NASA

SECTION 29

52

	Presenter:
	Organization/Date: Orbiter 01/09/03

CRITICAL PROCESS CHANGES

STS-107 CRITICAL PROCESS CHANGE REVIEW SUMMARY

Presenter: Doug White

Organization/Date: Orbiter 01/09/03

Item Reviewed	No. of Items Reviewed	Period or Effectivity Covered	No. Found To Be Critical Process Changes
OMRSD Changes (RCNs)	9	STS-107 Specific & Non-Flight Specific Changes Approved 9/20/02 – 11/7/02	0
OMRSD Waivers & Exceptions	16	STS-107 Specific	0
IDMRD Changes (MCNs)	4	Approved 9/20/02 – 11/7/02	0
IDMRD Waivers & Exceptions	1	Approved 9/20/02 – 11/7/02	0
EDCPs	7	Closed 9/20/02 – 11/7/02	1
Boeing Specifications	41	Released 9/20/02 – 11/7/02	1
Boeing Drawings	146	Released 9/20/02 – 11/7/02	0
Material Review	204	Approved 9/20/02 – 11/7/02	0

- All process changes were reviewed and none constrain STS-107

CRITICAL PROCESS CHANGES

Presenter:
Doug White
Organization/Date:
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Engineering Design Change Proposals (EDCP's):

Enhanced or Advanced Master Events Controller Acceptance Test Modification (ECN-A6)

- AMEC S/N 10 experienced multiple failures during SAIL burn-in testing
  - TT&E at Autonetics discovered 3 missing inductors
- Autonetics acceptance test procedure failed to verify continuity on AMEC 28 vdc return paths
- Autonetics test specification was revised to add new paragraph to measure continuity between all returns on connectors J2, J3, J8 and DC returns on J9, J10
- This test will verify all inductors are installed and continuity on all return paths
  - Note: OMRS test performed at KSC will detect open returns since each LRU output driver is individually tested with its own return

CRITICAL PROCESS CHANGES

Presenter:
Doug White
Organization/Date:
Orbiter 01/09/03

Engineering Specifications:

OMS/RCS Crossfeed Line Heater Configuration Change (ML0310-0063)

- During STS-109 post flight data review, it was determined that the OMS/RCS crossfeed line heater zones 3 & 4 (aft) were influencing heater zones 1 & 2 (doghouse)
- It was determined that the there were too many heater wraps at the zone 3 & 4 interface with zones 1 & 2, and that the zone 1 & 2 thermostats & sensors were located too close to the interface with zones 3 & 4
- Reduced the number of wraps at the zone 3 & 4 interface with zones 1 & 2
- Relocated the zone 1 & 2 thermostats & sensors away from the zone 3 & 4 interface

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CONFIGURATION CHANGES AND CERTIFICATION STATUS

CONFIGURATION CHANGES AND CERTIFICATION STATUS

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18 Modifications Implemented During the STS-107 Processing Flow

- Total listing of STS-107 modifications and certification details are in backup
  - Modification certification has been processed and approved

First Flight Items:

- New System Control Module (SCM) battery
- Two Advanced Master Events Controllers (AMECs)
- Summary presented on following pages

CONFIGURATION CHANGES AND CERTIFICATION STATUS

Presenter: Doug White

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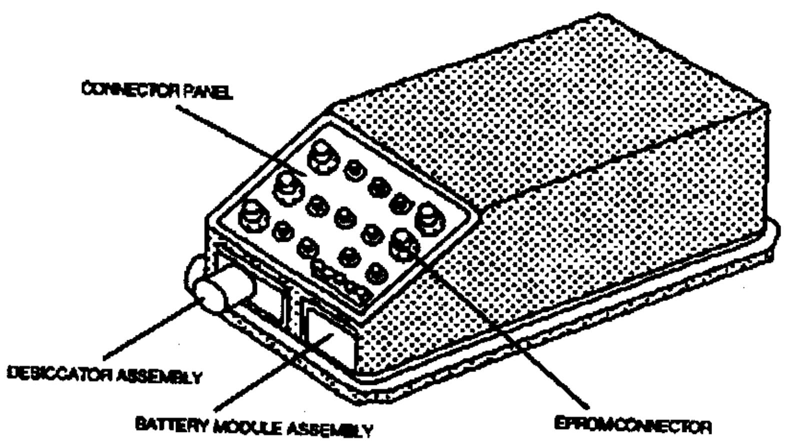
MCR 23061 New System Control Module Battery — FIRST FLIGHT

- The SCM is the main interface for all the inputs/outputs of data and control signals between the OEX Recorder and the Orbiter avionics/Modular Auxiliary Data System (MADS)
- The modification replaces expended obsolete GFE 2.8 VDC battery (Catalyst Research 3440) with a new 3.6 VDC battery (Tadiran TL 5134)



System Control Module

Battery Module Board Assembly With Obsolete Battery Cell Installed

CONFIGURATION CHANGES AND CERTIFICATION STATUS	Presenter: Doug White
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First Flight of Two Advanced Master Events Controllers (AMECs) on STS-107

- There are two MEC/EMEC/AMEC LRUs per Orbiter
- AMECs (single flight configuration) have successfully completed 13 missions
  - First flight of AMEC was in September 2000 (STS-106 in OV-104)
- STS-107 flight configuration:
  - AMEC S/N 5 in slot 1 (avionics bay 4)
    - Installed in April 2002
  - AMEC S/N 8 in slot 2 (avionics bay 5)
    - Installed in May 2001 – 1 flight
- AMECs installed in OV-102 successfully completed ATP, OMRS testing and have been subjected to over 1000 hours of burn-in testing at SAIL with no anomalies

CONFIGURATION CHANGES AND CERTIFICATION STATUS

Presenter:
Doug White
Organization/Date:
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Advanced Master Events Controller (AMEC) (cont)

- No anomalies have occurred during ground processing testing of AMECs S/N 5 and 8
- AMEC-related issues:
  - AMEC S/N 6 and S/N 3 produced spurious non-critical outputs on OV-104 during the STS-98 and STS-110 flows
    - Testing to date has resulted in sporadic recurrences of the condition during power up
      - AMEC S/N 6: 2 occurrences in ~14,000 power cycles
      - AMEC S/N 3: 0 occurrences in ~5,900 power cycles
    - Analysis indicates that the condition is the result of the design's failure to ensure the power-on reset of non-critical command internal registers
    - Condition is isolated to non-critical commands
      - Critical and Fire 3 commands are not affected
    - Can only occur at AMEC power-up and is not a flight constraint or concern

Presenter:

