STS-114 Flight Readiness Review
29 June, 2005

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Director NESC

STS-114 Return to Flight Constraints – Open Work

- Expected Debris Flight Rationale Peer Review
- Orbiter Damage Assessment Models Peer Review
- Orbiter Body Flap Actuator

STS-114 Return to Flight Constraints – Closed Work

- T-0 Umbilical Review
- GH2 Vent Arm Behavior Predication Model Review
- External Tank Independent Assessment
- Kevlar Composite Over-Wrapped Pressure Vessels
- Rudder Speed Brake Power Drive Unit Gear Scuffing
- High Pressure Oxidizer Turbo Pump Knife Edge Seal Cracking
- Space Shuttle Program Recurring Anomalies Review
- External Tank LOX Feedline Bellows Drip Lip Environmental Testing
- Rudder Speed Brake Structural Margins
- Orbiter Main Propulsion System Feedline Flowliner Cracks
- Reaction Control Sub-system Thruster Mounting Flange Cracking
- Orbiter Wing Lead Edge Attach Hardware Testing
- ISS Post Proof NDE of European Module Welds

Non-Return to Flight Constraints – Open Work

- External Tank LOX Feedline Bracket Ice Elimination
- External Tank LOX Feedline Bellows Ice Elimination
- Shuttle/ISS Orbiter Repair Maneuver (constraint to first use)
- Micro-Meteoroid Orbital Debris Risk Assessment
- Reaction Jet Driver
- Non-Destructive Evaluation for Thermal Protection System
- Cure In Place Ablative Applicator
- Body Flap and Rudder Speed Brake Actuator Bearings
- Solid Rocket Booster Hold-down Post Stud Hang-up
- Orbiter Flexhose Corrosion

Non-Return to Flight Constraints – Closed Work

- BUMPER II Micro-Meteoroid Orbital Debris Inspection
- KSC PC GOAL Data Integrity
- Rotating Service Structure Stress Analysis

STS-114 Return to Flight Constraint - Open

29 June 05

Roe

- Expected Debris Flight Rationale Peer Review
- Orbiter Damage Assessment Models Peer Review
- Orbiter Body Flap Actuator

- **Description and Scope:**
  - The Space Shuttle Program (SSP) requested that the NESC conduct a peer review of the STS-114 flight rationale
  - Assessments by the Orbiter and External Tank (ET) engineering teams demonstrated that the Space Shuttle System could not be fully certified for flight through expected foam or ice debris liberated from the ET
  - The SSP developed a flight rationale based on Accepted Risks using best estimates of the impact capability margin for the orbiter thermal protection system (TPS) and a Monte Carlo-based probabilistic analysis of foam and ice debris. Relevant flight history data and other physical data such as the reduced void (defect) count for the new redesigned foam was also used to develop the flight rationale
  - The scope of the peer-review included the flight rationale logic, available engineering data, methods to determine the likelihood and “best estimate” of expected debris, and probabilistic methods to characterize risk

- **Background (review tasks):**
  - Assess the flight rationale logic and identify the limitations and gaps in the supporting engineering data
  - Assess both the “certification rigor” and “best estimate” methods to compute the impact capability margin (C/E) of Orbiter Reinforced Carbon Carbon (RCC) and tile
  - Conduct an engineering evaluation of the physics of foam debris liberation from each unique ET location
  - Assess the Monte Carlo-based probabilistic estimate of the likelihood of critical impact damage to the Orbiter from foam and ice debris

- **Results:**
  - An assessment of the engineering data available to support the flight rationale has been completed and limitations have been identified
  - A final report of the findings of the peer-review has been released to the stake holders. The report includes 14 recommendations.

- **Results (continued):**
  - The NESC formed two conclusions:
    - For Foam Debris: The NESC has concluded that the probabilistic results, supplemented by additional engineering data, physics considerations, and the level of control over debris liberation, provide a reasonable engineering foundation for a flight rationale for STS-114 based on accepted risk due to expected foam debris.
    - For Ice Debris: Based on the available test data and analysis results, the NESC has concluded that the feedline brackets, bellows and ET umbilical ice debris environment is not sufficiently characterized or understood to assign the level of risk. To establish the flight rationale for STS-114, additional work is required to develop adequate controls for ice.

- **Program/ Project response/ action plan/ corrective action:**
  - Program has accepted the risk for expected debris at the June 24, 2005 Design Verification Review Board

- **Issues/constraints/open work:**
  - The following recommendations remain open:
    - The risk assessment for tile seals and penetration should be completed, including the threat from popcorning debris.
    - A physics-based engineering analysis of the risk to tile from ET umbilical ice and baggie debris should be completed prior to STS-114 to ensure that adequate impact capability exists for impact scenarios consistent with past flight environment.
    - An evaluation of effective controls of ice debris from the ET umbilical ice should be completed prior to STS-114 and implemented via Launch Commit Criteria (LCC).
    - An evaluation of effective controls of ice debris from the feedline brackets should be completed prior to STS-114 and implemented via LCC. In addition, risk mitigation methods that can be implemented for subsequent missions to reduce overall program risks should be pursued as a high priority.
    - Focus the flight test objectives to obtain engineering data during STS-114 to characterize the ice debris environment for the ET feedline brackets at locations 1129 and 1377, mid bellows, and ET umbilical. Additional ground tests should be conducted to supplement the flight test data.

- **Flight Rationale/ Risk Assessment:**
  - NESC concurs with the SSP flight rationale for foam. Remaining open work will establish flight rationale for ice based on controls and risk acceptance.

- **Description and Scope:**
  - The Orbiter Project Office (OPO) requested that the NESC conduct a peer review of the Orbiter damage assessment models
  - A pre-flight and on-orbit assessment strategy involving a combination of new and existing math model tools has been developed to determine the impact tolerance and damage tolerance of the Orbiter thermal protection system due to impacts from debris
  - The objective of the NESC peer review is to determine if the tools and the assessment strategy are suitable to support STS-114
- **Background:**
  - An engineering data package for each math model tool was peer-reviewed, including the interface (input/output data requirements) with other tools
  - The peer review included an assessment of the end-to-end, integrated analysis strategy to address the compatibility of data exchange between the models and the propagation of uncertainties from the initial definition of the impact event to the final estimate of the resulting damage.

- **Results:**
  - The peer-review of all tools required for return-to-flight has been completed

Tile and RCC Tool	Data Pack Delivery to NESC	Requested NESC Review Complete***
Rapid Response RCC Damage Prediction Tool - Ice	Y	Y
RCC Damage Growth Tool	Y	Y
Tile Rapid Response Damage Model (ice)	Y	Y
Cavity Heating Tool	Y	Y
CFD for Cavity Heating: Smooth Baseline	Y	Y
CFD for Cavity Heating: Flight Traceability	Y	Y
Catalytic Heating Tool: Damaged	Y	Y
Boundary Layer Transition Prediction Tool	Y	Y
3D Acreage Tile Thermal Model	Y	Y
Special Configuration Thermal Models (8)	Y	Y
Tile Stress Tool – RTV bond line (45 deg)	Y**	Y**
Stress Assessor Tool	Y	Y
RCC DYNA Tool	Y	Y

** Tool is being modified and will be reviewed a second time, revised data package is not available

*** All tool peer-reviews are preliminary pending review of the end-to-end tool integration

- **Results (continued)**
  - Limitations in the use of each tool were identified. The most significant include:
    - The RCC DYNA tool is limited to only predictions of damage onset in the WLE panels, and is not experimentally validated for the nose cap and chin panel
    - The RCC Damage Growth Tool has not been experimentally validated for the WLE and wedge flow testing is necessary to validate
    - The boundary conditions used in the special configuration thermal models are not experimentally validated
    - Several tile tools were empirically developed and therefore are limited to the test database used to develop the tool

- **Program/ Project response/ action plan/ corrective action:**
  - Impact testing of the nose cap is scheduled to begin June 30th
  - Additional wedge flow arc jet tests are being planned

- **Issues/constraints/open work:**
  - RTF constraint
  - NESC peer-review of the integrated, end-to-end tile assessment tools will not be completed by the FRR. A face-to-face meeting on the integration of the tools is scheduled for June 29, 2005 with completion targeted for July 8.
  - Tile Stress Tool re-review is in-work and will be completed by July 8, 2005

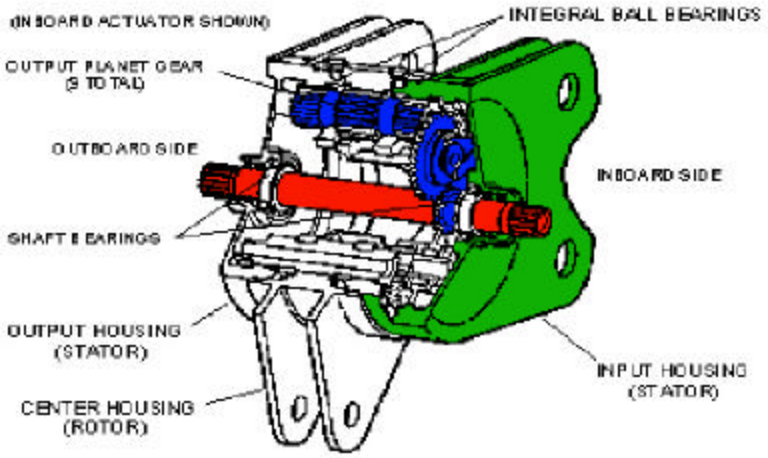
- **Flight Rationale/ Risk Assessment:**
  - Tools can be used for on-orbit damage assessments, with as documented limitations

Body Flap Actuator (BFA)

29 June 05

McManamen/Hall

- **Description and Scope:**
  - Due to similarity to Rudder Speed Brake (RSB) design the NESC is investigating the BFA design and margins
- **Background:**
  - The NESC is conducting an independent assessment into the cracked input spline, mis-ground ring gear tooth roots, and negative margins on planet gears



- **Results:**
  - Input spline shaft assessed by destructive analysis and system test
    - Shows the crack is most likely a product of manufacturing and did not propagate during system level testing or flight
  - Mis-ground ring gear tooth roots were produced during the manufacturing process and all flight units have this condition
    - Fatigue and strength testing of flight ring gear segments with mis-ground root indicates little impact to strength margin and shows considerable fatigue strength even after crack initiation
    - Expect planet gears will still be the limiting component for static strength and fatigue life

- **Results (continued):**
  - Planet gear Finite Element Analysis (under review) shows negative margin at ultimate loads based on 3-D Finite element model
    - Recent update to stress analysis predicts positive margin, however relies on assumption of ductile material properties allowing removal of stress concentration factor (Kt=1.0) and use of a plasticity factor (1.5)
  - Confirmation of assumptions used in analysis being verified by materials testing
    - 4 point bend test results of notched and un-notched samples show a stress concentration factor does exist which has a negative effect on stress and fatigue margins
      - Case region shows brittle behavior
        - Kt = 1.22-1.28 depending on gear geometry (for single load to failure)
        - Kf =1.67 – 1.76 for fatigue at 1000 cycles
    - A-Basis equivalent minimum material properties developed based on MIL Handbook 5J process (assumes exponential distribution with 99 % reliability and 95% confidence) = 312 ksi
      - Hamilton Sundstrand currently using 311 ksi
  - Additional NESC tests support flight rationale
    - GRC spur gear strength and fatigue testing shows the 9310 gear material to be very robust
      - Numerous tests at low cycle-high load region of S/N curve show high strength to crack initiation and considerable residual fatigue strength to point of failure

Body Flap Actuator (BFA)

29 June 05

McManamen/Hall

- **Program/ Project response/ action plan/ corrective action:**
  - Orbiter Project and NESC agree on findings for cause of input spline cracking
  - Project agrees mis-ground tooth roots could reduce margins
    - Effect is being accounted for in the analysis for static strength and fatigue margins
  - Available fatigue life on OV-103 unit is under review given the predicted stress levels and cracks found post qualification testing
    - SSP Problem Resolution Team (PRT) recommends limited life based on point of crack initiation
    - Currently OV-103 has 30 missions
  - Project updating static strength and fatigue margins based on new findings

- **Issues/constraints/open work:**
  - Constraint to flight - static strength and fatigue life margins should be updated based on test derived stress concentration factor and A-Basis minimum material property data
    - Could result in negative static strength margin and possibly negative fatigue margins

