Technical Panel Fact-Finding Status

Mr. Joe Cuzzupoli, Lead

Technical Panel
CAIB Recommendations

3.2-1 External Tank (ET) Debris Shedding

3.3-1 Reinforced Carbon Carbon (RCC) Structural Integrity

4.2-3 Two Person Closeout

3.3-2 Orbiter Hardening

4.2-1 Solid Rocket Booster Bolt Catchers

6.4-1 Thermal Protection System (TPS) Inspection and Repair

Technical Panel
Acceptance Recommendations

1. R4.2-1 Solid Rocket Booster Bolt Catchers – Dr. Chuck Daniel

2. R4.2-3 Two Person Close Out – Mr. Joe Cuzzupoli

Technical Panel

4.2-1 – Solid Rocket Booster Bolt-Catchers

Dr. Charles Daniel

4.2-1 – Solid Rocket Booster Bolt-Catchers

CAIB Recommendation

Test and qualify the flight hardware bolt catchers.

RTF TG Interpretation

Meaning of the CAIB recommendation is clear.

4.2-1 – Solid Rocket Booster Bolt-Catchers

NASA Implementation

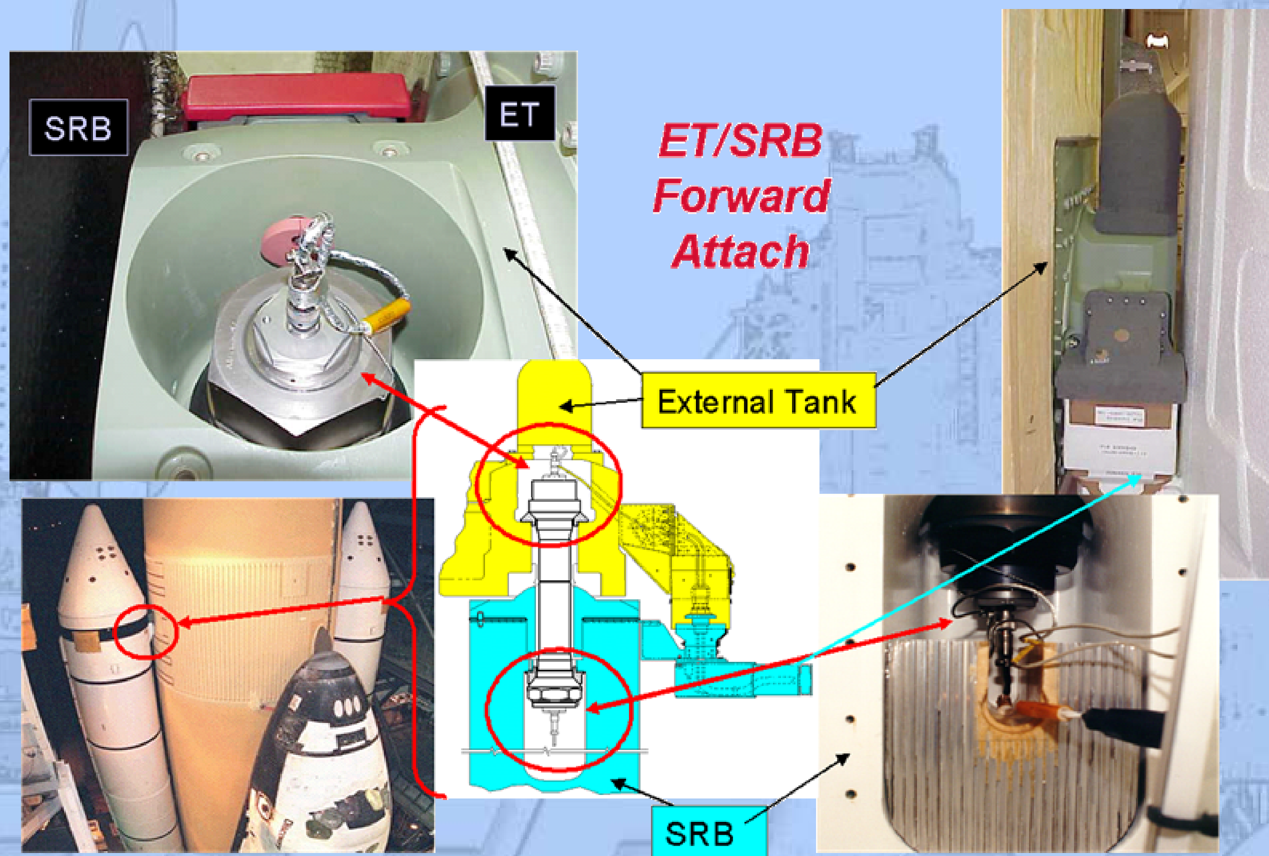
- Bolt Catcher design changes.
  - Bell Housing Material changed to stronger material and thickness doubled
  - Bell Housing changed from a two piece welded design to a single piece forging
  - Bell Housing TPS changed to machined cork
  - Attachment bolts doubled in size and material changed to provide for added strength
  - Inserts increased in size and strength
  - Impact absorption material changed to improved material and design modified
  - New design incorporated integrated O ring
- NSI Pressure Cartridge design change
  - NSI retention device incorporated in bolt to eliminate NSI ejection

