliseconds
    - Background tasks scheduled for the unused portion of the 40 ms cycle
  - DPS displays (Green Screen) is a background task
- Crew was unaware of the frozen display

STS-110-V-04: MEDS IDP 2 MSU BITE AND FCW BUFFER OVERFLOW ERROR	Presenter:
	Organization/Date: Orbiter/09-17-02

Discussion: cont

- This MSU error (Protocol Failure: Status Phase Error) has only been seen in the field 3 times before (IDPs – 116,-118 & -131)
  - IDP-116 single occurrence found in SAIL VM Dump (Nov 2000)
  - IDP-118 single occurrence found in SAIL VM Dump (June 1999)
  - IDP-131 single occurrence found in MSU idp.ost file while investigating unrelated EEPROM anomaly at SMS (October 2000)
    - Believe this error occurred several months earlier since the IDP software version identified in the log was an earlier IDP software version
  - Unlike the STS-110 occurrence, an FCW BUFFER OVERFLOW error was not observed in these incidences
  - No re-occurrence of a Protocol Failure has been reported by any of these non-flight IDPs or the STS-110 IDP
- All four occurrences have been transient and cleared
- Normal IDP operation not dependent on MSU operation

STS-110-V-04: MEDS IDP 2 MSU BITE AND FCW BUFFER OVERFLOW ERROR

Presenter:

Organization/Date:
Orbiter/09-17-02

Actions Taken:

- Incorporated code change in IDP SW VI 3.01
  - IDP SW modification results in meeting the implied requirement, “Attempts to access the MSU shall not prevent the processing of any IDP SW capability”
    - MSU services task are now a background task and will be run as the last task in background processing for each minor cycle
    - MSU services task executes only if the foreground task and all other background tasks have completed
  - Anomalous MSU/SCSI communications can no longer preclude background tasks from executing
  - IDP SW VI 3.01 loaded into OV-104 July 25, 2002

STS-110-V-04: MEDS IDP 2 MSU BITE AND FCW BUFFER OVERFLOW ERROR	Presenter:
	Organization/Date: Orbiter/09-17-02

Risk Assessment:

- Frozen (i.e. stale or erroneous) data on DPS display could lead to loss of vehicle (ref. CIL 05-3A-IDP-02)
- Mission phase dependent and varies from benign to safety of flight
  - Crew has no visibility into problem occurrence
  - Potential exists for an inappropriate crew response during time critical situation
  - Could lead to loss of crew/vehicle

Acceptable for STS-112 Flight:

- Change has been incorporated in IDP SW VI 3.01
  - Change lowers the MSU services task priority to a priority that is lower than any other IDP SW task
  - Software installed on OV-104 and successfully tested

STS-110 RCS THRUSTER FAILURES

Presenter:

Organization/Date:
Orbiter/09-17-02

Observation:

- Three RCS thruster anomalies occurred during the STS-110 mission
  - Thruster L1A failed off during NC3 burn
  - Thruster F1D had several low chamber pressure pulses during rendezvous ops
  - Thruster F3L experienced two low chamber pressure pulses during post-undocking ISS fly-around

Concern:

- Loss of RCS thruster redundancy
- Unknown worst case consequence of continued operation of thruster with low chamber pressure

STS-110 RCS THRUSTER FAILURES

Presenter:

Organization/Date:
Orbiter/09-17-02

Discussion:

- **Summary of thruster anomalies**

	L1A (S/N 215)	F1D (S/N 484)	F3L (S/N 411)
Fault	Failed off	3 Consecutive Low Pc, 80 ms Pulses	2 low Pc 80ms Pulses
Chamber Pressure	Max 20 psia	63-65 psia	65 and 69 psia
Fault Consequence	Deselected for remainder of mission	Not deselected by RM Pc>26psia	Not deselcted by RM Pc>26psia
Fuel/Ox flow confirmed	Yes. Drop in injector Temps	Yes. Drop in injector Temps	Yes. Drop in injector Temps
Flight History	5th thruster / 9 Ox and 23 fuel vlv	5th thruster /16 Ox and fuel vlvs	5th thruster / 18 Ox and 5 fuel vlv

STS-110 RCS THRUSTER FAILURES

Presenter:
Organization/Date: Orbiter/09-17-02

Actions Taken:

- Sluggish valve identified as most likely cause of the two low Pc anomalies through fault tree analysis
  - Failure mode outside of historical database
  - Previous testing of valve mismatch up to 40 ms lag showed no problems with thruster
  - Unknown effect with degraded valve mismatch
    - Worst case scenario is ox vapor to migration into fuel injector holes for fuel valve lag and subsequent reaction
  - Valve mismatches up to 280 ms would not result in RM deselection of the thruster
- Valve mismatch test performed at WSTF
  - Determine effect of increasing valve lag time > 40 ms
  - Determine sufficiency of RM to protect for sluggish valves
  - Establish Pc vs. lag baseline – correlate to flight data

STS-110 RCS THRUSTER FAILURES

Presenter:

Organization/Date:
Orbiter/09-17-02

Actions Taken: cont

- Valve mismatch test showed no detrimental effect to thruster
  - Varied lag time from 40 ms to 280 ms on fuel and ox valves for 80 and 320 ms pulses
  - Monitored several test parameters to determine if any reactions in injector occurred (Pc, manifold pressures, valve accelerations and injector temperatures)
    - Nominal thruster performance seen on each pulse other than expected start-up delay
    - No manifold or Pc spikes seen and no leakage occurred on either fuel or ox valves
  - Additional tests performed with increased lag times for an 80 ms pulse to attempt to duplicate low Pc condition
    - Low Pc indications (~40 – 80 psia) seen with 60 ms lag
- Concluded that valve mismatch up to 280 ms does not result in thruster damage
  - RM sufficient to deselect thruster for lags > 280 ms

STS-110 RCS THRUSTER FAILURES

Presenter:

Organization/Date:
Orbiter/09-17-02

Actions Taken: cont

- STS-110 thruster failure analysis
  - Performed valve GN2 response tests
  - Conducted hot-fire tests
    - With helium saturated propellants (approximate flight condition)
    - With unsaturated propellants (normal ATP condition)