Body Flap Actuator (BFA)

29 June 05

McManamen/Hall

- **Flight Rationale/ Risk Assessment:**
  - Project flight rationale based on having passed original qualification test program and NESC bench testing
    - Sufficient waiver rationale
  - NESC STS-114 flight rationale based on the following:
    - NESC bench testing demonstrated robustness of 9310 gear material
      - Tolerant of high loads to crack initiation
      - Considerable residual strength after crack initiation to the point of fracture
    - Strength margin at ultimate load based on successfully completing ultimate load test without failure
    - Inherent robustness of the nine planet gear system providing parallel load paths able to redistributes internal loads relieving loads on yielded or cracked teeth
    - OV-103 fight units have been inspected during refurbishment - no cracks found
    - Sufficient waiver rationale exists

STS-114 Return to Flight Constraint - Closed

29 June 05

Roe

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T-0 Umbilical Review

29 June 05

Wilson

- **Description and Scope:**
  - NESC reviewed Space Shuttle Program (SSP) plan to address issues raised by an S&MA independent assessment team (IAT) following the STS-112 System A pyrotechnic fail-to-fire incident
- **Background (review tasks):**
  - SSP built models and conducted testing to address IAT concerns
  - Some IAT team members did not concur with the SSP's actions and recommended additional work
- **Results:**
  - NESC concurred with the SSP's corrective actions and flight rationale and generated four recommendations to improve the models and gather additional data for assessing actual margins
  - In a follow-on effort, NESC performed additional work to better-understand the T-0 interface and the mechanics of a corrosion-induced intermittent electrical failure

- **Results (continued):**
  - Integrated plate / connector modeling
    - Analysis of dynamic load at connector interface indicates significant margin exists with anticipated loads generating only 1.5 pounds of force against a 40 pound connector retention spring
    - NESC recommendation remains to instrument interface during future launch and anchor models
  - Detailed connector examination and testing
    - Results are consistent with earlier failure analysis and with corrosion on pins as most probable cause of failures noted
    - Pins have patches of corrosive by-product that are completely insulative and "persistent" – they are not dislodged when probed
    - Socket-to-pin contact has limited ability to "wipe" connections and dislodge corrosive products
    - Intermittent connection in presence of corrosive products duplicated
  - Estimate of quad-redundant circuit failure probability
    - Estimated probability of failure = 1×10^{-3} for single circuit at T-0 interface and 1×10^{-10} for quad redundant circuit
    - Assumptions: Single failure in 113 missions. Probable cause of the failures observed was corrosion, and corrective actions have eliminated that failure mode. No other common cause failure mode exists.

T-0 Umbilical Review

29 June 05

Wilson

- **Program/ Project response/ action plan/ corrective action:**
  - SSP has levied actions to address NESC recommendations
- **Issues/constraints/open work:**
  - No RTF constraint
  - NESC recommendation to instrument T-0 interface through launch and collect additional validating data should be implemented at the earliest opportunity
- **Flight rationale/ Risk Assessment:**
  - NESC concurs with existing flight rationale

Gaseous Hydrogen (GH2) Vent Arm Behavior Prediction Model Review

29 June 05
Wilson

- **Description and Scope:**
  - KSC iTA requested a review of the GH2 vent arm math models and verify/validate results
- **Background (review tasks):**
  - GH2 vent arm hit the pad structure during retraction for the STS-108 mission
  - Subsequent corrective action resulted in development of a dynamic model of the arm and retraction mechanism. Recent updates to that model have resulted in a proposed decrease in maximum allowable launch-day winds from 34 knots to 24 knots
- **Results:**
  - NESC team concurs model is well-designed and comprehensive
  - Four concerns raised
    - Freeplay caused by wear in arm joint mechanisms should be measured and the model revised accordingly
    - Extrapolation of winds from 60-feet to 250-feet may not be accurate
    - Validation drop tests performed in low wind conditions, not in problematic winds
    - Precise impact point of arm within latch is not known

Gaseous Hydrogen (GH2) Vent Arm Behavior Prediction Model Review

29 June 05

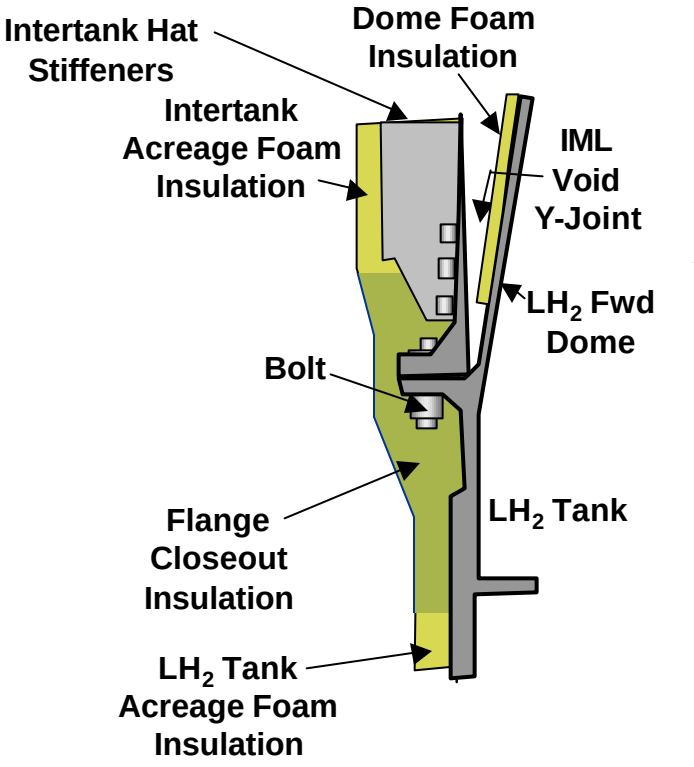
Wilson

- **Program/ Project response/ action plan/ corrective action:**
  - Reduction of wind constraint limit from 34 knots to 24 knots appears reasonable, given uncertainties
- **Issues/constraints/open work:**
  - Wind constraint may be revised if NESC concerns are addressed
    - Improve model with inclusion of freeplay
    - Provide direct measure of winds at 250-foot level
- **Flight rationale/ Risk Assessment:**
  - NESC concurs with existing flight rationale which includes an LCC constraint on winds greater than 24 knots

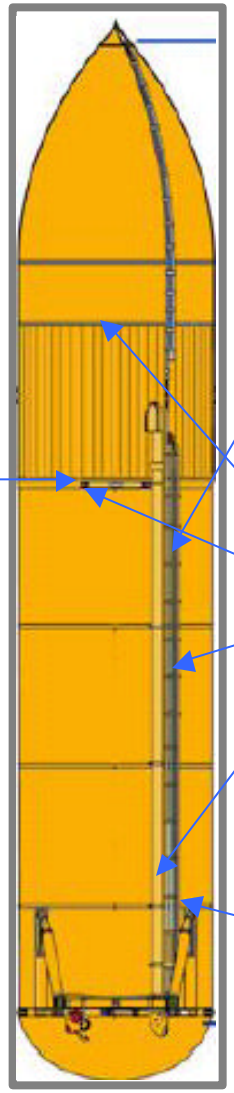
NESC Activities on External Tank Project

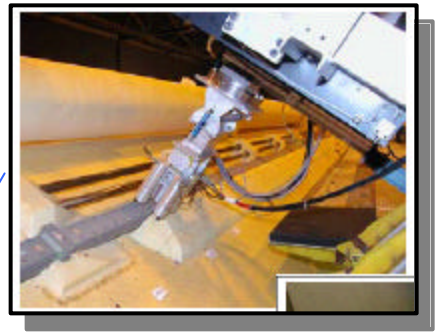
29 June 05

Cash

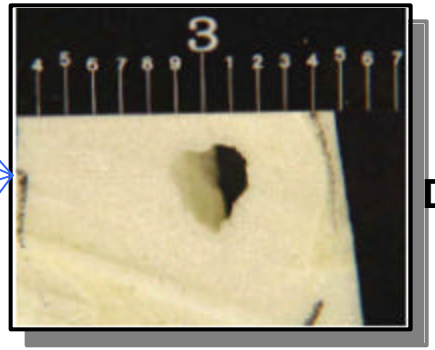


Intertank Flange Section





NDE of PAL Ramps



Foam Dissection Data

LO2 Feedline Bellows

ET Independent Assessment

29 June 05

Cash

- **Description and Scope:**
  - Independent review of External Tank (ET) return to flight activities. Provide appropriate technical expertise to participate in key technical interchange meetings and milestone reviews
- **Background:**
  - The NESC formed a team of experts in the areas of Materials, Structures, Fracture Mechanics, NDE, Thermal, Fluids, Human Factors, Systems Engineering and Statistics to independently review the ET redesign, testing, analysis and improved processes for the application of Sprayed On Foam Insulation (SOFI)
- **Results:**
  - A series of white papers/recommendations on various issues were submitted to the ET Project which included the following topics; ET Certification, Statistical Methods, Manually Sprayed “fly-as-is” foam certification, Human Factors, and application of fracture mechanics in SOFI
  - Formal Review Item Discrepancies (RIDs) have been submitted during the ET Design Certification Reviews documenting all issues identified by the NESC team

ET Independent Assessment

29 June 05

Cash

- **Program/ Project response/ action plan/ corrective action:**
  - ET Project has implemented numerous NESC recommendations
  - ET Project has prioritized all RIDs and remaining work considered a constraint to RTF
  - ET Project has written a “Verification Limitations for External Tank Thermal Protection System” Document to outline specific limitations for verifying the debris requirements

- **Issues/Constraints/Open Work:**
  - No RTF constraint - 20 of 20 RIDs closed.
  - Redlines to the Verification Limitations document submitted by NESC and incorporated by ET Project

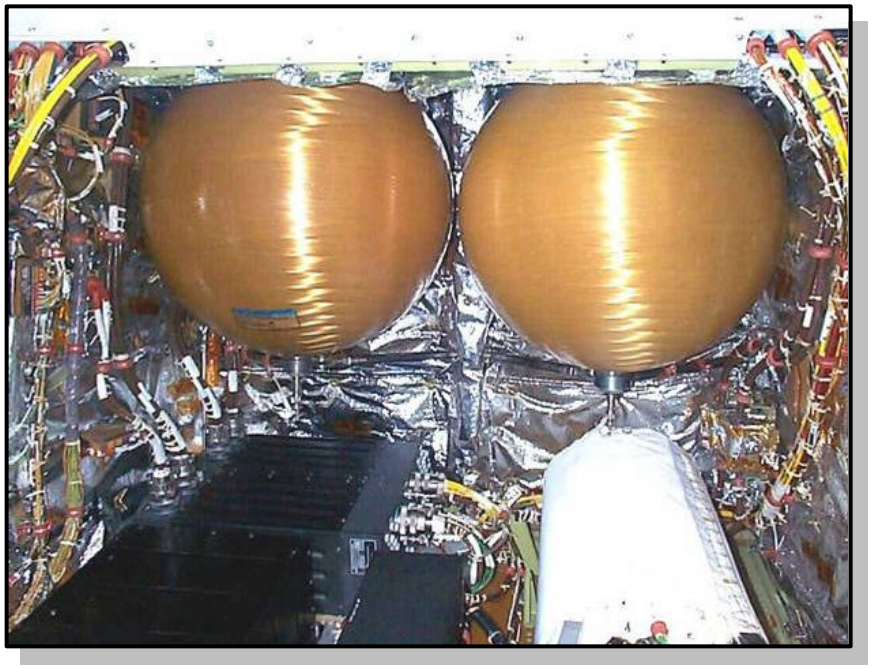
Kevlar COPV Flight Rationale Issue

Stress Rupture Failure of Composite Over-wrapped Pressure Vessels

29 June 05

Cameron

- **Description and Scope:**
  - In response to an alternate view, the NESC was asked to evaluate the flight rationale for the Orbiter Composite Over-wrapped Pressure Vessels (COPV)
- **Background (review tasks):**
  - The NESC conducted an inde-pendent evaluation of the flight hardware certification, with experts from structures, materials, NDE and COPV disciplines
  - Reviewed design certification and qualification test results and stress rupture test results from the Lawrence Livermore National Laboratory (LLNL) which provided stress rupture reliability data