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SPECIAL TOPICS

SPECIAL TOPICS FOR THE STS-107 FLIGHT READINESS REVIEW

Presenter: Doug White

Organization/Date: Orbiter 01/09/03

Topic	Presenter
• OV-102 MPS LH2 Feedline Flow Liner Cracks	David Rigby
• BSTRA Ball Cracks	David Rigby

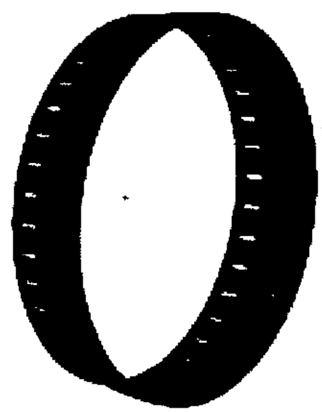
OV-102 MPS LH2 FEEDLINE FLOWLINER CRACKS

Presenter: David Rigby
Organization/Date: Orbiter 01/09/03

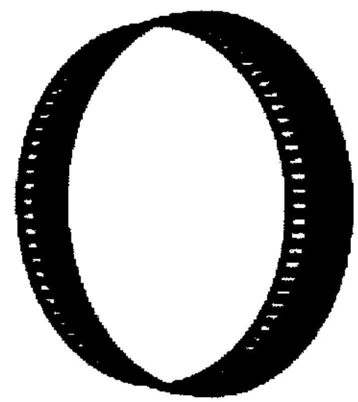
Observation:

- Inspections of MPS LH2 engine feedline flowliners revealed cracks in the gimbal assembly flowliners near the SSME interface
- Inconel flowliner weld repairs previously cleared for flight on STS-112 and -113
- STS-107 is first flight of repaired CRES flowliners – similar in all details except:
  - Material is CRES 321 instead of Inconel 718
  - Roughly twice as many slots, reducing parent material in-between slots from 0.75 inches to 0.25 inches

OV-103 & subs Inconel 718 flowliner



OV-102 CRES 321 flowliner



OV-102 MPS LH2 FEEDLINE FLOWLINER CRACKS

Presenter: David Rigby
Organization/Date: Orbiter 01/09/03

Approach to Clear Weld Repair of CRES Flowliners for One Mission is the Same as Inconel Flowliners

- Developed processes to weld all detectable cracks and to polish slots on OV-102 LH2 CRES configuration
- MSFC completed fatigue testing of coupons representative of repair process
  - Tested fatigue life with and without repair welds at room temperature and cryogenic conditions
  - Determined minimum weld life relative to parent material (i.e., knockdown factor due to repair)
- Used reverse fracture bounding analysis to estimate safety margin in clearing repaired flowliner for flight
  - Derived conservative crack growth rate curve that bounds known crack data in CRES 321 flowliners: 3 slot-to-slot cracks on OV-102, 1 partial crack on MPTA
  - Applied appropriate weld knockdown factor and required scatter factors to determine safety margin

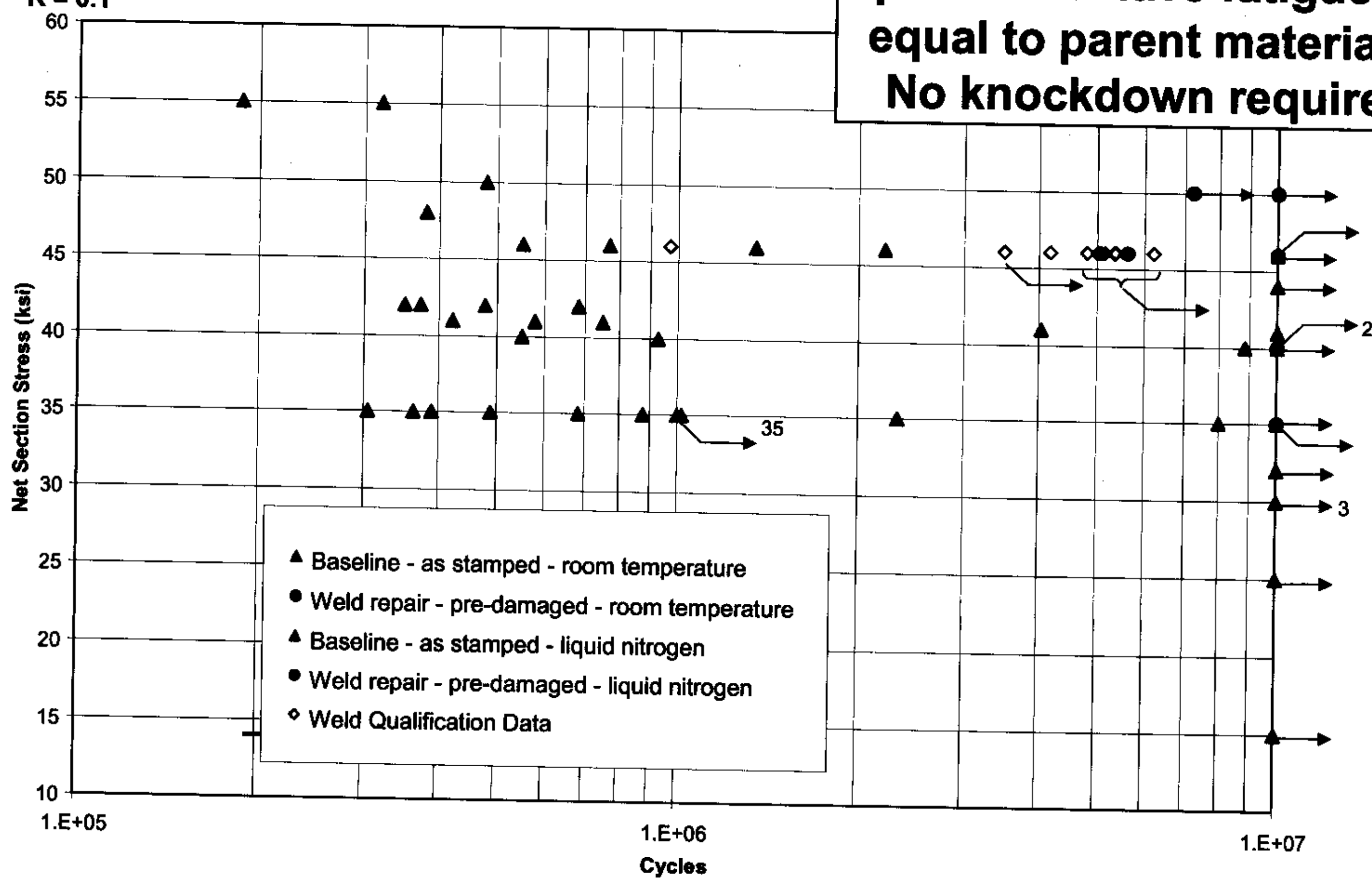
OV-102 MPS LH2 FEEDLINE FLOWLINER CRACKS