ENGINE	FAILURE MODE	GN2 RESPONSE		HOT-FIRE TEST RESULTS	
		OX VLV	FU VLV	SATURATED PROPELLANTS	UNSATURATED PROPELLANTS
F1D S/N 484	Low-Pc	Pass	Did not open	Ox valve response was nominal, fuel valve was delayed by ~40 msec	Ox valve response was nominal, fuel valve was delayed by 15-20 msec
F3L S/N 411	Low-Pc	Pass	Did not open	Ox valve response was nominal, fuel valve was delayed by ~40 msec	Both valve responses were nominal
L1A S/N 215	Fail-off	Pass	Did not open	Ox valve response was nominal, fuel valve was delayed by ~40 msec	Both valve responses were nominal

STS-110 RCS THRUSTER FAILURES

Presenter:

Organization/Date:
Orbiter/09-17-02

Actions Taken: cont

- Failure analysis conclusions
  - F1D, F3L and L1A fuel valve have extruded pilot seals based on GN2 response results
  - Saturated propellants appear to further degrade extruded fuel valve response as compared to unsaturated propellants
  - Hot-fire tests confirmed valve sluggishness (due to extrusion) was the cause for the low-Pc observed on F1D and F3L
  - Worst case effect of a low-Pc thruster (60-100 psia) would be possible future fail-off
- Reviewed history of OV-104 thrusters
  - 11 of 38 thrusters replaced this flow due to STS-110 R&Rs
  - No evidence of performance problems on any OV-104 thruster currently installed during last GN2 response test at WSTF
- Analyzed propellant samples from OV-104 RCS manifolds/tanks
  - Propellant samples met specification requirements

STS-110 RCS THRUSTER FAILURES

Presenter:

Organization/Date:
Orbiter/09-17-02

Risk Assessment:

- Failed off/leak thruster is Crit 1R/3
  - Redundant thrusters exist in all firing directions
- No adverse impact of thruster utilization with low Pc due to sluggish valve
  - Valve mismatch tests showed that a sluggish valve does not result in hardware damage
  - RM is sufficient to deselect thruster with worst case valve mismatch
  - Flight rules require thruster with low Pc to be put in last priority - will only be used if other thrusters fail
  - Worst case of sluggish valve operation due to seal extrusion is a fail-off

STS-110 RCS THRUSTER FAILURES

Presenter:

Organization/Date:
Orbiter/09-17-02

Risk Assessment: cont

- Risk mitigation actions are in place to reduce failures
  - Preventative maintenance flushing performed on all primary thrusters at OMDP, as well as those used for in-flow replacements
  - Full manifold R&R required for any thruster removal to preclude collateral damage
  - GN2 chamber purge implemented during turnaround operations to reduce propellant vapor build-up
  - Molecular sieve of oxidizer implemented at KSC
- Thruster processing team evaluating cause of extrusion (reported results 8/23)

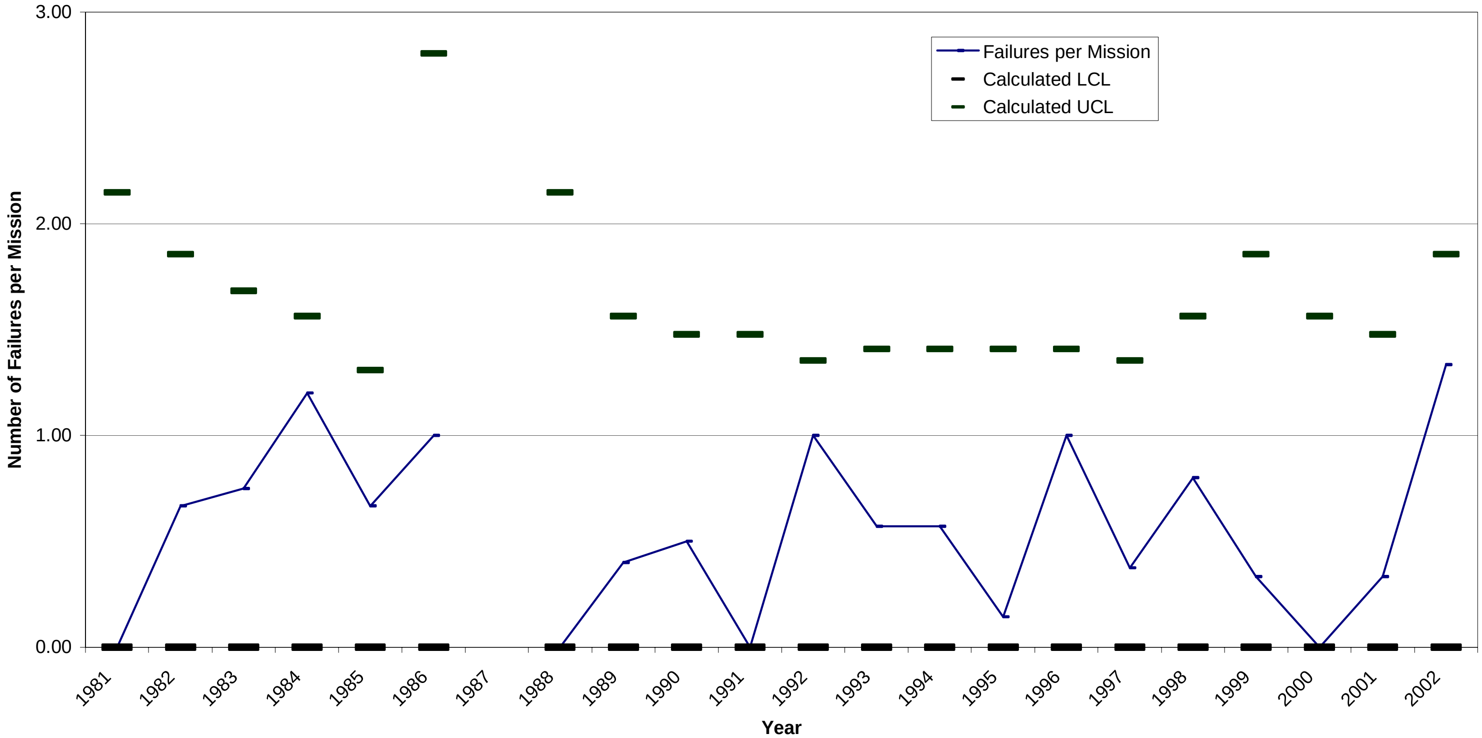
STS-110 RCS THRUSTER FAILURES	Presenter:
	Organization/Date: Orbiter/09-17-02