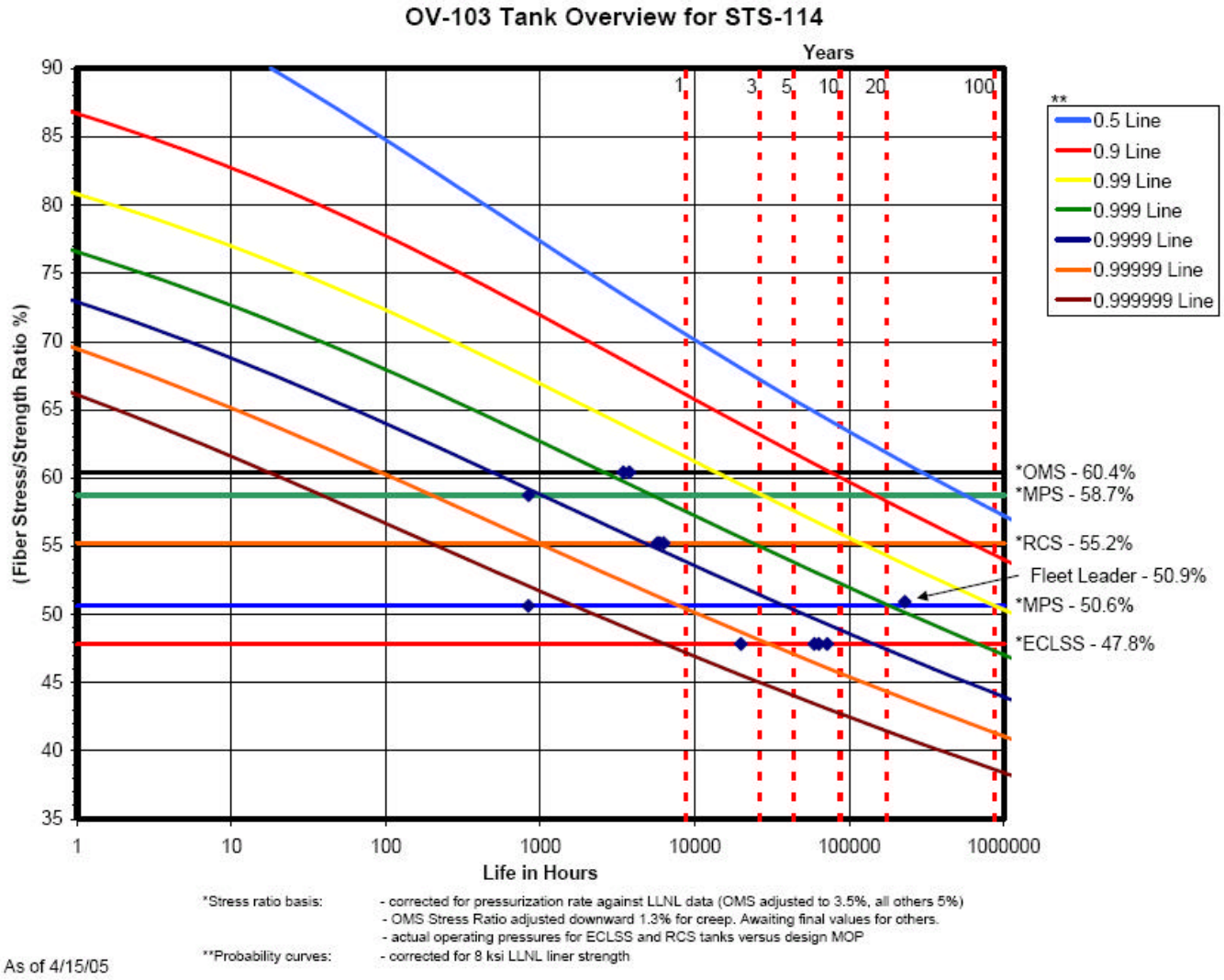
- **Results:**
  - Review of data from LLNL, SSP qualification and fleet leader COPV tests indicates that there is significantly less Stress Rupture (SR) life margin remaining in our COPVs than was stated in existing program documentation
  - In particular, the OMS He bottles are currently at higher stress levels than earlier recognized and each have <1 year accumulated time at pressure, indicating a design life reliability of <0.999 based on the LLNL SR life prediction curves. The remaining tanks all have SR life predicted design reliability greater than 0.999 for their current stress levels and times at pressure
  - Efforts by both program experts and NESC experts have been unsuccessful in identifying additional margin on the OMS GHe tanks
  - All of the Orbiter COPV have exceeded their 20 year certified age life, as indicated during the certification verification review (Documented in AVF-002061) and recertification efforts are in work
  - COPV Hazard Reports and CILs are currently in review by S&MA, to update reference to Stress Rupture failure, a “Burst Before Leak” failure mode, and assess impacts of flight risk and ground processing risk on operations

Kevlar COPV Flight Rationale Issue

Stress Rupture Failure of Composite Over-wrapped Pressure Vessels

29 June 05

Cameron



Kevlar COPV Flight Rationale Issue

Stress Rupture Failure of Composite Over-wrapped Pressure Vessels

29 June 05

Cameron

- **Program/ Project response/ action plan/ corrective action:**
  - The Orbiter Project is aggressively working the stress rupture issue with the NESC
- **Issues/constraints/open work:**
  - Analysis of hardware data and statistics continues, and STS-114/121 flight rationale will be based on assessment of conditional probability of future failure, based on past flight history and future single mission exposure time, and operational work-arounds including lower OMS He flight pressures and delayed pressurization of tanks to flight loads (Chit in work: J5898)
  - Review of recommended actions (analysis, testing, operational) to support long term re-certification and multi-mission flight rationale continues
  - Hazard review by S&MA is in work, to review flight and ground processing risk due to stress rupture (Burst Before Leak)
  - No RTF Constraint
- **Flight Rationale/ Risk Assessment:**
  - Current analysis of single mission predicted reliability of the combined system of COPV, with minimal impact to operations, indicates an estimated COPV system (24 vessels) reliability better than .9995 for STS-114/121

Rudder Speed Brake (RSB) Power Drive Unit (PDU) Gear Scuffing

29 June 05
McManamen

- **Description and Scope:**
  - Consultation with the Orbiter Program to develop and conduct test and analyses to assess the gear scuffing that has been found in a RSB PDU
    - Inspection of RSB PDU S/N 403 in October 2001, for unrelated spool stop investigation, revealed scuffing (damage to gear teeth surface) in 2 gears
    - Concern that backdrive can occur and gear failure is possible resulting in a critical failure
    - Most probable cause is in-flight hydraulic motor backdriving through gear box resulting in motor/gear overspeed
- **Background:**
  - Worked with Program to perform the following:
    - Define and conduct a series of bench level tests
      - Determine and bound the parameters necessary to generate scuffing in this application
      - Compare these results to the operational scenarios that can create the backdriving event
      - Develop a worst case gear teeth damage scenario

Rudder Speed Brake (RSB) Power Drive Unit (PDU) Gear Scuffing

29 June 05

McManamen

- **Background (continued):**
  - Fatigue life degradation and debris generation determined from this data and used to determine a tolerable scuffing time per flight
  - Conducted testing on flight gears at bench and system level
  - Completed analysis and testing on gear box oil to determine possible tribological degradation
- **Results:**
  - Testing simulated PDU scuffing for nominal operation, steady state backdriving, transient backdriving and wear subsequent to scuffing event
    - WAM testing produced scuffing damage and progression of surface changes similar to PDU but at more severe conditions
    - Tests required more severe conditions for scuff initiation than predicted for 50 HP, 14000 rpm PDU backdrive scenario (need higher speed, stress, temp, roughness)
  - Subsequent detailed examination of PDU S/N 403 scuffed ring and pinion gear show heavy plastic flow and scuffing at tip suggesting scuff initiation at pinion tooth tip and not at high point single tooth contact (HPSTC)
    - Deflections in the loaded tooth during transient backdriving event cause pinion tooth tip to dig in to ring tooth root which results in the tooth tip being “machined” similar to a designed tip relief

Rudder Speed Brake (RSB) Power Drive Unit (PDU) Gear Scuffing

29 June 05

McManamen

- **Results (continued):**
  - Contact stress is much higher than assumed due to very small radius and initial interference
  - Event occurs over a very shot duration, rounds over the tooth tip and then continues operating on damaged surface showing little additional wear
  - GRC testing also able to produce scuffing and tooth tip wear supporting the theory scuffing is occurring due to high load in backdriving event and no tip relief causing pinion tip to dig into root of ring gear
  - Both WAM testing and GRC spur gear testing show that once scuffing has occurred subsequent wearing on the rough surface is minimal-more like a polishing effect and most likely a self limiting event having only a small effect on PDU life
  - Oil testing results of the various used conditions as well as the difference between 882 and 882 NASA show that tribologically speaking there is very little difference between any of these oils and you would expect normal PDU performance with any of these oils

Rudder Speed Brake (RSB) Power Drive Unit (PDU) Gear Scuffing

29 June 05

McManamen

- **Program/ Project response/ action plan/ corrective action:**
  - Test/analysis developed and conducted jointly with the Program
- **Issues/constraints/open work:**
  - Completed bench testing by May 26, 2005 and reported to NESC Review Board Phase I and Phase II on June 2, 2005
  - Reviewed PRT and NESC findings with Orbiter Project Office on 6/8/05 with recommendation to remove the return to flight constraint for STS-114
  - Additional testing using flight gears required to fly additional flights with a scuffed PDU
- **Flight Rationale/ Risk Assessment:**
  - Flight rationale based on successful completion of bench testing and analysis showing PDU margin with scuffed gears for remainder of mission

Space Shuttle Main Engine (SSME) High Pressure Oxidizer Turbopump (HPOTP) Knife Edge (KE) Seal Cracking	29 June 05
	Gentz

- **Description and Scope:**
  - Assess the identified root cause(s) of the SSME HPOTP Turbine Outlet and Outlet Duct KE seal cracking and impact/damage tolerance analyses of seal debris
  - Review SSME Project Office flight rationale
- **Background:**
  - Cracking and seal debris have been observed in Turbine Outlet KE seals (F/N 072) from five HPOTPs
    - On-going root cause identification with primary suspected contributor of vortex shedding/acoustic dynamic excitation
  - Cracking has been observed on Outlet Duct KE seals (F/N 011) from four HPOTPs
    - On-going root cause identification with proposed failure mode of combined seal operating pressure loading and operating clearances producing seal flutter/dynamic vibratory load

SSME HPOTP KE Seal Cracking

29 June 05

Gentz

- **Results:**
  - NESC concurs with SSME Project proposed flight rationale for STS-114
    - No open actions or requirements have been identified that are considered constraints to the safe operation of the HPOTPs for the identified Deviation Approval Request (DAR) inspection/life limits
  - Engineering analyses and tests are ongoing in the effort to isolate the root cause(s) of KE seal cracking.
    - Examinations into crack initiation mechanisms should be reinvigorated in the areas of PWA SP1143 physical and mechanical properties, KE seal fabrication, and HPOTP assembly procedures.
    - Crack driving forces analyses and tests should be expanded to encompass the full range of KE seal dimensional variations and SSME operational environments.
    - Engineering test and analysis results should be institutionalized through the generation of engineering reports to support ongoing and future investigations

SSME HPOTP KE Seal Cracking

29 June 05

Gentz

- **Program/ Project response/ action plan/ corrective action:**
  - None Required
- **Issues/constraints/open work:**
  - No NESC identified RTF constraints
  - SSME Project Office submitted and obtained approval of Level II waiver allowing exceedance to 754 second abort scenarios and allow for a 6 second on-pad abort