4.2-1 – Solid Rocket Booster Bolt-Catchers

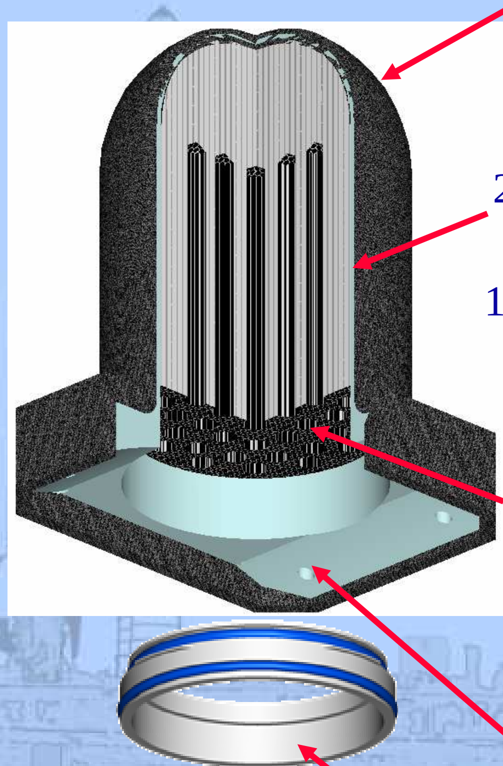
NASA Implementation

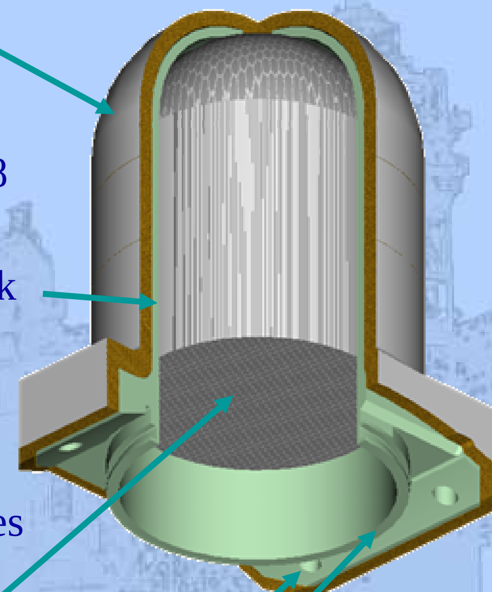
- GMIPS reestablished and delegations reinforced
- Qualification by analysis anchored in test
- Factor of Safety of 1.86