Acceptable for STS-112 Flight:

- No history of marginal performance on any OV-104 thruster during last GN2 response test at WSTF
- WSTF test data showed no adverse impact of thruster utilization with low Pc caused by sluggish valve operation
  - RM is sufficient to deselect thruster with valve lags beyond the test database
- Redundant thrusters exist for each firing direction
- Flight rules exist for failed off thrusters
- Not a safety-of-flight issue
- Risk-mitigation actions in place to reduce failures

RCS THRUSTER FAILURE HISTORY	Presenter:
	Organization/Date: Orbiter/09-17-02

RCS Thruster Failure History Control Chart (Variable Sample Size)



	Presenter:
	Organization/Date: Orbiter/09-17-02

CONFIGURATION CHANGES AND CERTIFICATION STATUS

BACKUP

CONFIGURATION CHANGES AND CERTIFICATION STATUS

Presenter:

Organization/Date:
Orbiter/09-17-02

OV-104 STS-112 Modifications and Certification

MCR/Modification	Certification Method			Certification Approval Request No.	Approval Date	Remarks
	Test	Analysis	Similarity			
MCR 19343 MPLM T-0 Data Scar Wiring Implementation				N/A *	N/A	* Previously certified materials and processes.

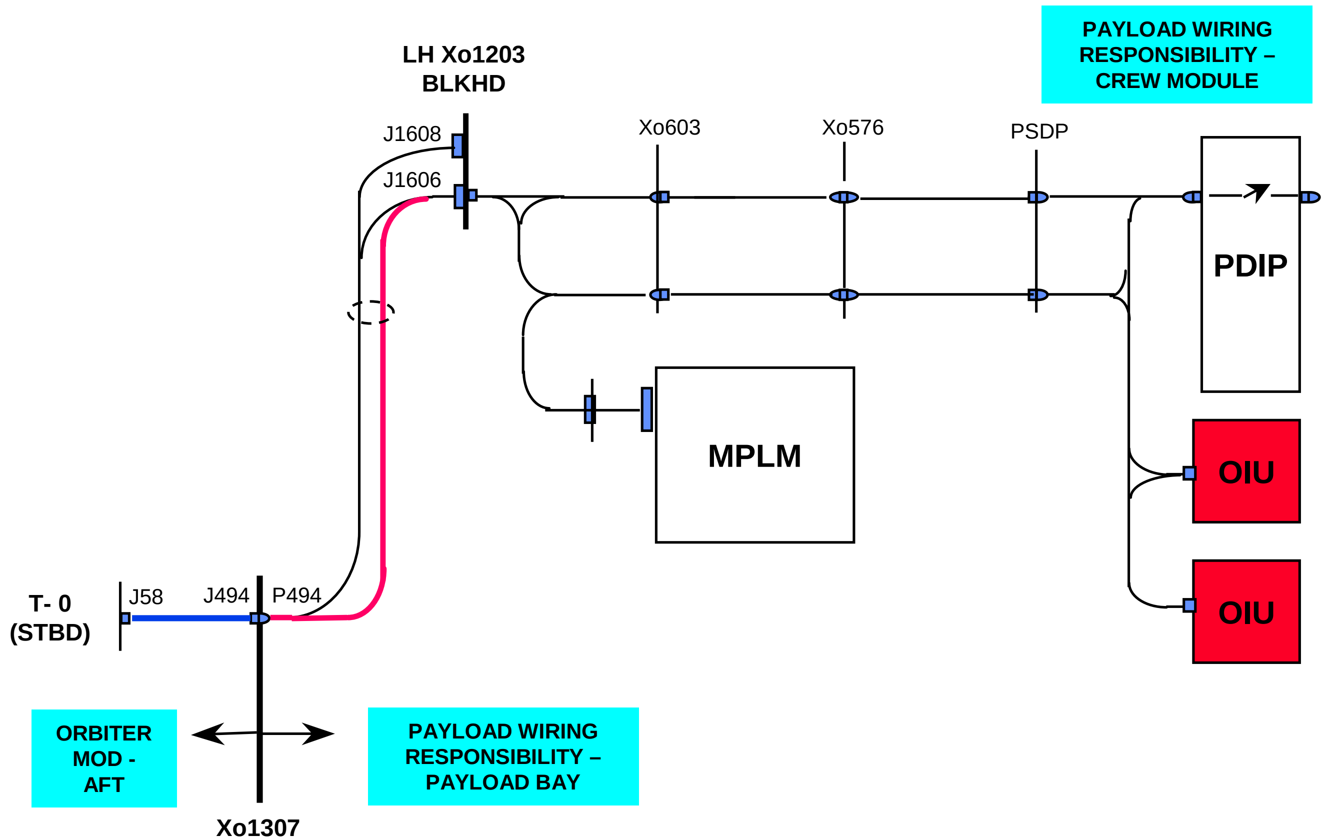
- The Multi-Purpose Logistics Module (MPLM) is a cargo element for transporting and transferring supplies and materials to the International Space Station
  - Future flights of the MPLM will provide capability to transport perishable materials requiring refrigeration
  - Thus, Orbiter and Payload Integration modifications will be required to provide active cooling for the MPLM during flight and ground processing, which include vehicle and T-0 umbilical modifications to provide MPLM dedicated 120v power and 1553 data wiring paths
- MPLM requires power and command / data handling services provided by the OPF, MLP and the MPLM Service Vehicle (MSV), a mobile control room which will be a part of the landing convoy
  - Routing of the power and command / data wiring will be joint responsibility
    - Payload Integration has responsibility of wiring from the MPLM / ROEU location in the payload bay to the Xo 1307 bulkhead
    - Orbiter has responsibility of wiring in the aft from the Xo 1307 bulkhead to the starboard T-0 umbilical and the modifications to the T-0 umbilical
      - Aft fuselage data line scar wiring installed this flow
    - Ground Ops will provide the ground side wiring from the T-0 umbilical in the OPF, for the MLP and for the landing convoy MSV (T-0 to the existing purge trailer and ultimately to the MSV)
- Ground Ops and payload integration requested early verification and checkout of the T-0 data wiring concept prior to the first actively cooled MPLM flight, which will be accomplished during this processing flow in the OPF and at the PAD via chits J5463 and J5464