Presenter: David Rigby

Organization/Date: Orbiter 01/09/03

MSFC Coupon Testing

Testing showed weld repair specimens have fatigue life equal to parent material = No knockdown required



OV-102 MPS LH2 FEEDLINE FLOWLINER CRACKS

Presenter: David Rigby
Organization/Date: Orbiter 01/09/03

Reverse Fracture Analysis

- Used fracture theory to derive crack growth rate curve (crack length vs. missions) to bound crack inspection data from OV-102
  - Three locations on downstream flowliner in E2 feedline with cracks completely across 0.25 inch ligament
  - After ligament fails, adjacent ligaments would have increased stress, but inspections found no damage
  - Crack growth rate curve compatible with this damage (next page) would grow from initiation to across ligament in 23 missions
- Crack on MPTA feedline sectioned
  - Rate of crack growth observed vs. MPTA firings
  - Superimposed on plot derived from OV-102 cracks – Good correlation on growth rate (slope of curve next page)

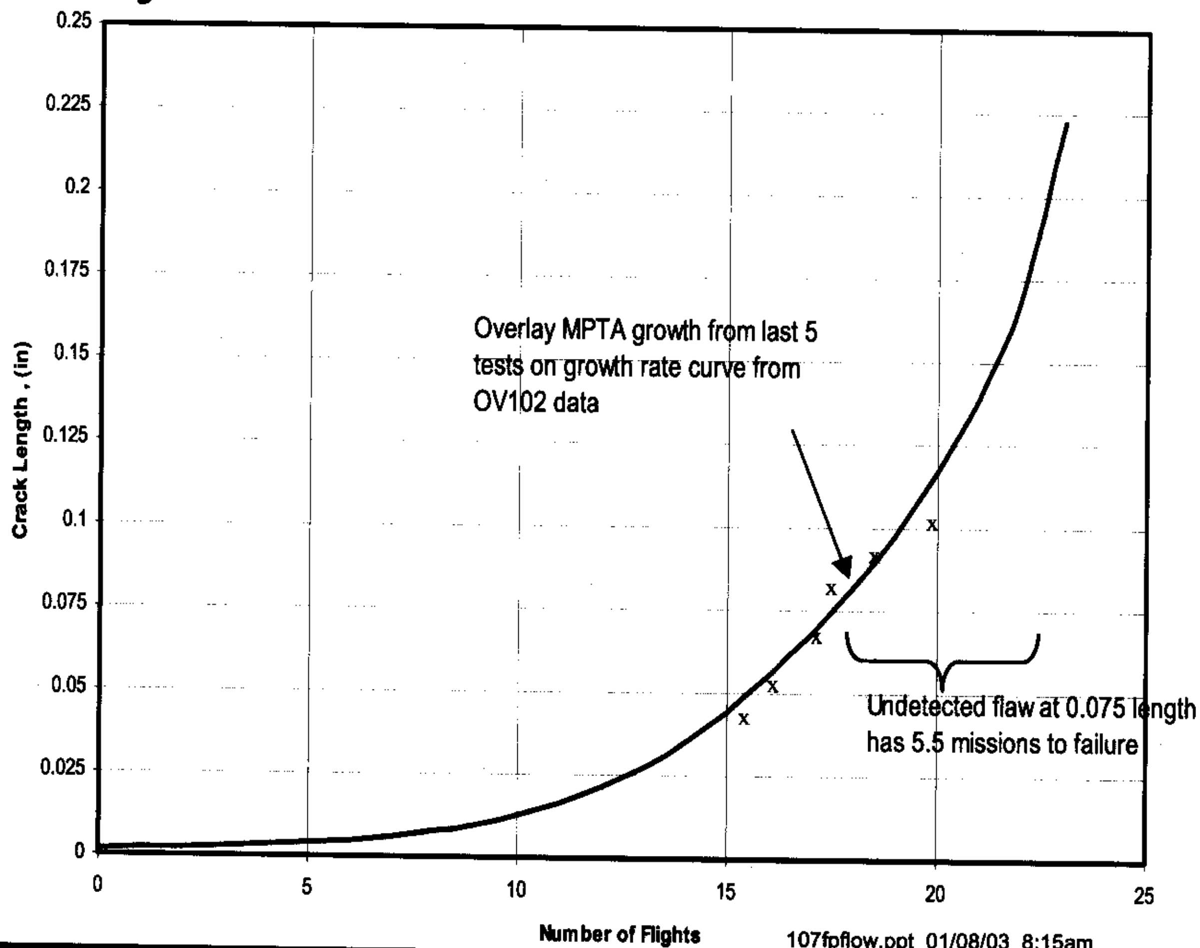
OV-102 MPS LH2 FEEDLINE FLOWLINER CRACKS

Presenter:
David Rigby
Organization/Date:
Orbiter 01/09/03

Crack growth rate curve enveloping OV-102 crack data and correlated by overlay of MPTA crack data

Weld repaired ligament has 23 missions from initiation to slot-to-slot propagation.

An undetected crack (assumed .075 long) in parent material has 5.5 missions to slot-to-slot propagation.



OV-102 MPS LH2 FEEDLINE FLOWLINER CRACKS

Presenter:
David Rigby

Organization/Date:
Orbiter 01/09/03

Reverse Fracture Analysis

- For weld-repaired ligaments, material testing at MSFC showed no knockdown factor for welds. Maintained standard scatter factor of 4 for initiation
  - Safety factor on life = 23/4 = 5.75
- For ligaments with no detected cracks, assumed 0.075" undetected flaw. Maintained standard scatter factor of 2 for propagation
  - Safety factor on life = 5.5/2 = 2.75
- Special consideration given to residual stresses resulting from weld repairs across full width of ligament but did not change safety factor
  - Residual stresses measured on welded specimens of approximately 25 ksi – Correlated with analysis prediction
  - Fatigue testing confirmed this level of mean stress has insignificant effect on fatigue life

OV-102 MPS LH2 FEEDLINE FLOWLINER CRACKS

Presenter: David Rigby
Organization/Date: Orbiter 01/09/03

OV-102 Actions Completed:

- Cracks welded, post repair NDE completed, & clean-up of repairs completed
- Polishing of downstream and upstream gimbal flowliner slots completed
- Other LH2 feedline NDE inspections performed
  - Dye penetrant inspection of gimbal yoke to flange weld completed
    - Dye penetrant indications from shallow weld cooling cracks found during inspection
    - Blended out without issue
  - X-ray and/or borescope of gimbal bellows and bellows to yoke welds completed with no issues
- Final MSFC coupon testing to assure that dimensions of actual OV-102 repair welds were represented in material property data – Completed, no issues