SSME HPOTP KE Seal Cracking

29 June 05

Gentz

- **Flight Rationale/Risk Assessment:**
  - Risk mitigation to protection against F/N 011 and/or F/N 072 seal debris generation leading to rupture of heat exchanger, failure of third stage turbine blades, or blockage of Main Injector Posts
    - F/N 011 and F/N 072 seal cracking and operational experience
      - Low likelihood of F/N 011 web and seal cracking liberating debris within inspection/life limit
      - System tolerance to immediate failure/rupture from estimated maximum, “smart”, or abraded debris (shape, mass, and velocity) generated from F/N 072 seal
        - Estimated maximum “smart” debris mass of ~0.1 gram
        - Predicted tolerant debris mass to HEX penetration of ~0.7 gram
    - Continued abrasion of F/N 072 seal debris to smaller, more uniform, and tolerable size.
    - Installation of new seals with verified assembly clearances within drawing allowables prior to HPOTP acceptance test and flight.
    - Review of HPTOP acceptance test dynamic data for anomalous frequencies indicating seal/turbine blade rub or F/N 011 seal flutter.
    - 50% life limit/25% inspection limit of lowest time unit with critical cracking
      - Lowest time to teeth cracking for F/N 011 seal
      - Lowest time to turbine side tooth cracking for F/N 072 seal

SSP Recurring Anomalies Review

29 June 05

Wilson

- **Description and Scope:**
  - NESC team reviewed Space Shuttle Program (SSP) recurring anomalies
- **Background (review tasks):**
  - NESC formed eight engineering discipline teams (100+ engineers) to review hundreds of SSP recurring anomalies
  - Team reviewed SSP documentation including problem reports, hazard reports, etc. to identify hidden or unrecognized risk and elevate it for SSP attention
- **Results:**
  - 26 technical and 12 non-technical (collateral) issues were surfaced and 63 NESC recommendations generated
  - 6 issues required some action before return to flight. One of these was a technical problem and the others were requirements issues
- **Program/ Project response/ action plan/ corrective action:**
  - The SSP has responded to the RTF recommendations and is preparing an action plan to address the remaining recommendations

SSP Recurring Anomalies Review

29 June 05

Wilson

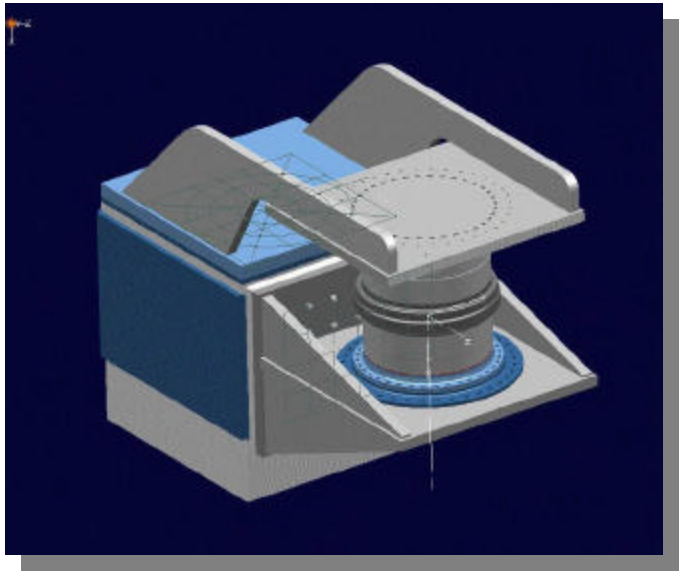
- **Issues/constraints/open work:**
  - SSP response to 6 NESC-identified RTF constraints is complete. NESC concurs with the program response to these items
- **Flight Rationale/ Risk Assessment:**
  - This activity should help the Program identify and address weakness in flight rationale

ET Independent Assessment
LOX Feedline Bellows Drip Lip Environmental Testing

29 June 05

Kirsch

- **Description and Scope:**
  - NESC is consulting with ET Project in testing to determine the effects on ice liberation resulting from the change from the baseline bellows foam design to the drip lip bellows foam design
- **Background:**
  - A new drip lip design has been incorporated in the bellows foam that reduces the formation of ice by 40%
  - The purpose of this test is to determine whether less ice is more easily liberated
- **Results:**
  - SSP has accepted NESC comments on the proposed test plan. Testing of the bellows area with the drip lip and non drip lip is in work. NESC is currently reviewing the results



LOX Feedline Bellows Test Article
Mounted to Vibration Test Fixture

- **Program/ Project response/ action plan/ corrective action:**
  - Program installed heater at the forward bellows

- **Issues/constraints/open work:**
  - Liberated ice represents a debris threat from both the drip lip and non-drip lip designs

- **Flight Rationale/ Risk Assessment:**
  - The Program has decided to install heaters that prevent the formation of ice at the forward bellows and has accepted the risk for ice at the mid and aft bellows
  - NESC has recommendation control for ice for STS-114 and to focus STS-114 test objectives to gather more data on ice. (see Expected Debris Flight Rationale Peer Review)

Rudder Speed Brake (RSB)

29 June 05

Hall

- **Description and Scope:**
  - Assess the possibility of a Criticality I Structural failure in the RSB actuators, in light of the low structural margins and the observed pitting and cracking on the OV-103 actuators
- **Background (review tasks):**
  - The NESC conducted independent testing and analysis to understand the fundamental mechanism of fretting damage, bench level testing to evaluate strength margins, and system level tests to demonstrate positive margin on previously flown hardware
- **Results:**
  - The NESC assessment concluded that the pitting and cracking damage is fretting type damage resulting from light loads and high cycle dither motion
  - Disassembly and inspection of the previously flown actuator used in the system level proof test actuator reveled nominal fretting (level 2 or less) and showed no visible signs of yielding or cracking after being exposed to the 1.25 x Limit loads

Rudder Speed Brake (RSB)

29 June 05

Hall

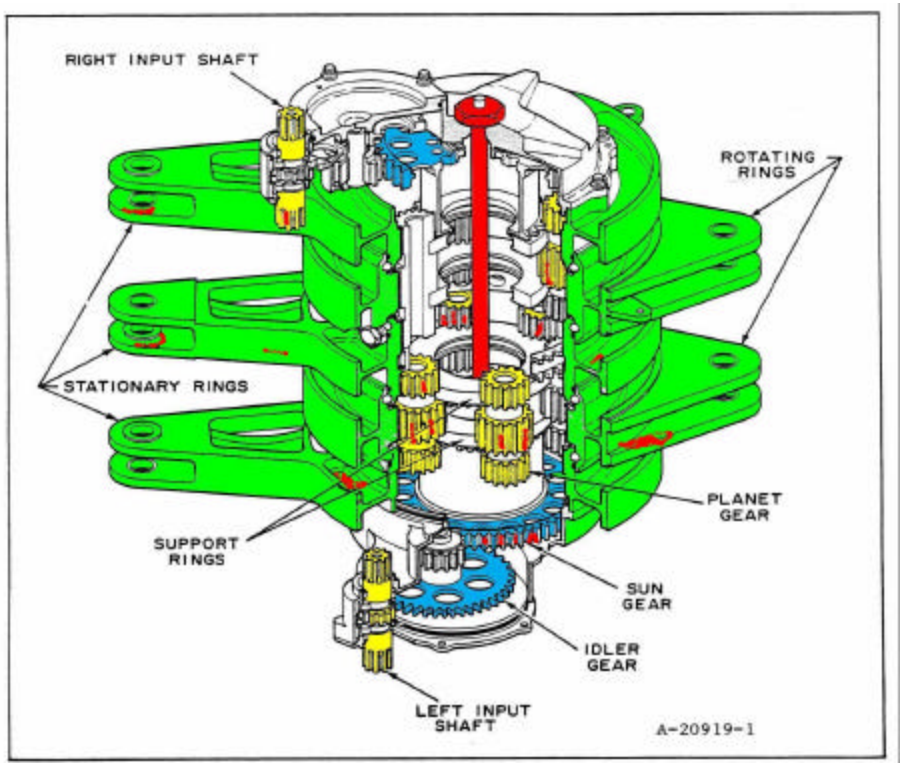
- **Results (continued):**
  - The NESC assessment concluded that the pitting and cracking damage is fretting type damage resulting from light loads and high cycle dither motion
  - Disassembly and inspection of the previously flown actuator used in the system level proof test actuator reveled nominal fretting (level 2 or less) and showed no visible signs of yielding or cracking after being exposed to the 1.25 x Limit loads
  - Demonstrated that fretting damage is relatively superficial and does not affect the root strength of flight gears
  - NESC conducted 4 point bending test to validate stress concentration factor assumption used by Hamilton Sundstrand in ultimate strength margin calculations – Completed April 22, 2005 and updated analysis shows positive margins

Rudder Speed Brake (RSB)

29 June 05

Hall

- **Program/ Project response/ action plan/ corrective action:**
  - NESC and Project agree to initial findings and recommendations
- **Issues/constraints/open work:**
  - RSB fatigue life is remaining open work necessary for continued usage of RSB hardware, but not a constraint to STS-114.
- **Flight Rationale/ Risk Assessment:**
  - Successful completion of gear bench testing, updated stress analysis indicating positive margins and the RSB system level proof test that demonstrated strength margin and performance at 1.25 x Limit Load



Orbiter Main Propulsion System Feedline Flowliner Cracks

29 June 05
Harris

- **Description and Scope:**
  - NESC performed test and analysis of cracks in the MPS flowliners of the liquid hydrogen feedline to the Orbiter main engines
  - NESC developed NDE techniques to detect flowliner cracks in situ to the Orbiter.
  - Inspections of the Orbiters in 2002 found a total of 11 cracks in the feedline flowliners. The cracks were weld repaired, the slots were polished, and the Orbiters returned to flight
- **Background:**
  - Conducted a failure analysis of cracks found in the flowliner of the Main Propulsion Test Article
  - Developed fatigue loading spectra for nominal flight conditions using the strain gage data measured during the hot fire tests previously conducted by the Program
  - Conducted fracture mechanics and fatigue crack growth analyses to determine the residual fatigue life of the flowliner for the certification loading conditions defined by the Program
  - Developed a high fidelity inspection method to assess the slot surface quality and to detect fatigue cracks as small as 0.001 inch
  - Conducted Computational Fluid Dynamics (CFD) analyses and acoustic tests to understand the physics of the flow field that excites the flowliner at the gimbal joint

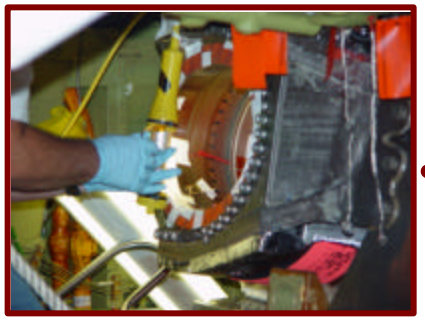
- **Results:**
  - The root cause of the cracks was found to be surface defects from the original flowliner manufacturing process. The slots were stamped, but never polished to remove the surface defects
  - The NESC recommended a re-inspection of the flowliners using a high-fidelity inspection method to verify that all fatigue cracks were found and repaired and also to assess the effectiveness of the slot polishing to remove the manufacturing defects (eliminate the root cause)
- **Program/ Project response/ action plan/ corrective action:**
  - The Program implemented the NESC recommendation. 42 additional cracks between 0.005 inch and 0.040 inch were found in OV-103. All fatigue cracks and surface defects were removed by polishing
- **Issues/constraints/open work:**
  - None
- **Flight Rationale/ Risk Assessment:**
  - Polishing removed the fatigue cracks and surface defects thereby restoring the fatigue life

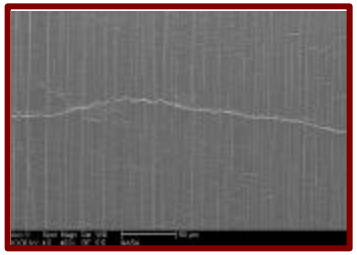
Orbiter Main Propulsion System Feedline Flowliner Cracks

29 June 05

Harris

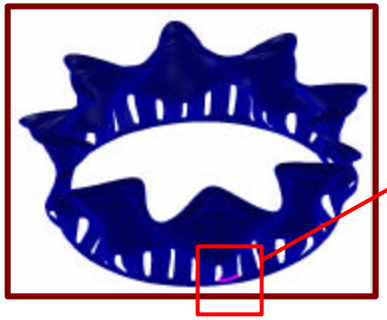
High-Fidelity Edge Replication Inspection Method