CONFIGURATION CHANGES AND CERTIFICATION STATUS

Presenter:

Organization/Date:
Orbiter/09-17-02

MPLM T-0 Data and Power Scar Wiring Implementation



CONFIGURATION CHANGES AND CERTIFICATION STATUS

Presenter:

Organization/Date:
Orbiter/09-17-02

OV-104 STS-112 Modifications and Certification

Process Improvements

MCR/Modification	Certification Method			Certification Approval Request No.	Approval Date	Remarks
	Test	Analysis	Similarity			
MCR 19560 FRCS Thermal Clip Deletion		X		CAR 137-01-320101-058H	3/8/02 A	• Deletes thermal transfer clips from the interface between the FRCS module and lower forward fuselage • Installation of these 477 clips is a time consuming process during FRCS mate • Thermal analysis indicates that the clips are not required and their removal will not cause structural thermal gradient concerns • Work savings process improvement for ground ops

CONFIGURATION CHANGES AND CERTIFICATION STATUS

Presenter:

Organization/Date:
Orbiter/09-17-02

OV-104 STS-112 Modifications and Certification

Corrective Action Mandatory

MCR/Modification	Certification Method			Certification Approval Request No.	Approval Date	Remarks
	Test	Analysis	Similarity			
MCR 19527 Critical Wire Redundancy Separation				N/A *	N/A	* Previously certified materials and processes.

Background:
- In 129 instances across the fleet, redundant wiring for crit 1 functions were routed together in common wire harnesses
  - 107 affected areas on OV-105 (OV-103 & subs) - 22 being unique to OV-102
  - Increased risk of system failure - loss of single wire harness could result in the loss of a critical function
  - Condition previously waived
- As part of the corrective actions from the fleet wiring investigation, it was determined these wires should be separated
  - Primary option was to separate redundant wires into separate existing or new harness runs
  - Secondary option was to separate redundant wires within a bundle using barrier material (i.e. convoluted tubing, teflon or mystic tape
  - Correction was not implemented if the determination was made that there would be significant risk to damaging wiring in the rework area versus benefit of the separation, or if major rework/redesign was required to accomplish(i.e. guillotines & hinged D&C panels)

Modification Performed This Flow:
- During paper closeout for STS-110 it was found that a clamp behind the MA73C panel may have inadvertently been left out
- Modifications confirms or installs clamp as required

CONFIGURATION CHANGES AND CERTIFICATION STATUS

Presenter:

Organization/Date:
Orbiter/09-17-02

OV-104 STS-112 Modifications and Certification

Corrective Action Mandatory

MCR/Modification	Certification Method			Certification Approval Request No.	Approval Date	Remarks
	Test	Analysis	Similarity			
MCR 17177 OME engine bolt change				17-12-621-0009-0001O	N/A	* Six for the OME fuel flange assembly will be changed out

Background

- During OMS engine scheduled maintenance at WSTF, there were two instances of bolts shearing off while being torqued up to required torque
- Investigation found the fuel torus bolts were being being run up to >80% ultimate
- OMS engine recently incorporated a seal design modification
  - Change from Omni to V seal
  - OMS fuel torus flange was analyzed by similarity
- Corrective action
  - Revisited analyses on fuel torus joint when seal replacement was performed
  - Replaced existing fuel torus bolts with higher strength bolts
  - Reduced fuel torus bolt torque enough to ensure both adequate seal and bolt strength margins
  - Created a new engine configuration (V598-430001) to reflect changes

Modification performed this flow

- Certification Approval Request 17-12-621-009-0001O was approved on 09/XX/02
  - CAR adds new engine configuration which requires higher strength bolts and lower torque for bolts on fuel torus

CONFIGURATION CHANGES AND CERTIFICATION STATUS

Presenter:

Organization/Date:
Orbiter/09-17-02

OV-104 STS-112 Modifications and Certification

Corrective Action Optional

MCR/Modification	Certification Method			Certification Approval Request No.	Approval Date	Remarks
	Test	Analysis	Similarity			
MCR 19112 Wirless Video System (WVS) Spread Spectrum Transceiver Upgrade				N/A *	N/A	* No Boeing certification impact – transceiver and associated certification is GFE responsibility • Original WVS system UHF operating frequency band of 400.2 MHz was limited by the FCC through July 2002. • Mod established upgraded GFE ORCA-XCVR-11 WVS transceivers with a UHF operating frequency band of 400.15 to 401 MHz, approved by the FCC for permanent utilization • Replaced the original ORCA-XCVR-01 • Boeing installation drawings and ICD updated to reflect the new GFE transceivers • Also cutout will be performed on Shelf 5 to allow easier access to transceiver connectors

CONFIGURATION CHANGES AND CERTIFICATION STATUS

Presenter:

Organization/Date:
Orbiter/09-17-02

OV-104 STS-112 Modifications and Certification

Corrective Action Optional

MCR/Modification	Certification Method			Certification Approval Request No.	Approval Date	Remarks
	Test	Analysis	Similarity			
MCR 17177 FRCS Attach Bolt Torque Class Revision			X	138-01-320101-058H	4/8/02 A	