4.2-1 – Solid Rocket Booster Bolt-Catchers



Bolt Catcher Design





TPS material

SLA-561

Machined Cork

Housing

2 pc. welded; 2219 Al; 1/8 in. thick

1 pc.; 7050 Al; 1/4 in. thick

Energy Absorber

Spiral Wound 5052 Al; 1400 psi crush; 10 holes drilled

5052 Al Honeycomb; 828 psi crush

Fasteners

A286; 3/8 in.; 180 ksi

MP35N; 9/16 in.; 260 ksi

O-ring Carrier

Separate

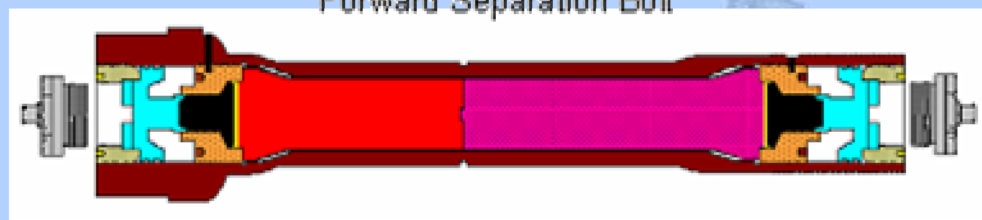
Integrated

STS-107 Bolt Catcher Design

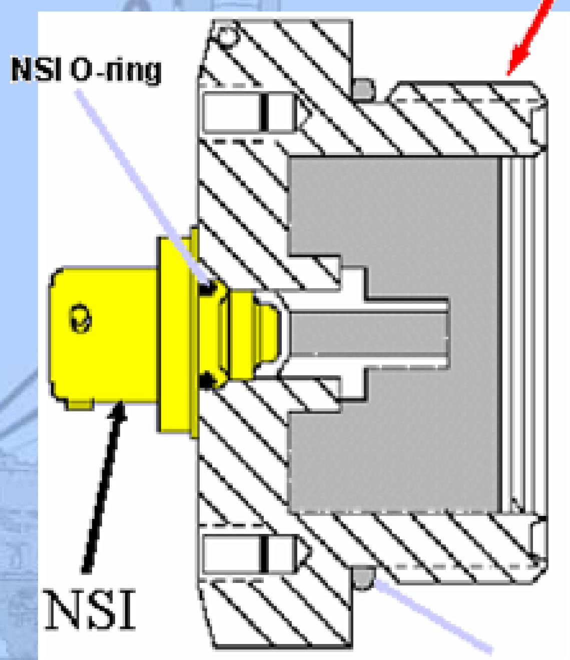
Final Bolt Catcher Redesign

NSI Pressure Cartridge

Forward Separation Bolt

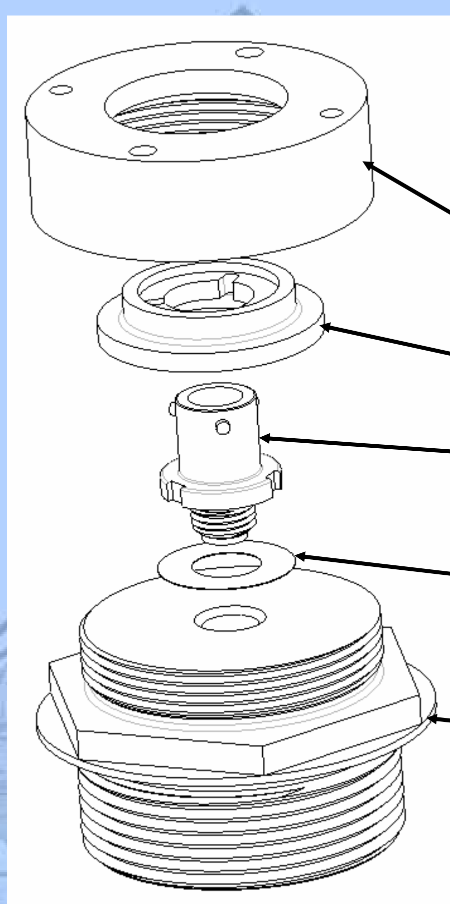


Previous Design



NSI-PC and NRD Components

NSI Pressure Cartridge w/ NRD



Cap, Retaining

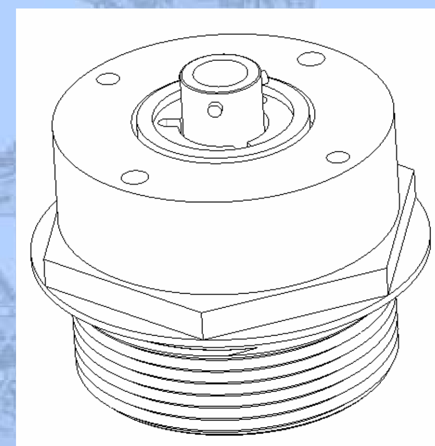
Washer, Retaining

NSI (no change)

Washer, Weld (no change)

Body, Cartridge

Expanded View



Assembled View

4.2-1 – Solid Rocket Booster Bolt-Catchers

NASA Verification Process

- Development Tests
  - Energy Absorber Characterization Tests
  - Bolt Catcher System Drop and Firing Tests
  - Bolt Catcher Static Tests
  - Attachment Fastener Prying/Bending Tests
  - Separation Bolt Velocity Tests
  - NSI Pressure Cartridge and NSI Retention Device FOS Quick Look Margin Tests
  - NSI Pressure Cartridge Burst Tests
  - NSI Pin Ejection Simulation Tests

4.2-1 – Solid Rocket Booster Bolt-Catchers

NASA Verification Process

- Qualification Testing
  - Bolt Catcher Structure and Assembly Qualification
    - Bolt Catcher housing and fasteners subjected to static load test to demonstrate a minimum of 1.4 Factor of Safety
    - Bolt Catcher housing with Energy Absorber subjected to drop test to demonstrate dynamic load capability and Energy Absorber crush depth at maximum separation bolt velocity
    - Bolt Catcher Insulated Assembly subjected to acoustic, vibration and separation bolt firing environments and with simulated NSI pin ejection environments
  - NSI Pressure Cartridge Qualification Complete
    - NSI Pressure Cartridge subjected to typical pyrotechnic component qualification testing
  - NSI Pressure Cartridge Factor of Safety (FOS) Certification Testing Complete
    - Pressure Cartridge with NSI Retention Device tested with machined wall and thread thicknesses

4.2-1 – Solid Rocket Booster Bolt-Catchers

Panel Assessment

- Fact Finding
  - Marshall Space Flight Center DCR process November 16 – 18, 2004, November 30, 2004 & December 3, 2004.
  - SRB Test Firing ATK, Utah, June 10, 2004
  - MSFC CDR Board May 27, 2004
  - MSFC CDR Pre-Board May 19, 2004
  - MSFC Delta CDR April 28-30, 2004
  - MSFC CDR November 5, 2003.