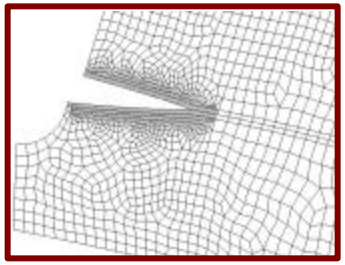


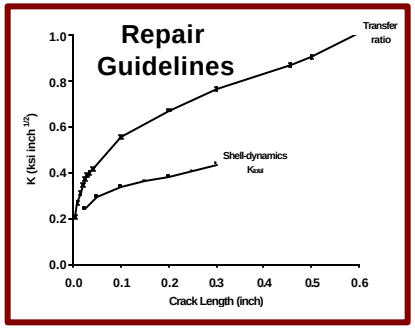


42 Cracks found in OV-103

Integrated Dynamics and Fracture Analysis Method







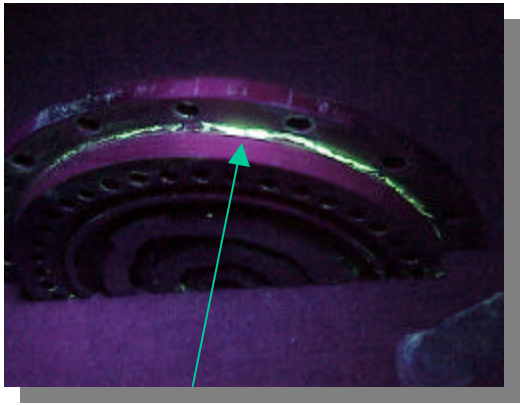
Cracks removed by polishing

Orbiter Reaction Control Sub-system (RCS) Thruster Cracks

29 June 05

Kirsch

- **Description and Scope:**
  - NESC performed tests to confirm the root cause of primary RCS thruster cracks. In addition testing was conducted to determine if cracks can propagate in service
  - NESC is developing NDE techniques to detect cracks
  - NESC performed tests to determine whether material properties of injectors were compromised by exposure to sodium hydroxide



Relief radius in S/N120 was cracked over a large fraction of its circumference

- **Background:**
  - Cracks were found during a routine operation on S/N 120 at the White Sands Test Facility depot in June 2004. Cracks are similar in nature to ones found early in the program and that were qualified on S/N 130 and S/N 132
  - In December of 2004 a thruster injector was inadvertently submerged in sodium hydroxide for weld surface preparation

Orbiter Reaction Control Sub-system (RCS) Thruster Cracks

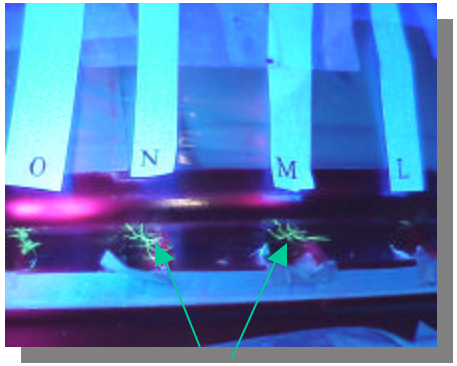
29 June 05
Kirsch

- **Results:**
  - NDE techniques are being developed for use at the depot level
  - The root cause of the cracking has been found to be hot salt-induced hydrogen embrittlement that occurred as a result of an etchant process during thruster manufacturing.
  - Destructive analysis of a qualification thruster indicated that cracks did not propagate by mechanical means
  - Destructive analysis of S/N 120 determined that exposure to sodium hydroxide cleaning during a chamber repair had negligible effects on injector material properties.
  - Stress and fracture analysis has determined that there is sufficient margin to detect a growing crack with a helium leak check during OMDP

Orbiter Reaction Control Sub-system (RCS) Thruster Cracks

29 June 05
Kirsch

- **Program/ Project response/ action plan/ corrective action:**
  - Project agrees with results
  - JSC SMA and Materials & Processes will conduct a complete audit of RCS Thruster processing
- **Issues/constraints/open work:**
  - None
- **Flight Rationale/ Risk Assessment:**
  - Root cause understood and confirmed cracks do not propagate in service

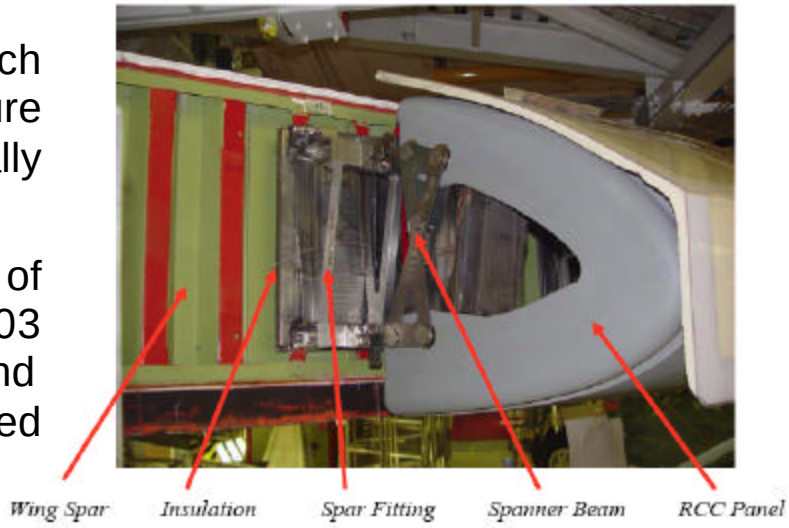


Nine of the sixteen counter bores in S/N120 had developed cracks

Orbiter Wing Lead Edge (WLE) Attach Hardware Testing

29 June 05
Harris

- **Description and Scope:**
  - Mr. Roger Tetrault requested a second look at the structural integrity of the WLE spar and the metal hardware that attaches the Reinforced Carbon-Carbon (RCC) leading edge panels to the wing spar
  - The scope of the assessment includes debris impacts that may occur during ascent and the potential for activation of aging-related failure mechanisms or time- and temperature-dependent degradation of material properties
- **Background:**
  - Conducted analysis of *Columbia* WLE attach hardware debris for anomalous failure mechanisms or indications of environmentally assisted aging
  - Conducted materials tests and analyses of orbiter flight hardware removed from OV-103 and new hardware to establish properties and assess indications of environmentally assisted aging



Orbiter WLE Attach Hardware Testing

29 June 05

Harris

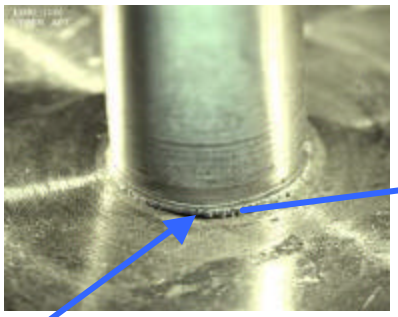
- **Background (cont'd):**
  - Performed thermal analysis to assess temperature of spar and attach hardware.
  - Conducted temperature-dependent aging tests to establish thresholds for activating aging degradation/failure mechanisms and measured property changes due to aging.
  - Performed stress analysis of attach hardware and spar for debris impact and reduced Allowables.
- **Results:**
  - Neither *Columbia* WLE debris nor hardware removed from OV-103, with 30 flights, show any indications of environmentally assisted aging related degradation.
  - Metallic components of the wing spar and RCC attach hardware, do not experience temperatures exposures that would cause environmentally assisted aging.
  - The one T-seal clevis that could experience temperatures, which would reduce its strength properties for the short duration of exposure, still has positive margin with the degraded properties.
  - Based on analysis of a single foam impact case (T-seal #9) wing spar and RCC attach hardware can withstand a foam impact well in excess of 1500 ft-lb.

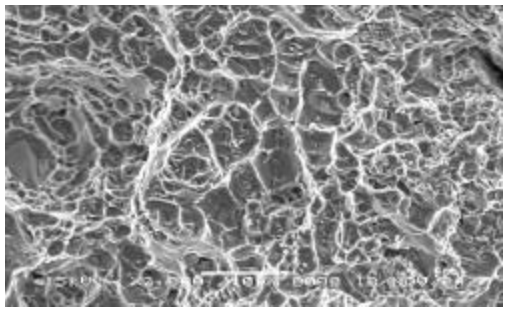
Orbiter WLE Attach Hardware Testing

29 June 05

Harris

- **Program/ Project response/ action plan/ corrective action:**
  - No corrective actions were recommended for the WLE spar and RCC attach hardware
- **Issues/constraints/open work:**
  - None
- **Flight Rationale/ Risk Assessment:**
  - Aging or degradation due to the environment has not reduced margins for WLE attach hardware





"Eyelash" crack penetrates the full thickness of the head

Classical dimpled rupture

Forensic Analysis of Failed T-Head Bolt from *Columbia* Panel 16 of the right WLE

ISS Post Proof NDE of European Module Welds (MPLM)

29 June 05

Gentz

- **Description and Scope:**
  - Perform independent and collaborative analysis, test, and evaluation of supporting structural analyses, NDE, and risk assessment associated with European modules that did not receive a post proof inspection
- **Background:**
  - NASA eliminated requirement for post-proof inspection on Node 2, Columbus Orbital Facility (COF), and three Multi Purpose Logistics Modules (MPLMs)
    - Relied on Leak-Before-Burst (LBB) philosophy and on-orbit leak detection of subcritical through-the-thickness crack
- **Results:**
  - Performed weld strength, crack growth, and fracture mechanics materials testing as input parameters to structural analyses
  - Developed Simulated Service Life (SSL) mechanical test methodology to provide empirical anchor to structural analyses
  - Matured Elastic Plastic Fracture Mechanics (EPFM) methodology to supplement Linear Elastic Fracture Mechanics (LEFM) technique

ISS Post Proof NDE of European Module Welds (MPLM)

29 June 05

Gentz

- **Program/ Project response/ action plan/ corrective action:**
  - MPLM Flight Modules (FMs)
    - Single sided eddy current inspection of FM-2 (STS-114) and FM-1 (STS-121)
    - Updated LEFM analysis to incorporate highest loaded weld and worst case manufactured weld peaking/mismatch (P/M) data
    - FM-3 not manifested
- **Issues/constraints/open work:**
  - No RTF constraint
  - Qualitative experience in welded pressurized structures shows experience of “crack enhancement” following proof testing
  - Limitations of LBB philosophy to habitable modules
    - Based on a strength versus fatigue life approach
    - Assumes pressure loss resulting in decreased stress field
    - No analytical or empirical correlation of weld through crack size to leak rate
    - MPLMs welds have corrosion protection coating that can mask leakage

- **Issues/constraints/open work (continued):**
  - Weld P/M values had a significant impact on weld stresses
  - Remaining Work
    - Node 2 (current flight schedule December 2006)
      - Update weld P/M magnification factors based on detailed Finite Element Modeling
      - Update structural analyses to include maximum deviation or specification allowable weld P/M values and updated P/M magnification factors
      - Perform SSL testing
    - COF (current flight schedule March 2007)
      - European Space Agency (ESA) responsibility
      - ESA/NASA evaluating NDE potential due to corrosion protection coating delamination
      - Transferring structural analyses and SSL methodology and results to ESA
- **Flight Rationale/ Risk Assessment:**
  - Inspection and analysis indicate adequate life for MPLM STS-114

Non-Return to Flight Constraint - Open Work

29 June 05

- ET LOX Feedline Bracket Ice Elimination
- ET LOX Feedline Bellows Ice Elimination
- Shuttle/ISS Orbiter Repair Maneuver (constraint to first use)
- Micro-Meteoroid Orbital Debris (MM/OD) Risk Assessment
- Reaction Jet Driver (RJD)
- Non-Destructive Evaluation (NDE) for TPS
- Cure In Place Ablative Applicator (CIPAA)
- Body Flap and Rudder Speed Brake Actuator Bearings
- Solid Rocket Booster Hold-down Post Stud Hang-up
- Orbiter Flexhose Corrosion