- The FRCS is attached to the forward fuselage at 16 locations.
  - 6 locations in the X direction – 4 locations at the aft bulkhead and 2 locations at the forward bulkhead
  - 10 (5 RH / 5 LH) locations in the Z direction at the FRCS lower sill and the lower forward fuselage sill mating surfaces
- The 10 Z direction attachment is accomplished by using bolts that fasten through the FRCS into cone bolts in the lower forward fuselage
  - The cone bolts contain a threaded female feature in the cone that receives the mating bolt
- It was found during a recent inspection of OV-102 that 4 of the 10 cone bolts had less than the required installation torque
- Investigation revealed that the cone bolt installation torque is to class 1 and the FRCS mating bolt is to class 3
  - It was suspected that removal of the FRCS mating bolts at the higher installation torque than the cone bolt installation torque could cause the loss of torque on the cone bolts
- The design change was to change the installation torque of both the cone bolts and the FRCS installation bolts to a class 2 torque to preclude this condition
  - FRCS installation OMI to be revised to require cone bolt torque verification prior to module installation

CONFIGURATION CHANGES AND CERTIFICATION STATUS

Presenter:

Organization/Date:
Orbiter/09-17-02

OV-104 STS-112 Modifications and Certification

Corrective Action Optional

MCR/Modification	Certification Method			Certification Approval Request No.	Approval Date	Remarks
	Test	Analysis	Similarity			
MCR 18755 Lightweight TSA Tool Retention Enhancement Mods Mission Kit MV0849A			X	01-25—849-660516-001G		• Tray modification to provide for new tool set • Different configuration on the way up
MCR 11620 P/L Bay Door drive rod fabric c/o covers				N/A		• Modifies PL Bay Door Drive Rod penetration closeouts by impregnating one side with RTV and installing fabric closeout covers. • Four locations were completed during this flow
MCR 17177 MPS Helium Tank Gap Verification				N/A		• Verifies gap between the anti-rotation arm and the adjusting bolt head is .00” to .002”
MCR 17177 Removal of Flight Caps				N/A		• Remove QD dust cap req’ts for ground coolant QDs . No technical reason for QDs to remain installed.

CONFIGURATION CHANGES AND CERTIFICATION STATUS

Presenter:

Organization/Date:
Orbiter/09-17-02

OV-104 STS-112 Modifications and Certification

Corrective Action Optional

MCR/Modification	Certification Method			Certification Approval Request No.	Approval Date	Remarks
	Test	Analysis	Similarity			
MCR 18755 Sky Genie Installation Fastener Change Mission Kit MV0607A			X	25-661607-001E	5/3/02	• Crushed sky genie pouch fastener installation grommets were observed prior to OV-105's previous mission • Attributed to torque engagement of fully-threaded screws • MR repairs have utilized over-sized washers • For STS-112, grommets have been repaired (returned to print) and installation fasteners changed to shoulder bolts to prevent grommet
MCR 18755 MA9N Frame Configuration Change First Flight			X	03-25-000907-001B	7/29/02A	• Interference problem exits between the MA9N frame and the adjacent LW locker MA16N making it difficult to install/remove the frame and to open the locker door.
MCR 19648 FRCS RTV Installation First Flight				N/A		• It has been determined via chit that the bulb seal provides an adequate seal between the FRCS and the orbiter on OV-104 as such the RTV application has been made optional

CONFIGURATION CHANGES AND CERTIFICATION STATUS

Presenter:

Organization/Date:
Orbiter/09-17-02

OV-104 STS-112 Modifications and Certification

Corrective Action Optional

MCR/Modification	Certification Method			Certification Approval Request No.	Approval Date	Remarks
	Test	Analysis	Similarity			
MCR 23070 Ferry Kit ET Door Modification First Flight			X	102-03-355130-001B	1/24/02	• During post flight inspection of the ET Ferry door attach point #7 a crack was observed. A new attach point was added at position #8.
MCR 19648 OV-103 Aft Ballast Shim Concern				N/A		• During vehicle inspections following OV-103 flight 29, a ballast was found outside the shim box. Hi-Locks have been added to the shim box
MCR 23077 ForwardOrbiter ET Attach Fitting Stud Redesign First Flight			X	08-45-5620010	10/15/01	• Post-Flight Inspection of OV-103s FWD ET Attach Point area revealed a crack in the attach fitting. Mod replaces the current stud design to an oval stud to eliminate damage to the structure

	Presenter:
	Organization/Date: Orbiter/09-17-02

SPECIAL TOPICS

BACKUP

	Presenter:
	Organization/Date: Orbiter/09-17-02

IMU SPECIAL TOPIC BACKUP

IMU-2 Z-Redundant Gyro Degradation

Presenter:

Organization/Date:
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COMMENTS: ARROW SHOWING LOCATION OF BROKEN PIN 8 EXIT LEAD WIRE ON 46 SLIP RING.

IMU-2 Z-Redundant Gyro Degradation

Presenter:

Organization/Date:
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IMU GYRO STATUS

HAINS NO.	FLTS	Operate HOURS (EST.)	LOCATION	GYRO CHNG.	ETI at CHNG	PLATF S / N	VERT GYRO S/N	VERT GYRO HRS	AZIM. GYRO S/N	AZIM. GYRO HRS	OLD VERT	OLD AZ
198(NF)	0		KG&N	Feb-93		102	2072		1820			1042^
199(NF)	0		ISL	Jul-96		101	1062		4115			1165^
200	15	5471	B/BS	Jul-91	1082	106	1849	*	1795			1831^
201	8	5326	KSC	Dec-97		103	5029!		6014!		1861^	1828-
202	10	5632	KG&N	Nov-95	931	120	4371		4394			
203	14	3715	OV-104-1	Jun-90		108	4086	*	4022	*		
204	1	4792	KG&N	Jun-98		109	6015!		940		4600-	
205	14	4600	OV-102-1	Jul-90		105	1325	*	1205	*		
206	0	0	B/BS		2323							
206a	0	2951	B/BS	Jul-90	1782	107	4051		4028			
207	16	4720	KG&N	Aug-90		114	4008	*	4763	*		
208	14	5758	OV-104-2	Oct-97		113	7041!		4961!		4095-	4123-
209	6	3147	OV-102-2	Aug-91		115	4063	*	4704	*		
210	8	4691	KG&N	Aug-97		119	5246#		6018!		4109^	4098
211	5	3539	OV-102-3	Mar-91		118	4059	*	4757	*		
212	13	4696	OV105-1	Dec-95		112	4620#		4078	*	4067^	
213	13	5385	OV-105-2	Aug-91		111	4036	*	4114	*		
214	7	4633	B/BS	Nov-91		110	4057	*	4753	*		
215	4	4993	OV-104-3	Mar-98		117	6017!		6113&		4082	4706
216	14	4561	OV105-3	Aug-91		116	4116	*	4727	*		
SPARE	0	2323	KG&N	Apr-00	2323	104	6115&		6124&		1732^	1499^
TOT =	162	80933										