4.2-1 – Solid Rocket Booster Bolt-Catchers

Recommendation

– **NASA has met the intent of CAIB Recommendation**

– **Accept for Full Closure**

Technical Panel

4.2-3 – Two-Person Close Out

Mr. Joe Cuzzupoli

4.2-3 – Two-Person Close Out

CAIB Recommendation

Require that at least two employees attend all final closeouts and intertank area hand-spraying procedures.

The CAIB subsequently provided the following clarification: It [This recommendation] was intended to apply to the entire space transportation system for all types of close outs. The external tank intertank was specifically called out but it was not intended to be limited to the tank.

4.2-3 – Two-Person Close Out

RTF TG Interpretation

- NASA will review and update process controls.
- Two employees to attend all final closeouts and critical hand-spraying procedures.
- At Michoud, Material Processing Procedures (MPP's) to be modified in accordance with 2-person closeout requirement. Quality control and Government Mandated Inspection Points (GMIP's) are also to be included in MPP's.
- Recent SSPO direction (March 3, 2004) each project manager to review/audit all flight hardware final closeouts at the shuttle element manufacturing sites and during launch preparation at KSC is consistent with Implementation Plan and CAIB intent.

4.2-3 – Two-Person Close Out

Summary

- **Plan**
  - Audit all major shuttle projects and elements
  - Programmatic Level Requirements documentation of two-person close-out
- **Status**
  - Audit complete
  - Receipt of Programmatic Level Requirements documentation
- **NASA closeout package submitted**
- **Recommendation: Accept for Full Closure**

Technical Panel

3.3-2 - Orbiter Hardening

Mr. Sy Rubenstein

3.3-2 - Orbiter Hardening

CAIB Recommendation

– **Initiate a program designed to increase the Orbiter's ability to sustain minor debris damage by measures such as improved impact-resistance Reinforced Carbon-Carbon and acreage tiles. This program should determine the actual impact resistance of current materials and the effect of likely debris strikes.**

3.3-2 - Orbiter Hardening

RTF TG Interpretation

- Initiate a program to increase the Orbiter's ability to sustain minor debris damage. Select and implement changes required for Return to Flight. Define additional changes if required for the balance of the Shuttle program

- Develop a detail test, modeling and analysis program to determine the actual impact resistance of current materials and the effect of likely debris strikes.

- For the first Orbiter returning to flight, a high confidence estimate of the impact resistance of installed material and the effect of likely debris strikes should be known.

3.3-2 - Orbiter Hardening

NASA Implementation

– System Integration Team defined debris (trajectories, velocity and mass) and defined critical debris
– ET project made significant changes to reduce critical debris
– Orbiter Damage Impact Assessment Team activity underway
  • Develop capability models for Tile and RCC
  • Conduct Large and Small Scale Material Testing
  • Testing Complete 2/05
  • Determine damage assessment and vehicle risk
  • Develop repair requirements if necessary

3.3-2 - Orbiter Hardening

NASA Implementation

- **Program selected 15 hardening Improvements (3 phased groups)**
- **SSP approved the Orbiter Project phased improvement plan**
- **Side Window testing Indicated a possible problem –implemented as a group 1 change**
- **Main Landing Gear Door Testing and Leading Edge System Carrier Panels indicated current design has low risk of likely debris impact effects – moved to group 2 list**
- **RCC testing has shown sensitivity to coating loss in high heating zones**

- ***The Balance of this presentation will deal with the Orbiter Improvement Program***

Orbiter Hardening Project Overview

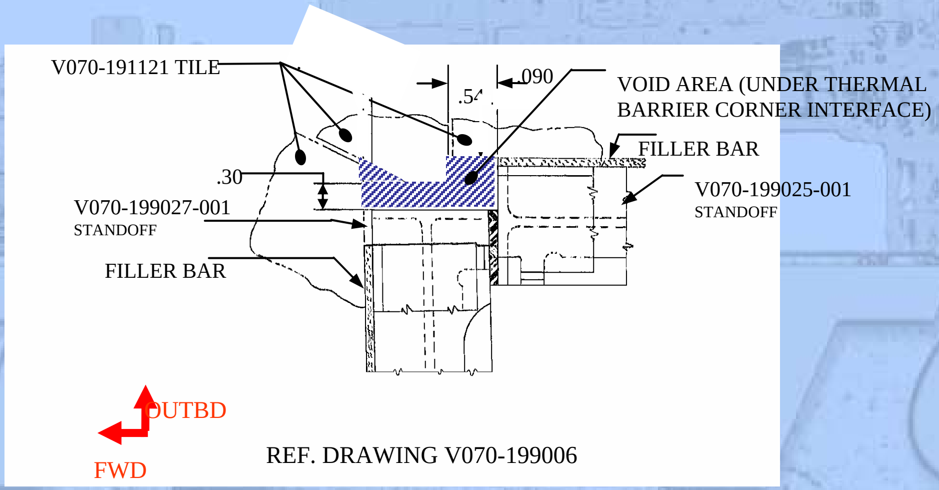
Family	Redesign Proposal	Phase
Wing Leading Edge SS	**“Sneak Flow” Front Spar Protection (RCC #5 – 13)**	**I**
	“Sneak Flow” Front Spar Protection (RCC #1 – 4, 14 - 22)	**II**
	Lower Access Panel Redesign/BRI 20 Tile Implementation	**III**
	Insulator Redesign	**III**
	Robust RCC	**III**
Landing Gear and ET Door Thermal Barriers	**Main Landing Gear Door Corner Void**	**I**
	Main Landing Gear Door Enhanced Thermal Barrier Redesign	**II**
	Nose Landing Gear Door Thermal Barrier Material Change	**III**
	External Tank Door Thermal Barrier Redesign	**III**
Vehicle Carrier Panels – Bonded Stud Elimination	**Forward RCS Carrier Panel Redesign – Bonded Stud Elimination**	**I**
Windows	**Thicker side window thermal panes**	**I**
Tougher Lower Surface Tiles	**Tougher Periphery (BRI 20) Tiles around MLGD, NLGD, ETD, Window Frames, Elevon Leading Edge and Wing Trailing Edge.**	**III**
	Tougher Acreage (BRI 8) Tiles and Ballistics SIP on Lower Surface.	**III**
Instrumentation	**TPS Instrumentation**	**III**
Elevon Cove	**Elevon Leading Edge Carrier Panel Redesign**	**III**
Tougher Upper Surface Tiles	**Tougher Upper Surface Tiles.**	**III**
Vertical Tail	**Vertical Tail AFSI High Emittance Coating**	**III**