LOX Feedline Bracket Ice Elimination

29 June 05

Kirsch

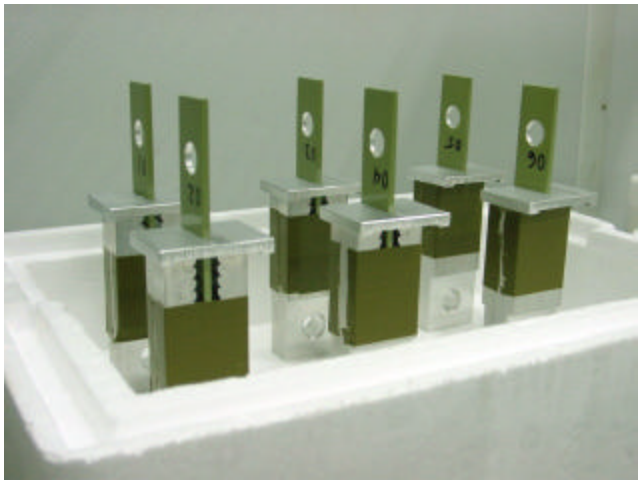
- **Description and Scope:**
  - NESC is developing alternative solutions for the prevention of ice at the LOX Feedline Brackets
- **Background:**
  - Ice is known to accumulate at the LOX Feedline brackets. This ice presents a debris threat upon launch. Solutions are being developed to manage the risk of ice up to and including launch
- **Results:**
  - The NESC is integrating ice expertise across the agency and industries to develop coatings to influence the formation and adhesion of ice on the feedline bracket area
  - Laboratory testing has shown that two coatings can influence the ice adhesion strength: Rain-X with MP55 additive and Braycote 601Ef with MP55 additive. (MP55 is a teflon powder material)
  - Ice liberation tests that rely on launch acoustic and vibration loads are being planned for developmental testing of candidate coatings
- **Program/ Project response/ action plan/ corrective action:**
  - SSP accepted risk for bracket ice at the June 24, 2005 Design Verification Review

LOX Feedline Bracket Ice Elimination

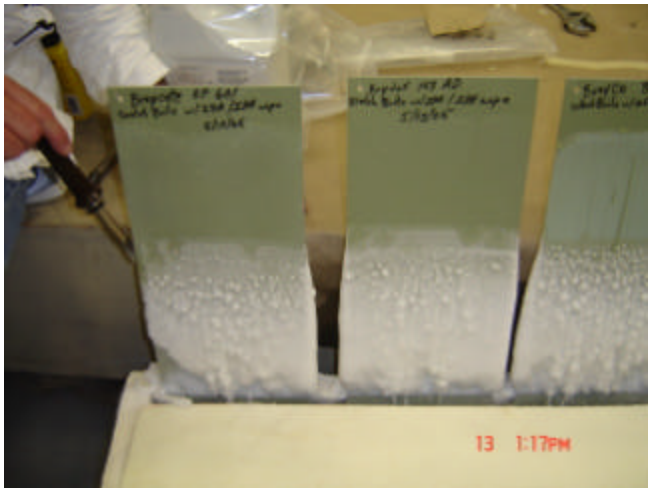
29 June 05

Kirsch

- **Issues/constraints/open work:**
  - NESC concurs with SSP acceptance of risk for bracket ice with noted recommendations
  - Candidate coatings continue to be evaluated for future flights
- **Flight Rationale/ Risk Assessment:**
  - This effort is being pursued in order to provide the SSP alternative solutions for the risk of ice at the bracket



Army Cold Regions Lab
ice adhesion coupon testing



Panel Testing at MSFC

ET LOX Feedline Bellows Ice Elimination

29 June 05

Kirsch

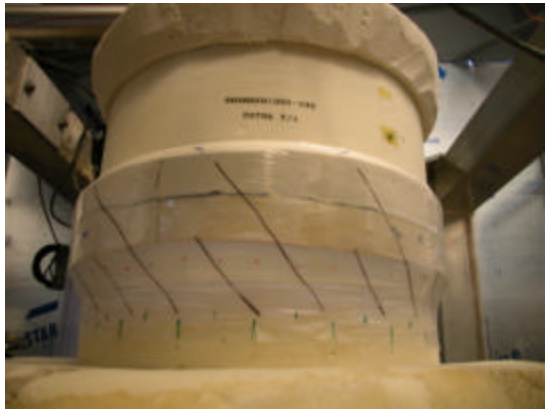
- **Description and Scope:**
  - NESC is developing alternative solutions for the prevention of ice at the LOX Feedline Bellows in addition to the bellows heaters being developed by the SSP
- **Background:**
  - Ice is known to accumulate at the LOX Feedline Bellows. This ice presents a debris threat upon launch. A design is being developed that would prevent the formation of ice in the pre-launch conditions and would be sacrificed upon launch
- **Results:**
  - NESC has developed a shrink wrap film filled with nanogel insulating beads that has demonstrated thermal performance in preventing ice at the bellows location under worst case temperature and humidity environments
  - Subscale and full scale test articles have been tested in thermal and aerodynamic environments:
    - Design prevents ice formation and allows for bellows articulation
    - Improved design releases early in launch (<250 fps) 15 out of 15 times
    - Improved design is stable during pad conditions (60 fps)
  - NESC supporting qualification testing of SSP's bellows heaters

ET LOX Feedline Bellows Ice Elimination

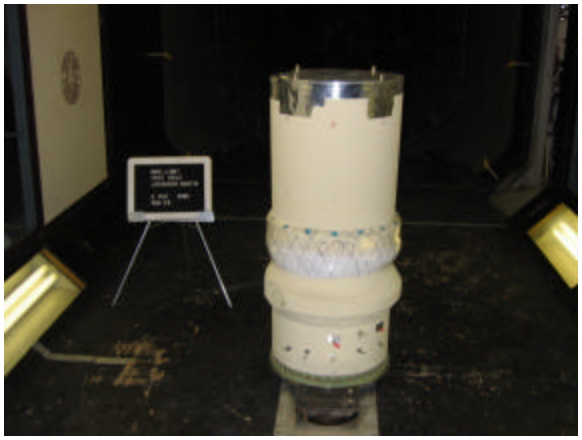
29 June 05

Kirsch

- **Program/ Project response/ action plan/ corrective action:**
  - SSP implementing heaters on forward bellows on STS-114
- **Issues/constraints/open work:**
  - Full scale thermal performance on sacrificial retainer is in work (ECD 15 July 2005)
  - Shrink wrap impact assessment is in work
- **Flight Rationale/ Risk Assessment:**
  - This effort is being pursued in order to provide the SSP a backup solution for the risk of ice at the bellows



Thermal testing of a full scale bellows

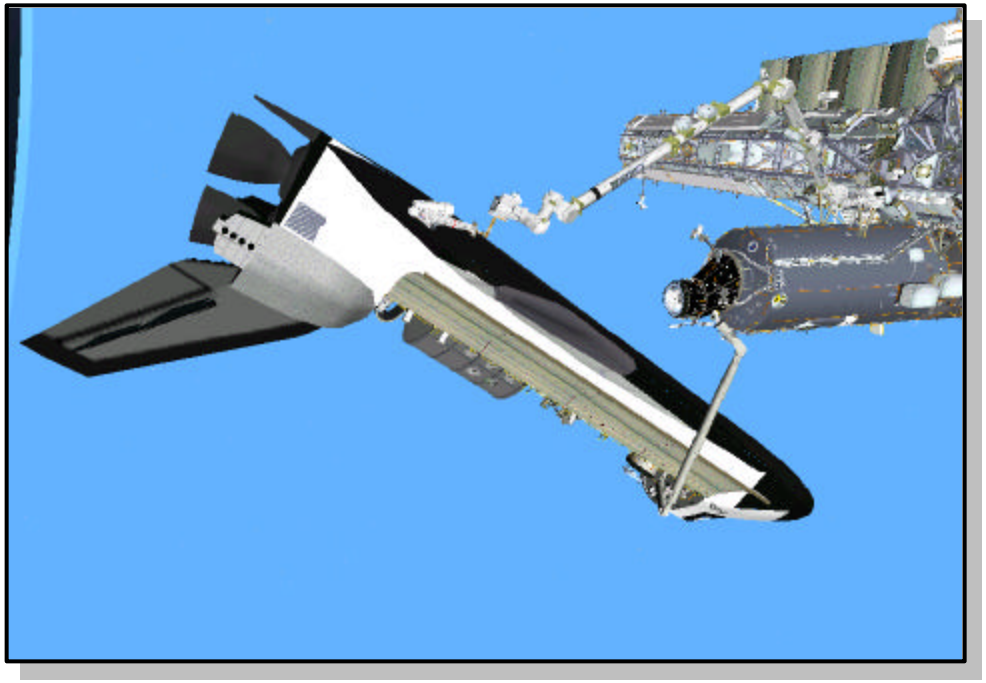


Wind tunnel testing of full scale bellows

Shuttle/ISS Orbiter Repair Maneuver

29 June 05

Dennehy



- **Description and Scope:**
  - In response to concerns over the complex dynamics and control of the Orbiter and ISS during the Orbiter Repair Maneuver (ORM) the NESC GN&C SPRT conducted a pre-RTF Peer Review of the ORM Working Group's modeling and analysis efforts at JSC on 8-10 June 2005

- **Background:**
  - ORM is a complex contingency operation with close proximity movements of flight structures, limited back-out opportunities and visibility, and high potential for adverse dynamic interactions between control systems, SRMS, SSRMS, and structure, possibly resulting in large or unstable relative motion between the Orbiter, the EVA Astronauts, and the ISS

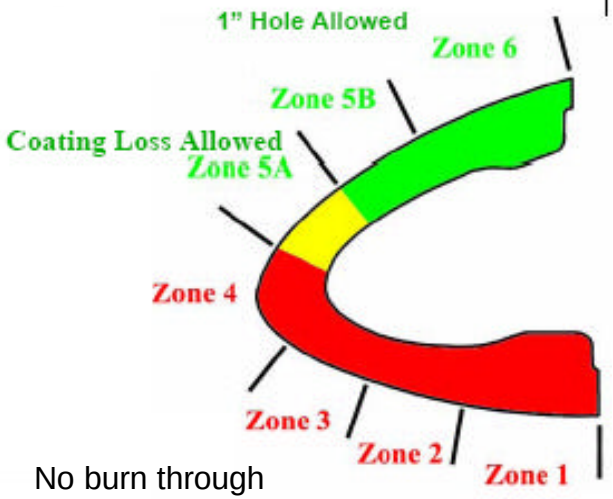
- **Background (continued):**
  - ORM consists of new and unfamiliar operations that are complex and pose risks (both know and unknown) to the crew and flight systems.
  - ORM is a “first of a kind” operation whose execution will require both the flight hardware and the crew to operate in a non-standard manner in regimes that are significantly outside the nominal operational experiences.
- **Results:**
  - NESC report developed summarizing ORM Peer Review findings and recommendations
  - Peer review team consensus is that there remains critical open work that must be completed prior to first use of ORM
  - The team also found that that lack of a dedicated full time ORM Lead System Engineer has impacted, and continues to impact, the integration and prioritization of open ORM analytical and operational planning work
  - The team found that the on-orbit contingency decision flow process/policy defining specifically when the ORM will be invoked had not been finalized
  - The team has developed the following prioritized set of recommendations which represents the minimum set of ORM analytical and operational planning tasks needed to have the ORM in place as a viable contingency for STS-114

- **Results (continued):**
  - Prioritized set of NESC recommendations on the ORM:
    - #1 Priority: Re-assessment of ISS attitude control system design and performance. Use high-fidelity simulation to show current design has adequate stability robustness margins. Also use high-fidelity simulation to demonstrate performance of ISS rate damping controller to recover stack from free drift rates at either the overnight park position or the repair position
    - #2 Priority: Complete the independent validation of the ORM integrated end-to-end dynamic simulation, to include benchmarking with Virtual Reality (VR) laboratory dynamics simulation
    - #3 Priority: Complete ORM contingency planning to include definition of: a) the ORM state-of-health/dynamic behavior monitoring procedures and protocols, b) the specific Contingency Action Plan for performing on-orbit analysis of worksite dynamic interactions, c) on-orbit pre-repair dynamic checks in the worksite environment and d) Failure Detection, Isolation and Recovery (FDIR) checks/tests

- **Results (continued):**
  - #4 Priority: Complete the analysis and simulation of the repair worksite dynamic interaction (i.e. assess relative motions between the EVA astronaut and Orbiter)
  - #5 Priority: Fully document and communicate all ORM operational constraints and hazards to Astronaut Office and mission control center staff
    - For example, need to document and communicate the fact that, if required during the ORM, an emergency Orbiter separation must be performed passively, using orbital dynamics with no thruster firings, from the overnight park position with the entire stack pitch down 45 degrees
- **Issues/constraints/open work:**
  - The set of five NESC prioritized recommendations, representing the minimum set of ORM analytical and operational planning tasks, need to be implemented in order for the ORM to be considered as a viable contingency for STS-114
- **Flight Rationale/ Risk Assessment:**
  - ORM contingency operations should not be invoked until, at a minimum, all NESC prioritized recommendations have been addressed