NOTES: 1) GYRO HOURS SHOWN ARE AFTER IMU INSTALLATION
2) GYRO CHANGE DATE IS KEARFOTT SHIPMENT DATE
3) * = GYRO HOURS SAME AS IMU OPERATE HOURS
4) ^ = GYRO DISASSEMBLED FOR FAILURE ANALYSIS
5) - = MARGINAL GYRO- DONT RE-USE
6) # = 1992 DELIVERY GYRO
7) ! = 1997 DELIVERY GYRO
8) & = 1998/99 DELIVERY GYRO

OV-102		
OV-103		
OV-104		
OV-105		
KG&N		
B/BS		
KSC		

Update 8/27/02 File: Gyro20827

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BOEING

USA United Space Alliance

	Presenter:
	Organization/Date: Orbiter/09-17-02

SAFETY, RELIABILITY AND QUALITY ASSESSMENT

SAFETY, RELIABILITY AND QUALITY ASSESSMENT	Presenter:
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SR&QA Has Performed a Comprehensive Evaluation of Baseline Risk Documentation and Change Documentation

Data Developed/Reviewed Includes:

- Orbiter Vehicle End-Item (OVEI) waivers
- FMEA/CILs
- Hazards
- OMRSD waivers/deviations, RCNs, and LCNs
- Change requests including software change notices
- IFAs and UAs
- Configuration Management Support
- Certification
- GIDEP ALERTS

SAFETY, RELIABILITY AND QUALITY ASSESSMENT	Presenter:
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System Safety

- There are no open Hazard Reports (HRs) for this mission

Reliability

- There are no open FMEA/CILs for this mission
- There are currently two open GIDEP ALERTs for this mission

Quality

- No significant issues to report

Pending completion of identified open work, there are no other known issues or concerns related to Safety, Reliability & Quality

SAFETY, RELIABILITY AND QUALITY ASSESSMENT

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GIDEP ALERTS

Alert No	Log Date	General Class	MFR Names	Part No	Due Date	QE Actn	NASA/ JSC	S_C
KP4-A-02-01	8-26-02	Universal Eyebolt	R.H. Froom & Company, Inc.	1182	9-16-02		*	M
E8-A-02-01	9-9-02	Inductor, Surface Mount, Leadless	Vanguard Elect.	93027-005	9-16-02			E

SAFETY, RELIABILITY AND QUALITY ASSESSMENT

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Analysis / Assessment Section

No	Title	Hazard Impact	FMEA/CIL Impact	SR&QA Closure
1.	STS-110 MEDS IDP MSU BITE and FCW Buffer Overflow Error. As a result of this status phase error, the DPS display was frozen.	ORBI 211 "Landings Which Exceed Design Limits Can Result in Loss of Crew and Vehicle" CAUSE 'A' Loss Of Guidance, Navigation And Control (GN&C) Functions or Failure of Onboard Landing Aids Due to Temperature Variation, Excessive Vibration, Mechanical Shock, or Piece Part Failure.	05-3A-IDP-02, 1/1, Erroneous Output 05-3A-IDP-01, 1R3, Loss Of Output	Potential loss of vehicle if display freezes during RTLS power pitch down and the crew could make an inappropriate response. Software code change was made in IDP making the MSU services a background task with the lowest priority so as to not cause any future anomaly. IDP SW VI 3.01 was loaded on OV-104 and successfully tested.
2.	Hydraulic Main Pump Mounting Flange Washers. The concern is that over time, cupped or bent washers may relax and result in loss of preload with subsequent failure of the APU-to-pump joint resulting in hydraulic fluid leakage.	ORBI 250 "External Leakage from the APU Fuel Feed System "	02-6-E06-01, Pump, APU Driven Main Hydraulic, Will not pressurize, CRIT 1R2 02-6-E06-03, Pump, APU Driven Main Hydraulic, Inability to maintain system pressure on demand, CRIT 1R2.	Reduced preload can result in higher effect of load cycles and possible reduction of fatigue life, but not instant pump failure. Incorporated washer mod on OV-104. This safety issue is closed for STS-112.

SAFETY, RELIABILITY AND QUALITY ASSESSMENT

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No	Title	Hazard Impact	FMEA/CIL Impact	SR&QA Closure
3.	IPR 110V-0067 newly designed MMU-1/SSR S/N 104 showed power cycle indications during power-up for recording. Single Computer Board S/N 20 removed and tested OK. Further testing of MMU S/N 104 found the problem was with the capacitor. Capacitor R&R for failure analysis. System Safety prepared a Fault Tree to aid in trouble-shooting.	No Hazard Report (See CAR AE2250) LCC requires 1 of 2	CRIT 2R/3 non-CIL	Testing showed a pulse input (192 microsecond) from the comparator. Normally the Power-On-Self-Test occurs when there is a power cycle or VME A/C failure signal input transient voltage for 215 milliseconds. Previous testing had not picked up the short spike. Either the capacitor was wide open or did not participate in the time-constant (energy hold-up card holds the charge until data is routed to flash memory, then allows shutdown). New MMU checks OK, as well as all other MMUs. Not an issue for STS-112.
4.	OV-104's thrust structure upper strut bearings found not swaged and coming out of position. Further displacement of these bearings could result in inadequate factor of safety	ORBI 277A "Loss Of Vehicle Caused By Loss Of Structural Integrity", Cause 'A'	No structural CILs	OV-104 thrust structure has been repaired.