3.3-2 – Wing Spar Protection

- **Issues:**
  - Unprotected area on lower wing spar may fail due to “sneak flow”
  - Requirement to tolerate ¼ “ hole due to high energy impact debris
  - Wing leading edge sub system (LESS) Carrier Panel (C/P) horse collar thermal barrier has no redundancy if adjacent tiles are damaged beyond existing sleeve
- **Design Solution**:
  - Redesign to add flow restrictor on LESS C/P box beam to limit plume sneak flow (10%) over top of access panel
  - Redesign LESS C/P “horse-collar” thermal barrier to add additional sleeve at IML end of thermal barrier
  - Install Strain Isolation Pad (SIP) on the lower exposed portion of wing spar for additional thermal protection
- **Status**
  - Modification is being implemented on OV-103 and OV-104 for panels #5 - 13
  - Modification on OV-105 during the current OMM will also include panels 1 - 4 and 14 – 22
  - Certification Requirements (CR) package and Certification Approval Request (CAR) for this modification (Panels 1-22) was submitted for approval in September 2004
- **Forward work**
  - Complete certification by DCR #1 in December 2004
  - Complete modification on OV-103 and OV-104. ECD January 2005

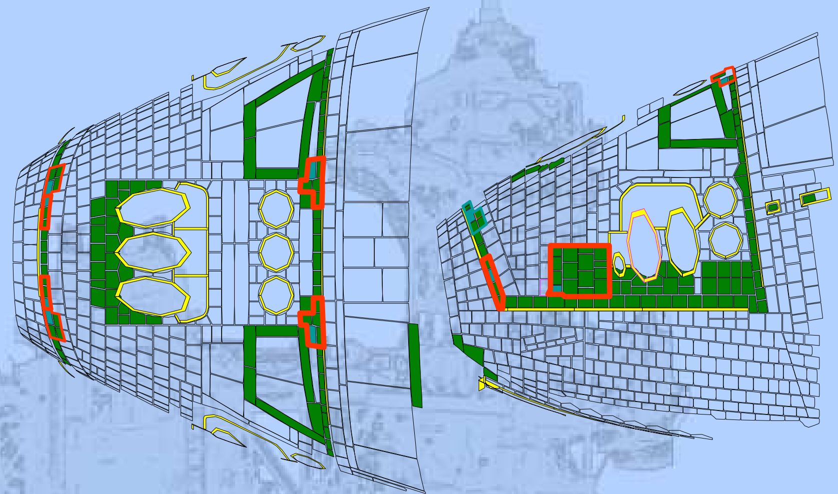
3.3-2 – MLGD Corner Void Elimination

- **Issues**
  - Current Main Landing Gear Door (MLGD) thermal barrier design has small voids under the forward and aft outboard corners. Damage would create a direct flow path to the structure/MLGD cavity
- **Design Solution:**
  - Fill the underlying cavities using stuffed ceramic sleeving (MB0135-066) bonded to the underlying structure
- **Status**
  - Engineering was released for all three Orbiters
  - Modification completed on OV-103 and OV-104
  - This modification was certified by similarity
- **Forward work**
  - Implement this modification on OV-105 prior to MLGD functioning (02/06)