- **Description and Scope:**
  - Evaluate the increased MM/OD risk prediction and associated Space Shuttle Program (SSP) activities prior to Return-to-Flight to further define the risk
  - NESC proposes that the SSP host a Technical Interchange Meeting (TIM) to address the risk assessment analysis and associated inputs, distributions, and results

- **Background:**
  - The new ascent damage allowable on Reinforced Carbon Carbon (RCC) resulted in an increased MM/OD risk assessment
    - The no burn through allowed on RCC lower surfaces resulted in risk estimate moving from ~ 1/496 to 1/22



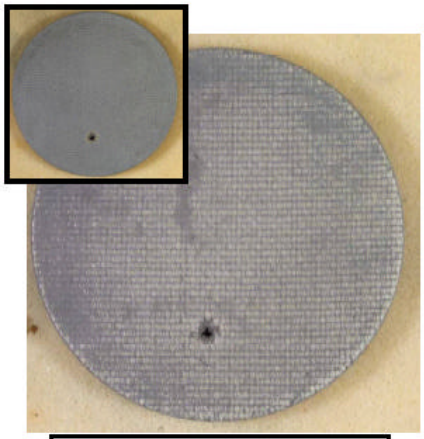
No burn through allowed for zones 1-5A, all 22 RCC panels

Micro-Meteoroid Orbital Debris (MM/OD) Risk Assessment

29 June 05

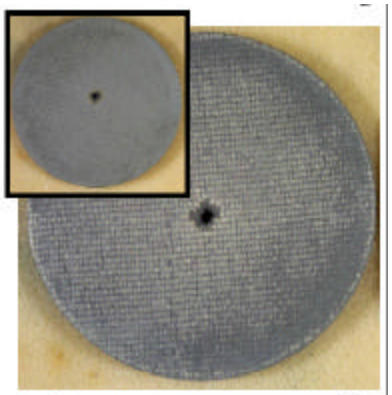
Labbe/Leggett

- **Background (continued)**
  - Orbiter Project Office (OPO) tasked to assess an updated MM/OD damage criteria on RCC for MM/OD that included breach of the RCC
  - Seven RCC specimens have been hypervelocity impacted and then tested within the Arcjet at Johnson Space Center (JSC).
    - MM/OD (hypervelocity) impacts create far less delamination when compared to ascent debris (low speed) impacts – this significantly reduces hole growth/size during entry
    - Assumption is delamination = 3x damage area
    - Test results used to update allowable damage
  - JSC Engineering Directorate has completed analyses that include:
    - RCC hole growth tool (OCCB baselined tool)
    - Wing Leading Edge breach flow analysis tool (uncertified, analytical & empirically based)
  - New risk calculations using the updated RCC damage criteria for MM/OD show the relative risk posture improving to ~ 1/192



Test #4
2960F/ 141 psf
0.091" dia. OML coating loss
No IML damage

Both Test #4 and #5 had no burn through



Test #5
2800F/104 psf
0.14" dia. OML coating loss
0.17" dia. IML coating loss

Micro-Meteoroid Orbital Debris (MM/OD) Risk Assessment

29 June 05
Labbe/Leggett

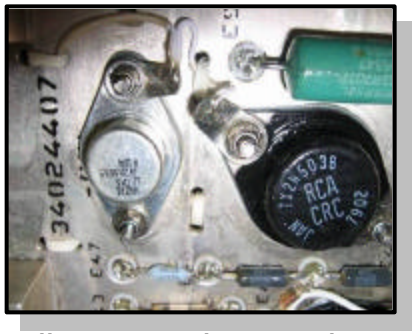
- **Results:**
  - NESC performed an extensive review of BUMPER and documented its lack of an uncertainty model
  - Due to its lack of uncertainty, caution needs to be exercised when using BUMPER predictions as part of an overall MM/OD risk assessment
  - BUMPER predictions provide a good estimate of relative risk, not an absolute overall risk
- **Program/ Project response/ action plan/ corrective action:**
  - In response, the International Space Station (ISS) and SSP have agreed to fly -XVV orientation while mated which will allow the ISS to partially shield Orbiter
- **Issues/constraints/open work:**
  - Orbiter Project Office plans to conduct a TIM of the models, analysis, and results with participation from independent organizations
- **Flight Rationale/ Risk Assessment:**
  - MM/OD risk needs to be treated with the same respect we are currently using for ascent debris
  - SSP should continue to evaluate and implement possible on-orbit MM/OD risk mitigations

Reaction Jet Driver (RJD)

29 June 05

Gilbrech

- **Description/Scope:**
  - NESC performed an independent assessment of an inadvertent RCS thruster firing during mated ISS operations due to single-point failures in the Orbiter RJD
- **Background:**
  - NESC risk assessment determined that previous risk assessments did not include data on aging. In particular aging of single-point failures; transistors and wiring.
  - NESC assessment of zero fault tolerant RJD design led to testing of 4 flown and 4 flight spare transistors to determine potential age effects
  - Conducting electrical characterization and destructive physical analysis (DPA) to assess condition of 25+ year old Darlington pair transistors (34 flights on one pair)
  - Conducting wiring tests to determine best configurations to protect for arc tracking



Darlington Pair Transistors

Reaction Jet Driver (RJD)

29 June 05

Gilbrech

- **Results:**
  - Lectromec tests to determine best configuration to protect for Kapton arc tracking complete.
    - Preliminary results briefed to JSC S&MA Technical Review Board on 5/12/05 including ISS iTA system warrant holder
    - Performed additional testing replacing 15A fuses with 10A fuses to envelope Orbiter schemes. 70% unprotected wire tests with 15A fuse opened valve, 20% for 10A test.
    - All protection schemes prevented openings, best-to-worst protection schemes established for recommendation to Program

- **Program/ Project response/ action plan/corrective action:**
  - SSP performing modified Acceptance Test Procedure on 6 flight spare RJD boxes with ECD of Nov 05. Once 4 RJD's have been re-tested (Oct 05), SSP will evaluate options/risks of installing these for STS-115

Reaction Jet Driver (RJD)

29 June 05

Gilbrech

- **Issues/constraint/open work:**
  - Inadvertent thruster firing not an issue until STS-115
  - Relay results of Lectromec Kapton arc track testing to ISS and SSP System Warrant Holders at 6/15/05 KSC walk down of OV-105 wiring
  - NESC recommends all RJDs flown after STS-121 receive modified ATP. SSP risk trade could affect NESC position
  - NESC recommends separating and protecting RJD command wires

- **Flight Rationale/Risk Assessment:**
  - Software patch to inhibit inadvertent thruster firing effective until STS-115
  - DPA evidence indicates 2k-Ohm resistance was latent defect that has not degraded over time and does not effect electrical performance

Non-Destructive Evaluation (NDE) for TPS

29 June 05

Generazio

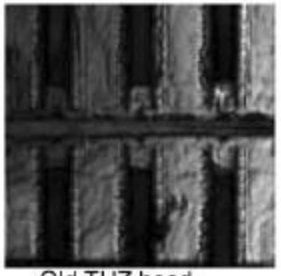
- **Description and Scope:**
  - Evaluate the development and application of NDE technology to detect critical defects in the ET foam
- **Background:**
  - NESC has supplemented the ET Project with NDE experts to develop and certify various NDE techniques including micro-focus x-ray, Terahertz (THZ) and backscatter X-ray. NESC continues to review alternate techniques available in industry
- **Results:**
  - ET NDE Plan: Revision complete
  - Improvements to Existing ET Project NDE:
    - Improving the signal response for THZ
    - Hardware improvements for both THZ and Backscatter X-ray (BSX) are in procurement
  - Over 20 responses to a Request for Information for new technology
    - Plan in place to mature up to 5 methods to be ready for certification for the ET Program
  - Certification Status: Micro-focus x-ray, THZ and BSX will be certified for engineering evaluations on stringer closeouts in August 2005. THZ and BSX will be certified for inspection of LH2 stringer closeouts and PAL ramps in December 2005

NDE for TPS

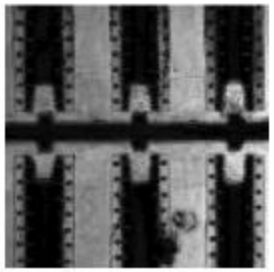
29 June 05

Generazio

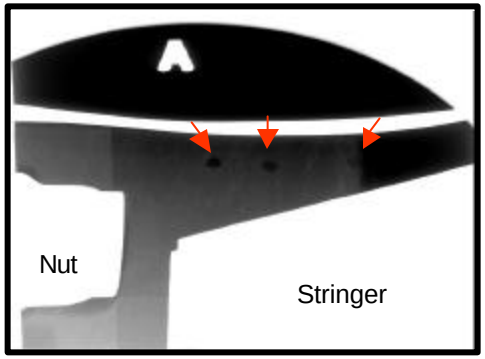
- **Program/ Project response/ action plan/ corrective action:**
  - Collaboration between Project and NESC NDE experts has been beneficial to the development of NDE techniques
- **Issues/constraints/open work:**
  - No RTF constraint
- **Flight Rationale/ Risk Assessment:**
  - NDE techniques in development have provided engineering information that qualitatively contributes to a reduction in risk
  - Once certified, these techniques will provide a quantifiable reduction in risk – December 2005



Old THZ head



New THZ head



Micro-Focus X-ray

Cure-In-Place Ablative Applicator (CIPAA)

29 June 05

Gentz

- **Description and Scope:**
  - Perform technology maturity evaluation of STA-54 to meet objectives outlined for STS-121 on-orbit “proof-of-concept” demonstration during Extravehicular Activity (EVA) 2
    - CIPAA functionality
    - Microgravity/vacuum effects on gas bubble generation and void formation
- **Background (Assessment Results):**
  - STA-54 is sufficiently characterized to meet the identified objectives for the STS-121 on-orbit demonstration
  - CIPAA discharge container design is not representative of tile repair
  - Proposed vacuum/crew cabin cure environment is not traceable to tile repair
  - Limited on-orbit data collection restricts correlation to ground-based sample processing
  - Risk mitigation opportunities exist to assess likelihood of energetic off gassing and adequate cure prior to the STS-121 on-orbit evaluation
  - Additional development activities (process control/sensitivities) are necessary to enable future on-orbit demonstrations and the long-term use of STA-54 for an on-orbit tile repair capability

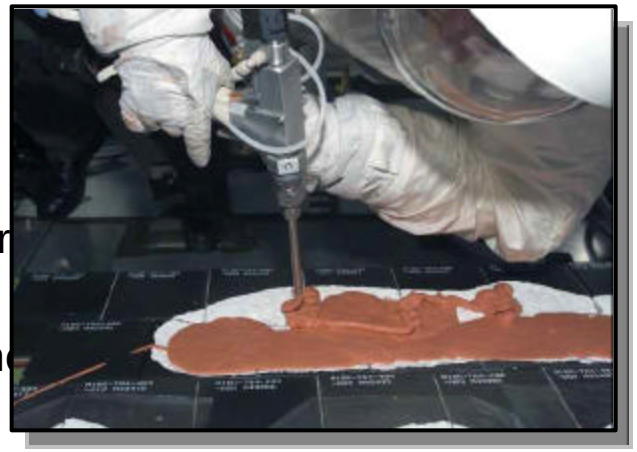
- **Results (Recommendations):**
  - Perform discharge in a vessel and cure environment with:
    - Representative nozzle to work surface standoff
    - Applied homogenously mixed STA-54 in adjacent rows and layered application method
    - Complete and continuous cure in space environment
    - Documented on-orbit application and cure environmental conditions
  - Assess risk mitigation activities of:
    - Engaging the National Center for Space Exploration Research (NCSER) to perform a comprehensive analysis of the potential for energetic off gassing during on-orbit dispensing and cure
    - Dispensing STA-54 in sustained vacuum better than 10^{-5} torr and exposure to a sustained negative or an average zero gravity environment during cure
    - Performing post-flight evaluation of STA-54 extracted from the STS-114 CIPAAs
  - Complete planned Detailed Test Plans to validate the structural integrity and thermal performance of STA-54 applied as an on-orbit tile repair capability