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No	Title	Hazard Impact	FMEA/CIL Impact	SR&QA Closure
5.	Hydraulic Main Pump Cap Bolts. Bolts at the port cap/front housing interface on the OV-102 hydraulic pumps are dry film lubricated (DFL); should be passivated. Concern is possible insert pull-out due to lower coefficient of friction of the DFL bolts; with potential hydraulic pump port separation and hydraulic fluid leak, resulting in loss of hydraulic system. Program has flown for 20 years with DFL bolts in hydraulic pumps with no pump failures due to insert pull-outs.	ORBI 250 "External Leakage from the APU Fuel Feed System"	02-6-E06-01, Pump, APU Driven Main Hydraulic, Will not pressurize, CRIT 1R2 02-6-E06-03, Pump, APU Driven Main Hydraulic, Inability to maintain system pressure on demand, CRIT 1R2. Worst-case effect is loss of one hydraulic	Tests performed at vendor, Parker-Abex, and at JSC confirms the residual strength & remaining preloads exceed the amount required to cause a gap in the pump cap and cause leakage. OV-104 Main Pump 3 port cap bolt 5 was X-rayed again this flow to determine if there was any degradation in the port cap/front housing insert threads due to mission effects and reassess the gap between the insert and port cap. M&P analysis and comparison to the previous X-rays is currently in work. The hydraulic community is currently performing additional testing and reviewing redesign options of the fasteners for both the SRB & Orbiter pumps. The OV-104 bolts were X-Rayed and Hydraulic Design accepted by MR. Certification Deviation 05C-30-281-029-0002H is being processed for use of DFL bolts on Main Pumps 2 & 3 for this flight.

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No	Title	Hazard Impact	FMEA/CIL Impact	SR&QA Closure
6.	The locking feature on –7XXX series connector savers, manufactured by Glenair, can become disengaged due to a defect in the "wavy" washer causing loss of locking feature. Four connectors savers installed during Monoball Production Break modification were found to loosen when an axial load was applied to the harness assembly. Similar hardware is present on the T-0 Umbilical, OMS pods, KU band Electronic Assemblies and several other mission kit installations (a total of 68).	No specific Orbiter Hazard Reports for connectors; however, Hazards address loss of LRU function. Launch vibration could cause rotation of connector saver coupling ring, vibration and dynamic forces could then cause inadvertent demate of connector saver and connectors. ORBI 234 deals with an unlocked KU-Band antenna impacting the Orbiter radiator.	Although there are no CILs on connector savers, the worst criticality would be 1R2 for the KU-Band EA-1.	System Safety developed a fault tree and identified criticality for the connectors with suspect connector savers. Taped OMS pod connector savers. PR COM 0340/0341/0342 applied tape to secure the KU-Band EA-1 connector savers (None installed on EA-2 or SPA). The tape will remain in place until connector saver redesign is implemented.

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No	Title	Hazard Impact	FMEA/CIL Impact	SR&QA Closure
7.	During Qual testing of the Light Weight Stowage Lockers in 1998, it was discovered that the Milson fasteners attaching the lockers to the wire trays failed the 20g crash load test. Vehicles flew with OVEI Waivers until the fasteners were replaced with the correct ones.	ORBI 257C “Unrestrained Objects in the Cabin Causing Crew Injury or Vehicle Damage”, Cause ‘A’ G-Loads (and/or Vibration) Causing Structural Failure of Restraint Devices, Mounting Structures, etc. Due to Improper Design or Installation of GFE/CFE”	M7-102-ML1-X-01, 1R2, Light Weight Mid-Deck Stowage Locker Assembly, Door Latch Assembly Breaks Under Flight Load (Premature Release). M7-102-ML2-X-01, 1R3, Light Weight Mid-Deck Stowage Locker Assembly Door Hinge Assembly Breaks Under Flight Load.	MCR 19376 “Milson Fastener Redesign”. Installed new Milson fasteners on the avionics bay 1, 2, and 3A thermal debris panels and Orbiter structure. No OVEI Waiver will be required for STS-112

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Analysis / Assessment Section

No	Title	Hazard Impact	FMEA/CIL Impact	SR&QA Closure
8.	STS-108 S/N 207 IMU Slip Ring Broken Wire Issue. X-Rays showed a break in the fan-out wire to 90 deg. Azimuth gyro motor drive. This was the third slip ring related failure. S/N 210 was removed form OV-104 to measure slip ring and brush block misalignment "wobble", which is believed to be a contributor to the wire failures along with flexing (usage related). Recently, OV-104 S/N 202, slot #1 annunciated platform fail BITEs and was replaced by S/N 203. Failure analysis at Kearfott verified that pin 44 was broken on the slip ring. They measured the "wobble" and it was twice the wobble of any other IMU and the wire shows indications of being necked down (workmanship related).	ORBI 051 Erroneous IMU Output Can Cause Loss of Guidance. RM can detect and isolate the first failure when it occurs. The isolation of a second failure with only two IMU's remaining is not achievable in 100% of the cases.	05-1-GN21-HA-INS-02, High Accuracy Inertial Navigation System (HAINS) Inertial Measurement Unit (IMU), Erroneous Output, CRIT 1R/2 (1R/3 for Loss of Output).	Flight Rationale based on subsystem redundancy. Assessment of the potential impact of the generic design flaw in the IMU gyro is continuing. Flight Rules allow continuation to Normal End of Mission after first IMU failure and next PLS after the second failure. Early flight termination must be discussed if IMU failure occurs on STS-112. S/N 203 (slot 1) & 215 (slot 3) have no slip ring failure history. S/N 208 (slot 2) had azimuth slip ring replacement. Long-term fix is redesign of Gyro Azimuth slip-ring mounting to prevent fracture of fan-out wires.