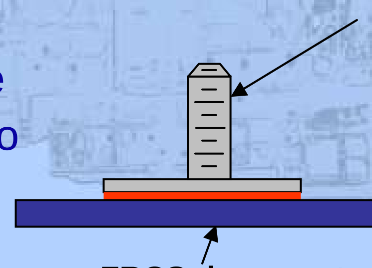


3.3-2 – FRCS Stud Elimination

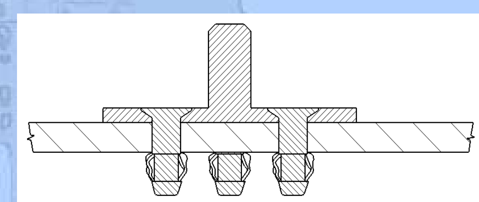
- **Issues:**
  - Current 10 FRCS carrier panel (C/P) installations) used bonded stud design
  - Flight history showed 2 carrier panels lost due to bonded stud failure
  - Complete loss of C/P could create a debris source which could potentially impact Orbiter critical areas such as windows and OMS pods.
- **Design Solution:**
  - Replace existing bonded studs with mechanically fastened (riveted) studs on FRCS
- **Status:**
  - Engineering was released for all three Orbiters
  - Modification on OV-103 and OV-104 is complete
  - Modification on OV-105 will be completed prior to OPF roll-out (3/29/06)
  - Modification certified by analysis and test
- **Forward work –**
  - Complete mod on OV-105



Bonded Stud



FRCS door or structure



Riveted Stud

3.3-2 – Window Improvements

- **Issues:**
  - Current Orbiter window thermal panes regularly sustain impact damage due to hyper velocity impacts on Orbit, low velocity impacts during ascent, or handling
- **Design Solution**
  - Redesign Orbiter side windows (#1 and #6), by increasing their thickness by 0.30 inch increases minimum margin of safety from 0.05 to 0.82
- **Status**
  - OV-103: New windows are installed. All window periphery tiles were removed and new tiles are being installed.
  - OV-104 and OV-105: Work authorization documentation is in work.
  - certified by similarity to current analysis

3.3-2 - Orbiter Hardening

Orbiter Hardening Project Summary

- **Phase II Projects**
  - Sneak flow front spar protection (RCC #1 – 4, 14 - 22)
    - Same certification approach as RCC #5 – 13 under Phase I
    - Forward work
      - Complete certification by DCR #1 in December 2004
      - Complete modification on all three Orbiters
  - MLGD enhanced thermal barrier modification
    - Current MLGD thermal barrier design has no redundancy
    - Impact tests conducted previously on a MLGD corner mock-up indicated current design has sufficient robustness against likely debris source
    - Enhanced thermal barrier modification will reduce tile over-hang/lip and provide redundant thermal barriers
    - Certification of this modification will be performed by test and analysis
    - Forward work
      - Complete and release engineering. ECD 4/05
      - Incorporate BRI-20 tiles when available (tile billet available in 4/05)
- **Phase III Projects**
  - Developments have been initiated
  - Final implementation plans for Phase III projects have yet to be made.

3.3-2 - Orbiter Hardening

Panel Assessment

- Fact Finding
  - Debris Summit February 12-13, 2004
  - Telecon with Orbiter Engineering April 5, 2004
  - Telecom with Shuttle Program, May 21, 2004
  - Tile Test article review, JSC June 28 -29, 2004
  - RCC Test article review on July 26 and 27, 2004
  - SSP Impact Testing and Debris Summit on August 10–12, 2004
  - Debris Summit debrief on September 3, 2004
  - Debris Summit on November 8 – 10, 2004
  - Review with SSP, November 18, 2004

3.3-2 - Orbiter Hardening

Recommendation

- Technical Panel Concurs with the selected Orbiter Hardware Projects

- NASA has defined an extensive program of test, and structural models to determine the actual impact resistance of current materials and the effect of likely strikes.
- However the technical panel has not yet seen the details of how the models will be combined with the test data and actual flight history data to produce these outputs.
- Due to the limited number of controlled test points and the relative uniqueness of the modeling activity (number and mathematical techniques) the technical panel does not yet understand the statistical significance of the planned results.

- Recommendation
  - Keep Open

Technical Panel

3.2-1 – External Tank (ET) Debris Shedding

(Status)

Mr. Richard Kohrs

3.2-1 – External Tank (ET) Debris Shedding

CAIB Recommendation

Initiate an aggressive program to eliminate all External Tank Thermal Protection System debris shedding at the source with particular emphasis on the region where the bipod struts attach to the External Tank.