OV-102 MPS LH2 FEEDLINE FLOWLINER CRACKS	**Presenter:** David Rigby
	Organization/Date: Orbiter 01/09/03

OV-102 Actions Completed (cont.):

All other feedline hardware (BSTRA joints, bellows to gimbal weld, bellows, and gimbal ring) is identical to other vehicles, previous analysis and flight rationale is applicable

- BSTRA joint: Backflow damps out prior to reaching the first BSTRA joint in the middle of the feedline
- Bellows to gimbal weld: Clear with 0.54 margin of safety (above 1.4 factor of safety) at cryogenic proof pressure
- Bellows: Clear for 51 missions using conservative analysis technique
- Gimbal ring: Clear for 100 plus missions

OV-102 MPS LH2 FEEDLINE FLOWLINER CRACKS

Presenter: David Rigby
Organization/Date: Orbiter 01/09/03

Acceptable for STS-107 Flight:

- Based on successfully completed crack repair welds, polishing of LH2 flowliner slots, internal feedline NDE inspections, coupon testing, and feedline analysis, there is adequate safety factor on the fatigue life of the CRES flowliners on OV-102 for STS-107
- Additional fracture test data will be gathered to develop flight rationale for future missions on OV-102
- Post-flight inspections of the flowliners will be conducted

MPS 17" Feedline Ball Strut Tie Rod Assembly Ball Crack	Presenter: David Rigby
	Date: Orbiter 01/09/03

Observation:

- OMRSD inspection of OV-103 17 inch LO2 feedline revealed a crack in the ball of the Ball Strut Tie Rod Assembly (BSTRA) nearest the LO2 manifold
- Similar design in 12 inch and 17 inch feedlines

Concern:

- Failure of ball could result in:
  - Lack of articulation capability of the feedline resulting in structural failure of the feedline
  - FOD generation
    - 17 inch feedlines upstream of feedline screens
    - 12 inch feedlines downstream of feedline screens

MPS 17" Feedline Ball Strut Tie Rod Assembly Ball Crack	**Presenter:** David Rigby
	Date: Orbiter 01/09/03

Flight Rationale Based on Resolution of Two Issues

- Joint performance with cracked balls
  - Cracks must be self-limiting
    - Ball remains intact
    - Load margins remain positive
  - Joint angulation capability not compromised
    - Friction
    - Binding
- FOD from cracked balls
  - Crack propagation does not create FOD
  - No spalling

MPS 17" Feedline Ball Strut Tie Rod Assembly Ball Crack

Presenter:
David Rigby

Date:
Orbiter 01/09/03

Agenda:

- MPS Feedline Introduction
- Vehicle Inspection Summary
- Qualification Testing Summary
- Build Records and Acceptance Testing of BSTRA Balls
- Approaches to Flight Rationale
- Testing Activities

MPS 17" Feedline Ball Strut Tie Rod Assembly Ball Crack

Presenter: David Rigby

Date: Orbiter 01/09/03

MPS Feedline Introduction:

- BSTRA joints are located in the two upstream joints of each 12 inch engine feedline and all three 17 inch feedline joints
- BSTRA provides internal structural support to feedline while allowing the joint to articulate to compensate for:
  - Cryogenic shrinkage
  - Pressure expansion
  - Dynamic loads
  - ET umbilical retract (17 inch feedline)
  - Structural deflections

MPS 17" Feedline Ball Strut Tie Rod Assembly Ball Crack

Presenter: David Rigby
Date: Orbiter 01/09/03

MPS Feedline Introduction (cont):

- Each BSTRA consists of two hubs, suspended in the flow stream by three struts mounted to pads on the pressure carrier, and a ball located inside the hub cups
  - Cups, Hubs, and Struts are manufactured from Inconel 718
  - Balls are manufactured from Stoody #2
    - Cobalt / Chrome / Tungsten Alloy
    - Vitrolube coating

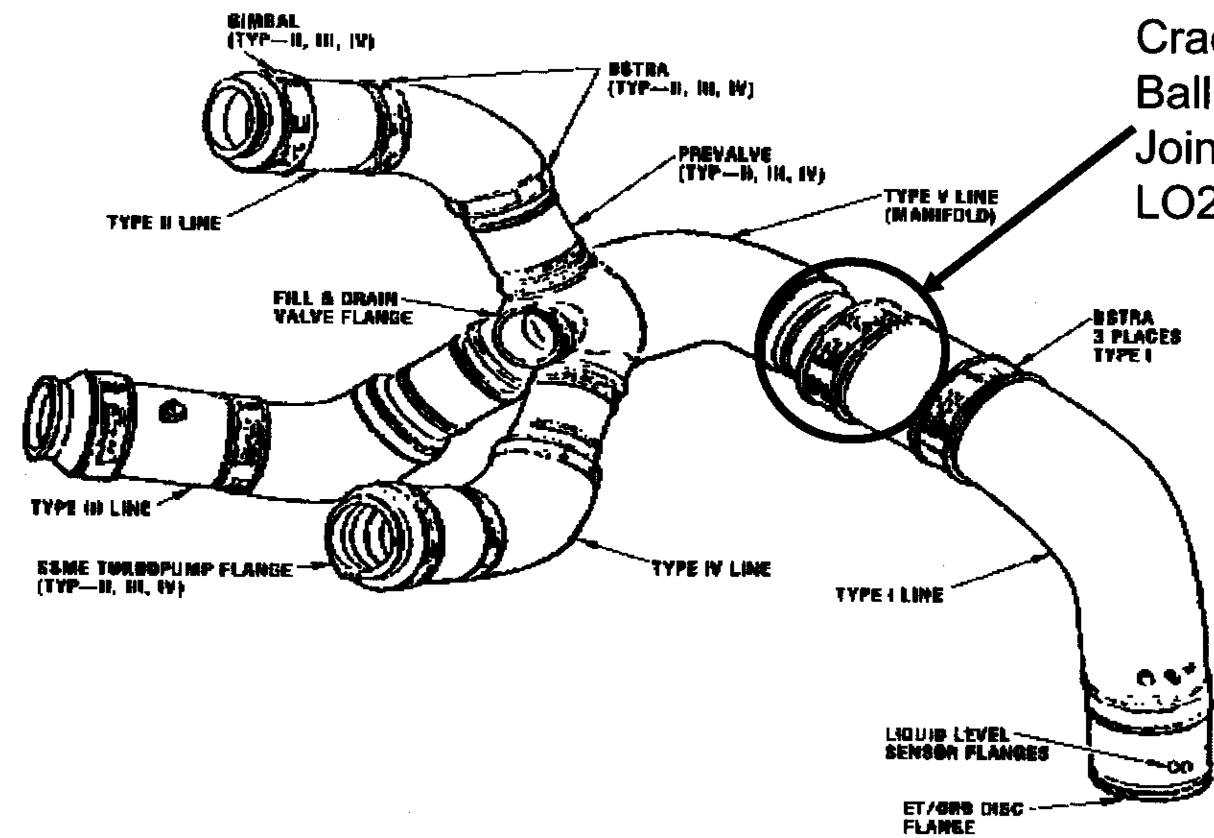
Feedline Description	Ball Diameter	Quantity of Balls per Vehicle
LO2 17 Inch	2.24 inches	3
LO2 12 Inch	1.75 inches	6
LH2 12 and 17 Inch	1.25 inches	9