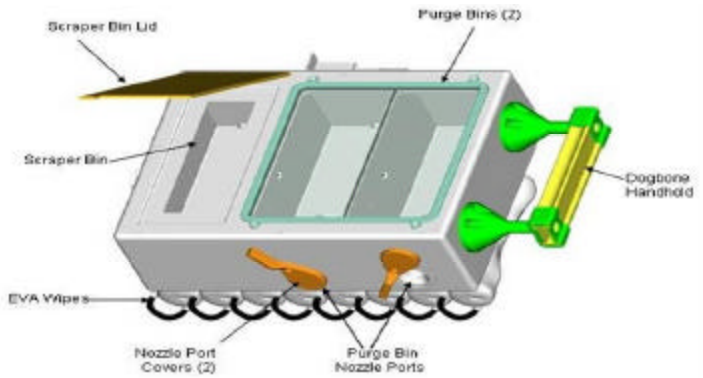
Cure-In-Place Ablative Applicator (CIPAA)

29 June 05

Gentz

- **Program/Project response/action plan/ corrective action:**
  - Pursuing alternate on-orbit collection container, a complete space vacuum/microgravity cure, and thermal data predictions during application and cur cycles
  - Engaging NCSER in physics-based modeling of th off gassing potential of STA-54 during space vacuum/microgravity exposure
  - Developing a lower vacuum (<10^{-6} torr) chamber with automated application techniques to characterize process sensitivities of STA-54
  - Examining dispensing options for post-flight evaluation of STS-114 CIPAA STA-54 material
- **Issues/constraints/open work:**
  - No RTF constraint
- **Flight Rationale/ Risk Assessment:**
  - Not a constraint to STS-114





Discharge Container

Body Flap (BF) and Rudder Speed Brake (RSB) Actuator Bearings

29 June 05

Jett

- **Description and Scope:**
  - Blackened ball and plastic deformed ball discovered in one of BF actuator input shaft bearings during re-furbishment of BF actuator
- **Background (review tasks):**
  - Assessment of design and history of all BF actuator and RSB bearings
  - Full scale bearing tests performed on previously flown BF actuator bearings and bench tests to attempt to duplicate the blackened ball and plastic deformation and test for margin
- **Results:**
  - Metrology shows BF actuator shaft bearings are highly stressed. Moderate bearing wear and discolored balls observed in most bearings. One bearing had blackened ball and another bearing had significant wear and/or plastic deformation
  - Successful completion of life testing of purposely damaged bearings and previously flown BF actuator shaft bearings
  - Blackened ball not duplicated during testing or bench test

Body Flap (BF) and Rudder Speed Brake (RSB) Actuator Bearings	29 June 05
	Jett

- **Program/ Project response/ action plan/ corrective action:**
  - Orbiter Project accepts the re-use of BF actuator and RSB bearings
  - A corrective action was initiated due to quality escape (inadvertently installed scrap bearing) which requires Hamilton Sundstrand to log and track detail parts that were removed from assemblies undergoing refurbishment
- **Issues/constraints/open work:**
  - No RTF constraint.
  - Blackened ball bearings were not duplicated, however not a flight constraint for STS-114 based on high resolution inspection confirming discoloration did not affect function of ball bearing
  - Testing necessary to duplicate blackened ball and to demonstrate 12 mission life is remaining open work necessary for continued usage of BFA bearings
- **Flight Rationale/ Risk Assessment:**
  - Based on successful bearing life testing and review of flight history, analysis and design, all previously flown bearings, BF actuator and RSB, are acceptable to re-fly for at least 12 Shuttle missions
  - Refurbished BF actuator shaft bearings should be designated as limited life components, and usage tracked and limited to 12 flights and 6 calendar years

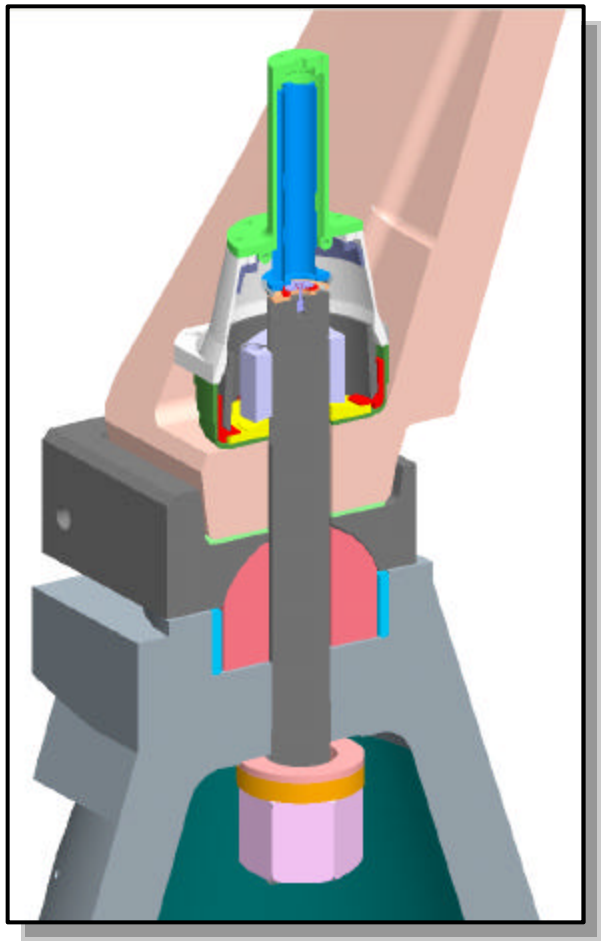
Recurring Anomalies Review

Solid Rocket Booster Hold-down Post Stud Hang-up

29 June 05

Cragg

- **Description and Scope:**
  - Perform independent analyses and tests to assess the root cause for Hold-down Post (HDP) Stud Hang-ups
- **Background:**
  - Tested NASA Standard Detonators (NSDs) at JSC to try to quantify the function time variation for two flight lots
  - Testing in progress at KSC and MSFC to attempt to isolate the variables that could cause hang-ups
    - Extensive instrumentation of hardware and video coverage to provide details of hardware interactions
    - Similitude of test equipment between KSC and MSFC to allow comparison of results
  - Computational model developed at SRI International.
    - ARC supporting computer runs for SRI model, quadrupling team's analytical capability
    - Test results from KSC and MSFC tests will be used to anchor the SRI model



Recurring Anomalies Review
SRB Hold-down Post Stud Hang-up

29 June 05

Cragg

- **Results:**
  - Results will be provided to the Solid Rocket Booster (SRB) Project at the conclusion of the testing and analysis
- **Program/ Project response/ action plan/ corrective action:**
  - Work in progress
- **Issues/constraints/open work:**
  - No RTF constraint. Testing schedule has been impacted by RTF work. An engineering report on results expected in September 2005
- **Flight rationale/ Risk Assessment:**
  - Program taking a probabilistic approach to stud hang-ups

Orbiter Flexhose Corrosion

29 June 05

Piascik

- **Description and Scope:**
  - Conducted a review of the Orbiter Project metal bellows flexible hose (flexhose) corrosion investigation
- **Background:**
  - Corrosion found in spare (replacement) flexhoses raised the concern of a possible corrosion threat to Orbiter systems by forming sites for fatigue cracking and/or promoting sites for enhanced corrosion
- **Results:**
  - The NESC evaluation confirmed that the Orbiter Project conducted a comprehensive evaluation and implemented sufficient actions to mitigate flex-hose corrosion
    - Statistically Significant Inspections: 500 of 900 spare and installed hoses inspected
    - Destructive Exam: A total of 3 hoses were found with significant corrosion
    - Orbiter Systems Evaluation: Environments are controlled to mitigate corrosion
    - Testing & Analysis: Flight environments not conducive to fatigue cracking
    - Corrective Actions: Tighter control of manufacturing cleaning process

Orbiter Flexhose Corrosion

29 June 05

Piascik

- **Program/ Project response/ action plan/ corrective action:**
  - None required
- **Issues/constraints/open work:**
  - No RTF constraint
  - It is recommended that the NESC conduct an in-depth Independent Assessment of the general use of metal flexhoses and the rationale of mitigating risk by “managing” a continuing anomaly; 30 to 40 flexhoses have been found with unacceptable collateral damage over the life of the program
- **Flight Rationale/ Risk Assessment:**
  - The flight rationale is to mitigate risk by conducting sample borescope inspection of selected flexhoses and conducting pre-flight leak checks

Non-Return to Flight Constraint - Closed

29 June 05

- BUMPER II Micro-Meteoroid Orbital Debris (MM/OD) Inspection
- KSC PC GOAL Data Integrity
- Rotating Service Structure Stress Analysis

BUMPER II Micro-Meteoroid Orbital Debris (MM/OD) Inspection

29 June 05
Scott

- **Description and Scope:**
  - Performed verification and validation of the BUMPER II MM/OD software/models
- **Background:**
  - NESC team verified software requirements, design, and code, and nationwide team of experts (SWRI, ARC, JPL, Aerospace Corporation, Sandia National Laboratories, Universities) validated environmental physics, ballistic limit equations, TPS damage, uncertainty models.
- **Results:**
  - Final Report approved by NESC Review Board on May 26, 2005. Completion of effort before July 30, 2005 including out briefing to stakeholders.
- **Program/ Project response/ action plan/ corrective action:**
  - Many findings and recommendations have already been implemented or are already underway. Need uncertainty models/error bars for MM/OD predictions.
- **Issues/constraints/open work:**
  - Bumper II does not include an uncertainty/error band on its results. Addition of an output uncertainty model is a recommended improvement.
- **Flight Rationale/ Risk Assessment:**
  - No RTF constraint

KSC PC GOAL Data Integrity

29 June 05

Kichak/Scott

- **Description and Scope:**
  - KSC Safety and Mission Assurance requested NESC assess an analytical approach developed to evaluate and retire Space Shuttle Critical Item List (CIL) items for an engineering advisory tool PCGOAL (Personal Computer Ground Operations Aerospace Language), used to verify critical functions
- **Results:**
  - NESC agreed that the method and analyses proposed by KSC engineering are consistent with good engineering practice
  - NESC team identified some areas for additional work and recommended independent verification and validation of PCGOAL
  - NESC concluded that it would be technically acceptable and preferred to include the entire network path as a single item on the CIL for the purpose of assessing data integrity risks
- **Program/ Project response/ action plan/ corrective action:**
  - NESC Report on 8 July 2004 and Program out brief on 27 July 2004
  - NESC Recommendations accepted and adopted
- **Issues/constraints/open work:** Not an RTF constraint
- **Flight Rationale/ Risk Assessment:** Closed/Acceptable Risk

Rotating Service Structure Stress Analysis

29 June 05
Raju

- **Description and Scope:**
  - Assess the integrity/validity of the structural analyses of the Rotating Service Structure (RSS) and Pad with the overloading caused by previous RSS modifications
- **Background:**
  - Over a period of years, weight was added to the RSS without regard to increased stresses in the structure and this process causes unmonitored reduction in margin
  - Based on the results of the Allowable Stress Design (ASD) criterion about 20 structural members had over-stress ratios between 1 and 1.05
- **Results:**
  - Based on the results of the Load and Resistance Factor Design (LRFD) computer analysis and after input loads were adjusted to more accurately reflect measured field data, the RSS can be used without modifications
  - Based on the stresses for the RSS Upper Bearing being peak stresses, not primary stresses, the review team agrees that the upper hinge bearing replacement can be postponed and is not a constraint to flight

Rotating Service Structure Stress Analysis

29 June 05
Raju

- **Program/ Project response/ action plan/ corrective action:**
  - KSC is in the process of responding to the review team's recommendations
- **Issues/constraints/open work (Team Recommendations):**
  - No RTF constraint
  - Develop a list of current critical structural elements and for these elements, as part of the current inspection/corrosion assessment process, prepare written report detailing Non-Destructive Evaluation (NDE)/Inspection results
  - Inspect "bridge" wall thickness for structural integrity to determine internal wall corrosion damage and assess the external condition
  - Attach strain gages to critical structural members prior to "jacking" during reinforcement operation to assess strain in these members after jacking and during "un-jacking"
- **Flight Rationale/ Risk Assessment:**
  - Closed/Acceptable Risk