3.2-1 – External Tank (ET) Debris Shedding

RTF TG Interpretation

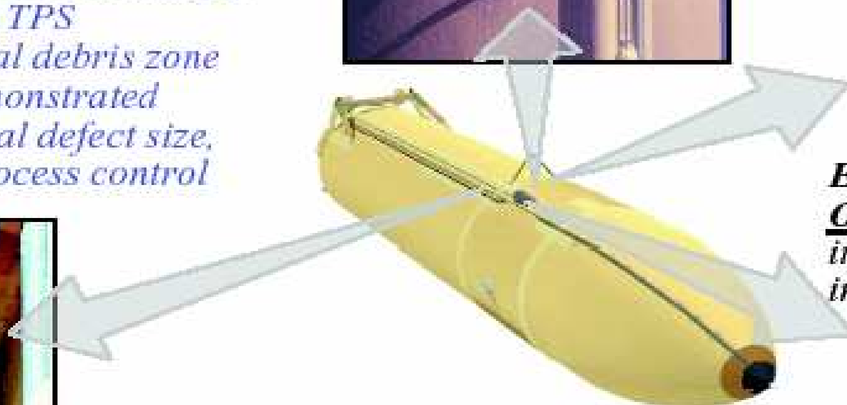
Eliminate all sources of critical debris by eliminating the bi-pod strut foam and determine the void size that correlates with a debris size that is acceptable, based on the transport and energy analysis.

3.2-1 – External Tank (ET) Debris Shedding

TPS Re-Certification (incl PAL ramps)
Objective: *Re-certify all TPS applications in the critical debris zone using tests, analysis, demonstrated process capability, critical defect size, allowable debris size, process control*

Intertank / LH2 Tank Flange
Objective: *Eliminate critical debris from the Intertank / LH2 tank flange closeout*

Bipod Fitting Ramp
Objective: *Eliminate critical debris from bipod area – Eliminate foam ramps*



*ET Camera System **
Objective: *Enhance in-flight imagery by installing camera in LO2 feedline fairing*

LO2 Feedline Bellows Ice
Objective: *Prevent or contain ice/frost debris from 3 bellows locations on LO2 feedline*

*TPS Non-Destructive Inspection **
Objective: *Develop TPS NDI for use on RTF PAL Ramps*

* *Tool for assessment of TPS integrity or Performance*

3.2-1 – External Tank (ET) Debris Shedding

Corrective Actions for Elimination of Debris

- **External Tank Project adopted a phased approach to respond to the CAIB recommendation**
- **Current ET Project Return to Flight Plan**
  - **Phase 1:** Develop, design, certify and implement the required modifications to the ET that will eliminate known critical debris sources
    - Required to return to flight
  - **Phase 2:** Develop, design, certify and implement enhancements that would further reduce debris sources
    - Continuous improvement – Can be incorporated into the ET production line
  - **Phase 3:** Activities that will explore the possibility of eliminating all debris
    - Will not be implemented due to plans to retire Shuttle at end of decade

3.2-1 – External Tank (ET) Debris Shedding

Corrective Actions for Elimination of Debris

- **Phase 1: Elimination of Critical Debris Phase**
  - Re-certify all TPS applications in critical debris zone for RTF debris requirement
  - Enhance or re-design areas of known "critical" debris sources
    - Forward bipod fitting
    - Intertank / LH2 flange closeout debris elimination
    - LO2 feedline bellows ice elimination
  - Develop TPS NDE capability as confidence tool for PAL Ramps
  - Enhance in-flight imagery through use of ET camera system

- **Phase 2: Further Reduction of Debris**
  - Redesign or eliminate LO2 and LH2 PAL ramps
  - Enhance NDI technology to use as an acceptance tool
  - Apply appropriate level of process controls and enhancements to in-line closeouts
  - Volume fill material in the Intertank "y-joint"
  - Enhance TPS thermal analysis tools to better size and potentially reduce TPS on the vehicle

3.2-1 – External Tank (ET) Debris Shedding

Phase 1: Return to Flight Approach

- Employing a lead tank/trail tank approach to support RTF
  - External Tank-120, planned to support the first RTF mission, will be shipped prior to final certification of the ET design
  - Phased Design Certification approach being used to assess certification readiness of the ET prior to shipment to the Kennedy Space Center
    - DCR I on-site review scheduled for 12/09/04 – 12/14/04 includes:
      - GUCP redesign
      - SRB bolt catcher
      - Camera system
      - Non-TPS re-verification activities
      - Redesigned non-TPS hardware
      - Closed PRCB actions
    - DCR II on-site review scheduled for 01/24/05 – 02/04/05 (after planned ship date / prior to ET/SRB mate) includes:
      - Redesigned TPS hardware
      - TPS re-certification
      - Development Flight Instrumentation (ET-121)
      - Open certification from External Tank Phase I DCR
  - To mitigate the risk associated with this approach, the trail tank will not be shipped until final design certification / re-certification

3.2-1 - TPS Re-Certification

- **Certification Summary**
  - Materials are certified
    - Additional confidence tests in progress
  - TPS applications meets propellant quality, structural integrity and ice/frost prevention requirements
  - Designs meet initial screening for debris allowable based on preliminary data (thermal / vacuum tests without cryo-ingestion)
    - TPS applications that did not meet initial screening were identified for removal / replacement (Longeron in addition to bipod and Intertank/LH2 flange)
    - Continuing thermal / vacuum tests with cryo-ingestion load environment to detect critical defect size