MPS 17" Feedline Ball Strut Tie Rod Assembly Ball Crack

Presenter: David Rigby

Date: Orbiter 01/09/03

LO2 Feedline Installation (Foamed, OV-103 and Subs)

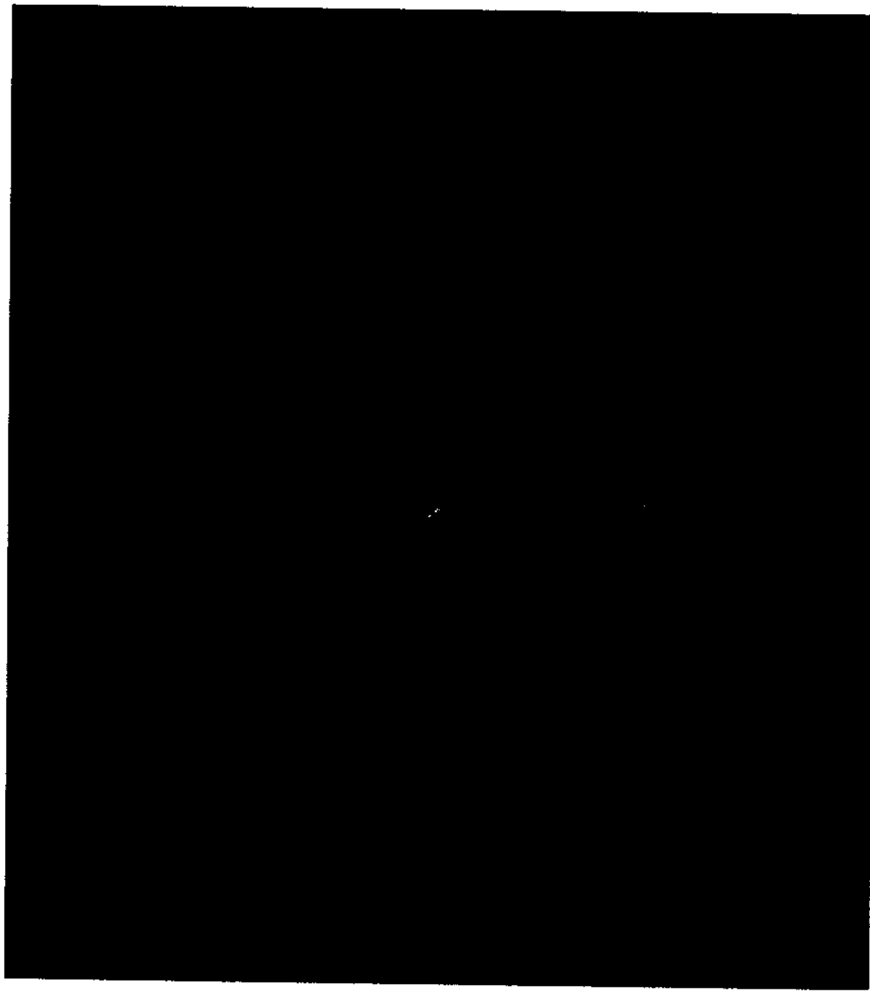


Cracked Ball in BSTRA Joint Nearest LO2 Manifold

MPS 17" Feedline Ball Strut Tie Rod Assembly Ball Crack

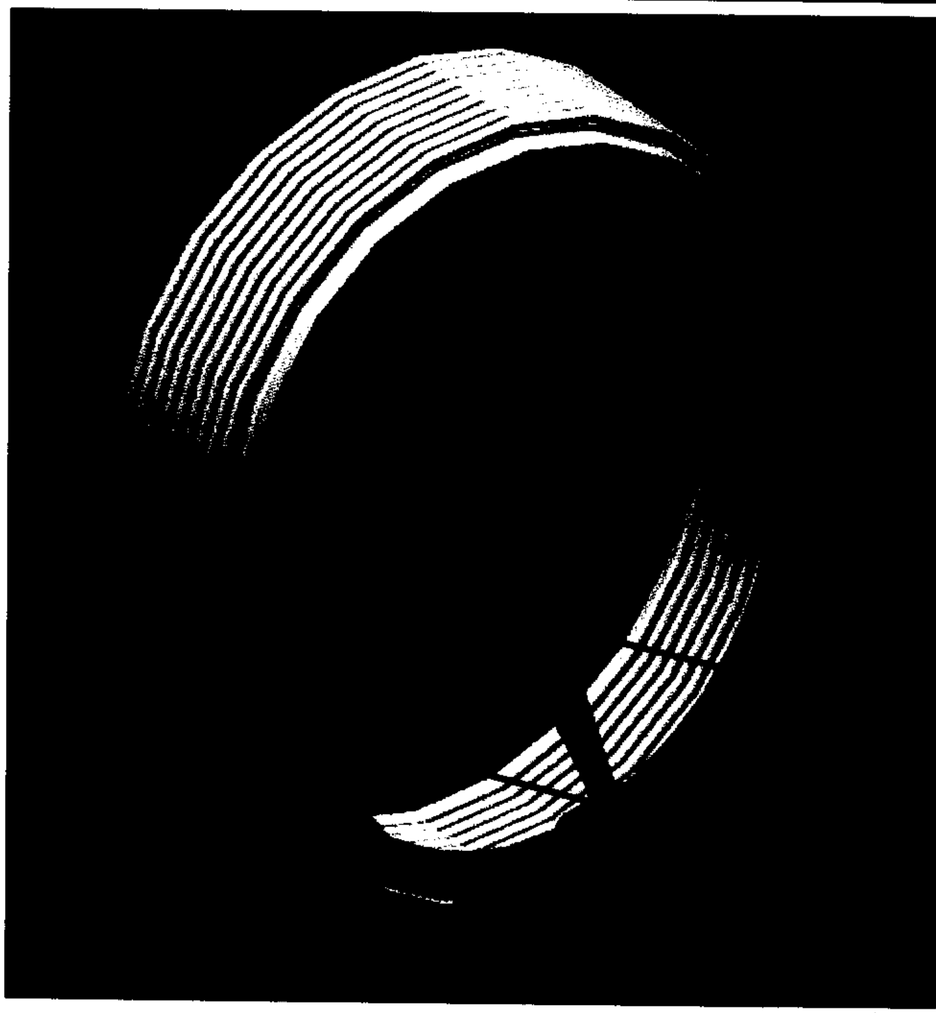
Presenter: David Rigby

Date: Orbiter 01/09/03



(LH2 Configuration Shown)