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No	Title	Hazard Impact	FMEA/CIL Impact	SR&QA Closure
9.	STS-109 IFA #4 Forward THC-X Contact Lost During OMS Burn. The CDR relaxed his grip on the THC during the NC2 burn and channel C was deselected prior to the other two channels. The switch inside the THC is a snap-action rotary device using magnets and Hall-effect sensors to ensure simultaneous activation and deactivation of all three discrete channels. It is impossible for one sensor to turn off by itself without a fault in the sensor or the signal path from the sensor to the MDM, or momentary loss of power to the THC.	ORBI-152 Manual Controller Failure Can Result In Loss Of Flight Control, Cause 'B' THC fails off from physical jamming or loss of discrete switch drive linkage due to vibration, mechanical / thermal shock, mishandling / abuse or piece part structural failure. HR will be updated, as well as the Background Section to include the IFA.	1R3 for this anomaly. 05-1-FC3142-1, 1R2, Loss of Output (fail Off) of two or more channels of the THC (Translation Hand Controller, Cmdr & Aft Station)	Post-Flight T/S showed the THCs have longer on-to-off tracking time (no spec for time). Nominal movement of THC will not cause momentary loss of contacts. A User Note was published to document this IFA, and training procedures implemented indicating that a condition can occur if the THC (RHC) grip is not held at the hard stop and if released slowly, could result in a channel fail indication. The recovery of this anomaly is that the channel should be reselected to regain fault tolerance.
10.	OME Nozzle Extension was contacted by the RH Drag Chute door facility platform during STS-112 flow.	No primary Hazard Report. See ORBI 277 "Loss of Vehicle Caused by Loss of Structural Integrity".	03-3-4006-1, OMS nozzle extension, structural failure, CRIT 1/1 due to structural damage from exhaust gas impingement.	Nozzle extension flange leak check was good. Stress analysis shows the load was well within normal flight loads. No issue for STS-112

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No	Title	Hazard Impact	FMEA/CIL Impact	SR&QA Closure
11.	MPS LH2 Feedline Flowliner Cracks. The small cracks discovered in OV-104 Main Engine #1 led to the grounding of the fleet when similar cracks were found in the other vehicles. Cracks have not bee seen in the LO2 feedlines. Boeing System Safety & NASA JSC SR&QA comprised Team 6, tasked with developing a Fault Tree and leading the effort to close-out potential causes. One of the possible causes of the cracks is the stamping process while forming the slots in the flowliners. After extensive assessments, X-rays, tests, 10X visual & eddy current inspections. The final plan is to polish the slot surfaces and weld the cracks. Follow-on work to be done include clearing the BSTRA joints, bellows, bellow weld, and gimbal ring.	ORBI 343 "Fire / Explosion in the Orbiter Aft Compartment Caused by Contamination in the Main Propulsion System", Cause F "Small Particle Contamination From MPS Hardware Material Wear and or Failure"	There are no primary CILs related to particles flaking from the 12 inch LH2 feedline. 03-1-0417-02 1/1 12-inch LH2 Line Rupture/leakage	System Safety concurs with the LH2 Feedline Flowliner crack resolution plan to weld the cracks and inspect each flight. The M&P analyses now show that the cracks are the result of high cycle fatigue and not hydrogen embrittlement. Weld repairs returns flowliners to near-print configuration. Material coupon tests provide the desired mission life. Bounding analysis in work to address potential for additional crack growth and to clear the remaining feedline components. Although there are a considerable number of open action items, they are all planned to be completed prior to flight.

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No	Title	Hazard Impact	FMEA/CIL Impact	SR&QA Closure
12.	Salad Bowl issue. During routine ET attach liner refurbishment, damage/material displacement was found on the Orbiter/ET aft attach shell assembly. Both OV-104 salad bowls had worn Kahrlon or impressions on the metal surface. Impairment of joint rotation can lead to increased bolt bending stress from the higher friction. Inspections have revealed that other vehicle salad bowls show damage; as well as 9 at the vendor or NSLD. The criteria are for no wear on the Kahrlon nor impressions on the aluminum surface. Stress analysis indicates that the salad bowls on OV-104 must be repaired. Transfer of the Orbiter on the Orbiter Transport System, which has sharp edged monoballs, has been identified as the most probable cause of the ET shell damage.	There are no Orbiter Hazard Reports directly related to the aft attach shell assembly. Premature failure of the aft attach bolt can cause structural failure of the vehicle (ORBI 277 Loss Of Vehicle Caused By Loss Of Structural Integrity) Reference INTG 051 "Premature Separation Of ET/Orbiter Forward Or Aft Structural Attachments"	There are no Orbiter FMEA CILs for damaged aft attach shell assembly as it is considered a structural component.	New/undamaged ET shell assemblies will be installed in OV-104. The steel OTS monoballs have been re-machined to correct the sharp radius. Palmdale is manufacturing new shell assemblies for OV-105 and OV-102. Upon replacement of the aft attach assemblies; OV-104 will be acceptable for flight on STS-112.

SAFETY, RELIABILITY AND QUALITY ASSESSMENT

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No	Title	Hazard Impact	FMEA/CIL Impact	SR&QA Closure
13.	Negative Margins for MPM Liftoff loads.	Orbiter Hazard Report ORBI 305 “inability to Close and Latch Payload Bay Doors” addresses MPM failures for inability to stow.	02-5B-P07-04, Pedestal Drive Linkage, fails free (Crit 1/1)	The refined loads assessment cleared the RMS and RMS camera loads, but analysis of the torque shaft showed a 21% negative margin. Of the three options evaluated to fix the problem, the Program selected the use of support blocks to limit the over-center deflection. Plan is to install the support blocks in the VAB. Certification will include a functional tests and stress analysis.
14.	S1 payload has 4 GSE "tooling balls" that were inadvertently left on the element, despite having “remove before flight” flags. There is a concern for the potential for FOD during ascent and contingency return in the Payload Bay as there is no verification that they won't come loose and they are not certified for flight.	Potential FOD hazard as well as Launch & Ascent impact damage. There are no Orbiter Hazard Reports related to FOD in the Payload Bay (covered by Payload ICD requirement).	There are no Orbiter FMEA/CILs related to FOD in the Payload Bay.	S1 tooling balls were taped on 8/26/02 with Permacel P213 fiberglass tape that has a 90° peel strength of 4.5 lbf/inch. This is a FOS of 2 (need 2.24 lbf to break loose). Although removal of the GSE tooling balls is preferred, the temporary fix of taping them in place with Permacel P213 is acceptable. Assessments were performed and determined acceptable risk of jamming Orbiter mechanisms as well as the potential impact hazard (“Lost and Found” PR). Action was assigned to ensure no recurrence of this type.