- **Open Work for Certification**
  - Required for DCR Phase I
    - None – Phase I DCR does not include TPS
  - Required for DCR Phase II
    - Stress and thermal analysis
    - Material re-certification tests
    - Margin demonstration tests
    - Critical defect hardware acceptance criteria to support Level II debris allowable

3.2-1 – External Tank (ET) Debris Shedding

Panel Assessment

- Fact Finding
  - ET RTF status, Michoud Assembly Facility, August 28, 2003
  - ET RTF status, Michoud Assembly Facility, September 30, 2003
  - ET RTF status, Michoud Assembly Facility, December 2, 2003
  - ET RTF status, Michoud Assembly Facility, February 3, 2004
  - ET RTF status, Michoud Assembly Facility, June 25, 2004
  - Telecon with SSP, July 16, 2004
  - Telecon with SSP, July 28, 2004
  - ET Technical Interchange Meeting, August 18-19, 2004
  - ET Flange CDR, August 30, 2004
  - ET Status meeting, November 9-10, 2004.

3.2-1 – External Tank (ET) Debris Shedding

Summary Status

- **Plan**
  - Mature
  - External Tank-120, planned to support the first RTF mission, will be shipped prior to final certification of the ET design.
  - Tank will be processed through the normal integrated launch preparation processes.
  - RTF TG will continue monitoring the process until final closeout.
- **Implementation**
  - The program has developed an aggressive plan to eliminate critical debris
- **Recommendation**
  - Keep Open

3.3-1 – Reinforced Carbon-Carbon (RCC) Structural Integrity

CAIB Recommendation

Develop and implement a comprehensive inspection plan to determine the structural integrity of all Reinforced Carbon-Carbon system components. This inspection plan should take advantage of advanced non-destructive inspection technology.

3.3-1 – Reinforced Carbon-Carbon Structural Integrity

Summary Status

- **Plan:**
  - Update OMRSD for inspection of RCC panels
  - Closure of all MR/PR's from detailed RCC NDE inspection
  - Receipt of PRCB Directive S064002
  - Closure of RFI Tech-046, RCC Impact Test Data
- **Status:**
  - Update of OMRSD and Closure of MR/PR's scheduled for January, 2005
  - Received PRCB Directive
  - Closed RFI Tech-046
- **Recommendation: Open**

6.4-1 – TPS On-Orbit Inspection and Repair

CAIB Recommendation

For missions to the International Space Station, develop a practicable capability to inspect and effect emergency repairs to the widest possible range of damage to the Thermal Protection System, including both tile and Reinforced Carbon-Carbon, taking advantage of the additional capabilities when near to or docked at the International Space Station.

For non-Station mission, develop a comprehensive autonomous (independent of Station) inspection and repair capability to cover the widest possible range of damage scenarios.

Accomplish an on-orbit TPS inspection, using appropriate assets and capabilities, early in all missions.

The ultimate objective should be a fully autonomous capability for all missions to address the possibility that an ISS mission fails to achieve the correct orbit, fails to dock successfully, or is damaged during or after undocking.

6.4-1 – TPS On-Orbit Inspection and Repair

Summary Status

- **Plan**
  - Orbital Inspection including OBSS, ascent cameras, On-Board camera, ISS assets and other sensors, is continuing to mature and offers the potential for a comprehensive level of orbital damage inspection
  - Integration of all inspection assets is maturing
  - Orbital Repair technique for both tile and RCC are continuing in development
  - Repair options down select is planned for January 7, 2005
  - Current status could allow for a limited repair capability for both RCC and tile on STS-114.
- **Implementation**
  - In Process
- **Preliminary NASA closeout package submitted**
- **Recommendation: Keep As Open**

Integrated Vehicle Assessment Sub-Panel Fact-Finding Status

Ms. Christine Fox, Lead

Purpose of Integrated Vehicle Assessment Sub-Panel

Activities to Date

- **STS-114 Operations Integration Plan (OIP) for TPS Assessment published 11/15**
  - **Includes Annex on Damage Assessment Process**
- **Operations Integration Plan developers have conducted:**
  - **A series of paper sims**
  - **An MMT with a TPS assessment event**
- **Aggressive simulation plan between now and scheduled flight**
- **OIP developers will participate in the DCR process**

Purpose of Integrated Vehicle Assessment Sub-Panel

Observations

- Operations Integration Plan becoming mature
- Have included many sources of data to support complex decisions
  - Models
  - Historical data
  - Real-time ground testing
- Senior NASA management accepts and supports the Operations Integration Plan
  - Plan and Damage Assessment Annex signed by Shuttle Program Manager

Purpose of Integrated Vehicle Assessment Sub-Panel

Summary

- OIP represents a significant and successful development effort
  - Defined a vision
  - Secured commitments across NASA boundaries
  - Developed a training program to support the effort
- OIP could serve as a model for other information assessment processes required to support complex decision-making
- IVASP will continue to monitor OIP development and training efforts

RTF TG

Action Item Summary and Closing Remarks

Mr. Dick Covey – Co-Chair