MPS 17" Feedline Ball Strut Tie Rod Assembly Ball Crack	Presenter: David Rigby
	Date: Orbiter 01/09/03



BSTRA Components

Upstream Housing

Upstream Strut Assy (Red)

Bellows

Downstream Strut Assy (Blue)

Downstream Housing

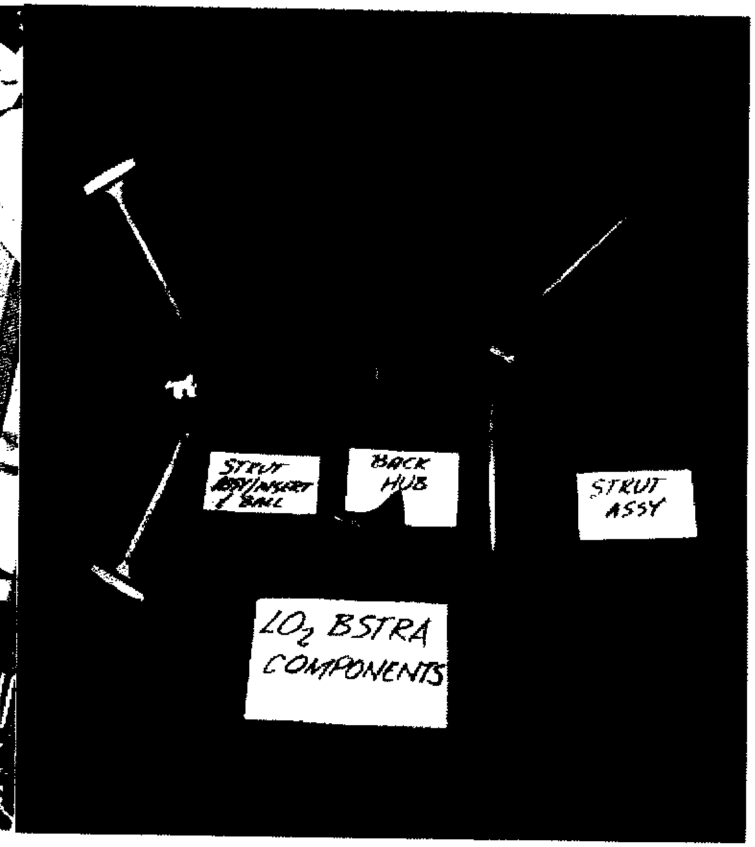
(LH2 Configuration Shown)

MPS 17" Feedline Ball Strut Tie Rod Assembly Ball Crack

Presenter: David Rigby	**Date:** Orbiter 01/09/03

Typical BSTRA Assembly

LH2 Feedline Shown



LO2 BSTRA Piece Parts

MPS 17" Feedline Ball Strut Tie Rod Assembly Ball Crack	Presenter: David Rigby
	Date: Orbiter 01/09/03

Vehicle Inspection Summary

- OMRSD inspection history
  - OV-105 "Big Bang" anomaly in mid-1990s raised concerns over BSTRA binding
    - Eventually cleared as an MLP-related noise
  - OMM borescope inspections implemented in 1995
    - Visual access limited to less than 25% of the surface
    - Ball is not rotated during the inspection
    - New borescope used for the first time during this inspection resulting in improved inspection capability
      - Closer inspection of balls possible due to decreased risk of damage from borescope
      - Better access to all sides of the balls / BSTRAs
      - Previous OMRSD inspections may not have seen similar indications on the ball due to access and the type of borescope used

MPS 17" Feedline Ball Strut Tie Rod Assembly Ball Crack

Presenter: David Rigby

Date: Orbiter 01/09/03

Vehicle Inspection Summary (cont)

Orbiter (Mission #)	OV-102 (28)	OV-103 (31)	OV-104 (27)	OV-105 (20)
LH2 12 Inch Engine Feedlines	TBD	Complete No Indications	Complete No Indications	Complete No Indications
LO2 12 Inch Engine Feedlines	TBD	Complete No Indications	Complete No Indications	Complete No Indications
LH2 17 Inch Feedlines	TBD	Complete No Indications	Complete No Indications	Complete No Indications
LO2 17 Inch Feedlines	TBD	Complete 1 Crack Indication	Complete No Indications	Complete No Indications
Previous OMRSD Inspection	Flight 27 Mar 2002	Flight 22 Feb 1997	Flight 21 May 2000	Flight 12 Jan 1998

MPS 17" Feedline Ball Strut Tie Rod Assembly Ball Crack

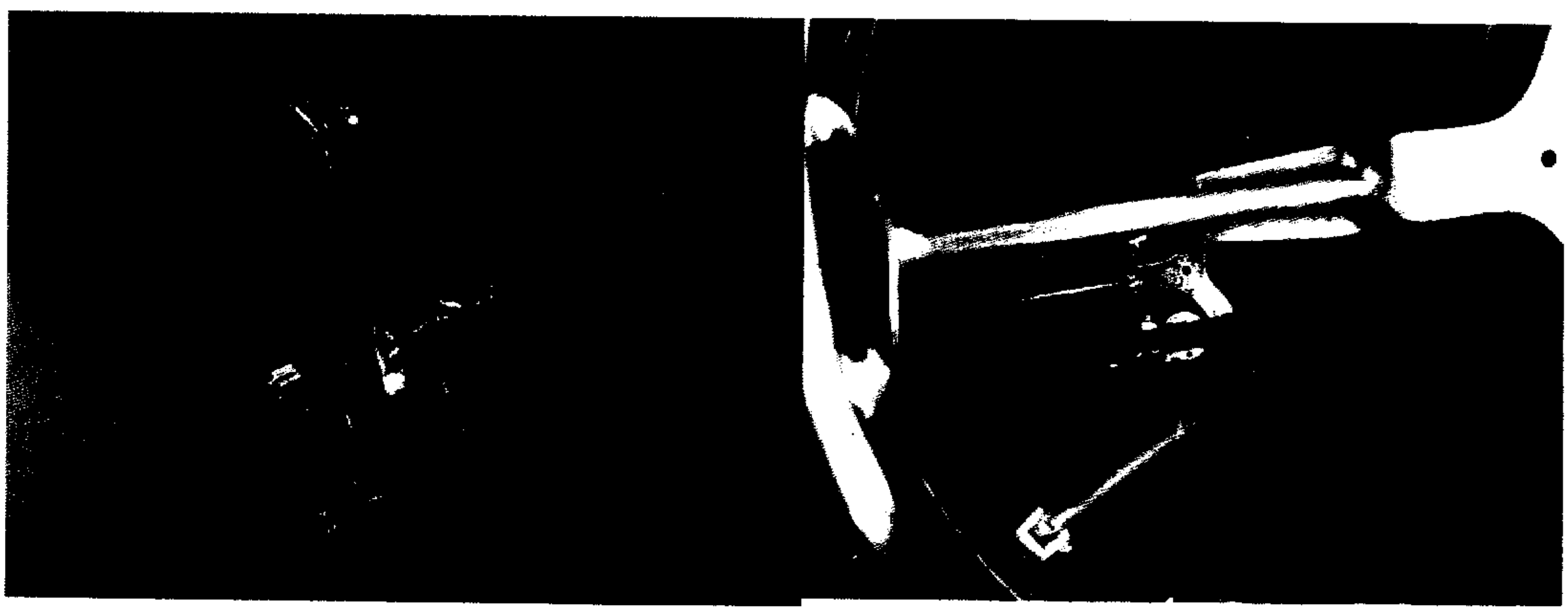
Presenter: David Rigby	**Date:** Orbiter 01/09/03

OV-103 17" BSTRA Ball Crack Indication

MPS 17" Feedline Ball Strut Tie Rod Assembly Ball Crack	Presenter: David Rigby
	Date: Orbiter 01/09/03

BSTRA Ball Inspection Tool

- Under development at JSC with KSC involvement
- Designed to unload BSTRA joint and allow full rotation and inspection of the OV-103 cracked BSTRA ball
- CHIT will be brought forward to the SSP when all design and implementation issues are resolved



MPS 17" Feedline Ball Strut Tie Rod Assembly Ball Crack

Presenter: David Rigby

Date: Orbiter 01/09/03

Other Feedline Assembly BSTRA Ball Inspections

Feedline Description	Status
MPTA LH2 12 Inch Engine Feedlines	E1 In-Work E2, E3 Complete
MPTA LO2 12 Inch Engine Feedlines	Complete
Qual Unit LH2 12 Inch Engine Feedline	Complete
MPTA LH2 17 Inch Feedline	Complete
MPTA LO2 17 Inch Feedline	Complete
Separation Test LH2 17 Inch Feedline	Complete

MPS 17" Feedline Ball Strut Tie Rod Assembly Ball Crack

Presenter: David Rigby

Date: Orbiter 01/09/03

Qualification Test History

- 1977 Rockwell / Arrowhead qualification testing
  - Simulated flight qualification environment thermal shock and loading (400 cycles)
  - Test utilized both LN2 and LH2
  - Conclusion
    - No failures occurred in test
    - No defects noted post test penetrant inspection
    - No cracks noted post test by metallurgical sectioning

MPS 17" Feedline Ball Strut Tie Rod Assembly Ball Crack	Presenter: David Rigby
	Date: Orbiter 01/09/03

Qualification Test History (cont):

- 1978 MSFC testing
  - MSFC concerns over the use of Stoody #2 in the feedlines
  - Stoody #2 bearings were already installed in the MPTA and cost and schedule considerations made it highly desirable to not change materials
  - Extreme thermal shock and loading
  - Tested bearings with and without cracks present
  - Test utilized both LN2 and LH2

MPS 17" Feedline Ball Strut Tie Rod Assembly Ball Crack

Presenter:
David Rigby
Date:
Orbiter 01/09/03

Qualification Test History (cont):

- 1978 MSFC testing (cont):
  - Conclusions
    - Material is prone to cracking from thermal/mechanical shock
    - Bearings may be cracked on receipt
    - Penetrant inspection is unreliable as compared to eddy current
    - No catastrophic failures and all bearings retained capability to perform intended function
  - The conclusion reached was that risk of failure was low; recommendation was to continue with MPTA with Stoody #2 bearings installed in MPTA ET lines
  - Program effects
    - ET project moved to Inconel 718 for BSTRA balls
    - Due to wear capability and plans for individual cyrogenic ATP of the balls, the Orbiter project continued with Stoody #2 balls

MPS 17" Feedline Ball Strut Tie Rod Assembly Ball Crack	Presenter: David Rigby
	Date: Orbiter 01/09/03

Qualification Test History (cont):

- LO2 and LH2 17" feedline qualification tests
  - 100 mission qualification tests
  - Post test inspection – no BSTRA related anomalies

- Build Records and Acceptance Testing of BSTRA Balls
- No anomalies found during search of build records
- Acceptance test procedures perform dye penetrant inspection following LN2 thermal dunk
  - Use of dye penetrant inspection as detection method for pre-existing cracks is inadequate to detect cracks

MPS 17" Feedline Ball Strut Tie Rod Assembly Ball Crack

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Date: Orbiter 01/09/03

Approaches to Flight Rationale:

- For OV-102 / STS-107, the working assumption is that OV-102 has cracks since ATP screening of the balls is found to be inadequate
- Three options considered
  - On-vehicle repair
    - Technical concerns eliminated this option due to accessibility issues
  - Off-vehicle repair
    - Turnaround time is prohibitive to near term flight schedules
  - Fly as is

MPS 17" Feedline Ball Strut Tie Rod Assembly Ball Crack

Presenter:
David Rigby

Date:
Orbiter 01/09/03

Flight Rationale Based on Resolution of Two Issues

- Joint performance with cracked balls
  - Cracks must be self-limiting
    - Ball remains intact
    - Load margins remain positive
  - Joint angulation capability not compromised
    - Friction
    - Binding
- FOD from cracked balls
  - Crack propagation does not create FOD
  - No spalling

MPS 17" Feedline Ball Strut Tie Rod Assembly Ball Crack

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Testing Activity to Support Flight Rationale

- Additional testing is required to support flight rationale development
  - Previous MSFC testing supported crack arrest mechanism for MPTA test program
    - Limited thermal / mechanical cycles
  - Qualification test program did not produce cracks
    - Arrest mechanism not demonstrated

MPS 17" Feedline Ball Strut Tie Rod Assembly Ball Crack

Presenter: David Rigby

Date: Orbiter 01/09/03

Severe Environments Needed to Crack Test Balls

- Extreme heat transfer required to crack test balls
  - 275 - 400 F (oven) to –100 F (glycol / dry ice)
  - Rapid thermal cycles 212 F (boiling water) to 32 F (ice water)
- Balls with and without notches did not start / propagate cracks despite multiple thermal and thermal / load cycles
  - May provide some rationale that OV-103 is unique

Ball Size	Total	Severely Cracked Balls	Less Severely Cracked Balls	Naturally Cracked Balls
2.24"	4	3	1	0
1.75"	2	1	0	1
1.25"	1	1	0	0

MPS 17" Feedline Ball Strut Tie Rod Assembly Ball Crack

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Cracks Must Be Self-Limiting

- Nominal Testing
  - Thermal and mechanical cycling of cracked balls until crack(s) arrest for minimum of 5 cycles at each load level
    - Slow Fill (5 cycles minimum)
    - Nominal Flight Profile (35 cycles minimum)
    - Maximum Engine Operating Pressure (5 cycles minimum)
- Load Margin Testing
  - 1.5x Nominal Flight Profile (5 cycles minimum)
  - 1.75x Nominal Flight Profile (5 cycles minimum)
  - Material property variability may be encompassed through success of margin testing

MPS 17" Feedline Ball Strut Tie Rod Assembly Ball Crack

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Cracks Must Be Self-Limiting (cont):

- Cyclic Margin Testing
  - Traditional shuttle testing methodology uses scatter factor on cycles for margin
  - Factor of 4 on nominal load cycles
  - For OV-102, ~30 flights coverage would require 120 cycles at nominal load levels; no scatter factor on higher load cases
  - Crack arrest on 2.24 / 1.75 inch balls may be able to show crack arrest on 1.25 inch balls acceptable
    - Alternate thermal profile may speed up testing and allow full additional cycles

MPS 17" Feedline Ball Strut Tie Rod Assembly Ball Crack

Presenter: David Rigby
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Cracks Must Be Self-Limiting (cont):

- If crack fails to arrest in severely cracked balls
  - Less severely cracked ball testing

  AND/OR

  - OV-103 inspection / harvest
- If crack fails to arrest in naturally cracked ball (1.75")
  - Full visual inspection on OV-102 to ensure no cracks
- Complete Eddy Current and CT scan of remaining spare balls to determine potential use for testing
- Testing ECDs
  - 2.24 inch balls: 1/11/03
  - 1.75 inch balls: 1/11/03
  - 1.25 inch balls: 1/12/03*

    * Using 287 F (oven) to –100 F (glycol / dry ice) to simulate LH2 thermal profile

MPS 17" Feedline Ball Strut Tie Rod Assembly Ball Crack

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David Rigby

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Joint angulation capability not compromised

- Friction
- Binding
- For all balls with cracks, vertical offset between surfaces will be measured
  - If offset greater than vitrolube thickness actual friction will be measured
    - MSFC developing testing capability
  - Initial work on a severely cracked 2.24 inch ball by MSFC M&P showed no issue
    - Measured 180 microinches offset maximum
    - 500 microinch vitrolube thickness minimum

MPS 17" Feedline Ball Strut Tie Rod Assembly Ball Crack

Presenter: David Rigby

Date: Orbiter 01/09/03

BSTRA Ball FOD Testing

- System design limits
  - Oxygen: 800 microns
  - Hydrogen: 400 microns
  - Prevalve screen: 1000 microns
    - 17" line upstream of screen
    - 12" line downstream of screen
  - Actions in work to determine acceptability of FOD with the SSME project

MPS 17" Feedline Ball Strut Tie Rod Assembly Ball Crack

Presenter:
David Rigby

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BSTRA Ball FOD Testing (cont):

- FOD related issues
    - Branching cracks
    - Material islands
    - Loss of parent material

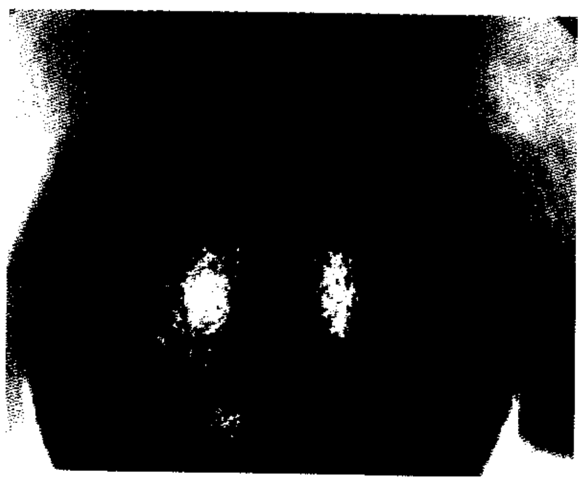
Type of cracks	Total Samples	Balls with Branching Cracks	Balls with Material Islands	Balls with Loss of Parent Material
Severe	4	4	4	2
Less Severe	1	0	0	0
Natural	1	1	1	0

MPS 17" Feedline Ball Strut Tie Rod Assembly Ball Crack

Presenter: David Rigby
Date: Orbiter 01/09/03

BSTRA Ball FOD Testing (cont):

- 2.24 Inch Severely Cracked Ball Shown



MPS 17" Feedline Ball Strut Tie Rod Assembly Ball Crack	Presenter: David Rigby
	Date: Orbiter 01/09/03

BSTRA Ball FOD Testing (cont):

- Testing to date has shown that the potential for FOD exists
- To understand the mechanism for particle generation and the potential associated particle size, we are investigating
  - Metallurgical analysis of the cracked balls
  - Completing additional testing
    - Less severely cracked ball testing
    - Complete Eddy Current and CT scan of remaining spare balls to determine potential use for testing
    - FOD characterization testing
  - Probabilistic Risk Assessment
  - Stress Analysis

MPS 17" Feedline Ball Strut Tie Rod Assembly Ball Crack

Presenter: David Rigby

Date: Orbiter 01/09/03

Flight Rationale Based on Resolution of Two Issues

- Joint performance with cracked balls
  - Cracks must be self-limiting
    - Ball remains intact
    - Load margins remain positive
  - Joint angulation capability not compromised
    - Friction
    - Binding
- FOD from cracked balls
  - Crack propagation does not create FOD
  - No spalling

MPS 17" Feedline Ball Strut Tie Rod Assembly Ball Crack

Presenter: David Rigby

Date: Orbiter 01/09/03

Conclusions:

- The test program to support flight rationale is still in work
- This test program and development of rationale for safe flight of the potentially cracked BSTRA balls is not yet complete
- Final flight rationale will be presented at the STS-107 PMMT review