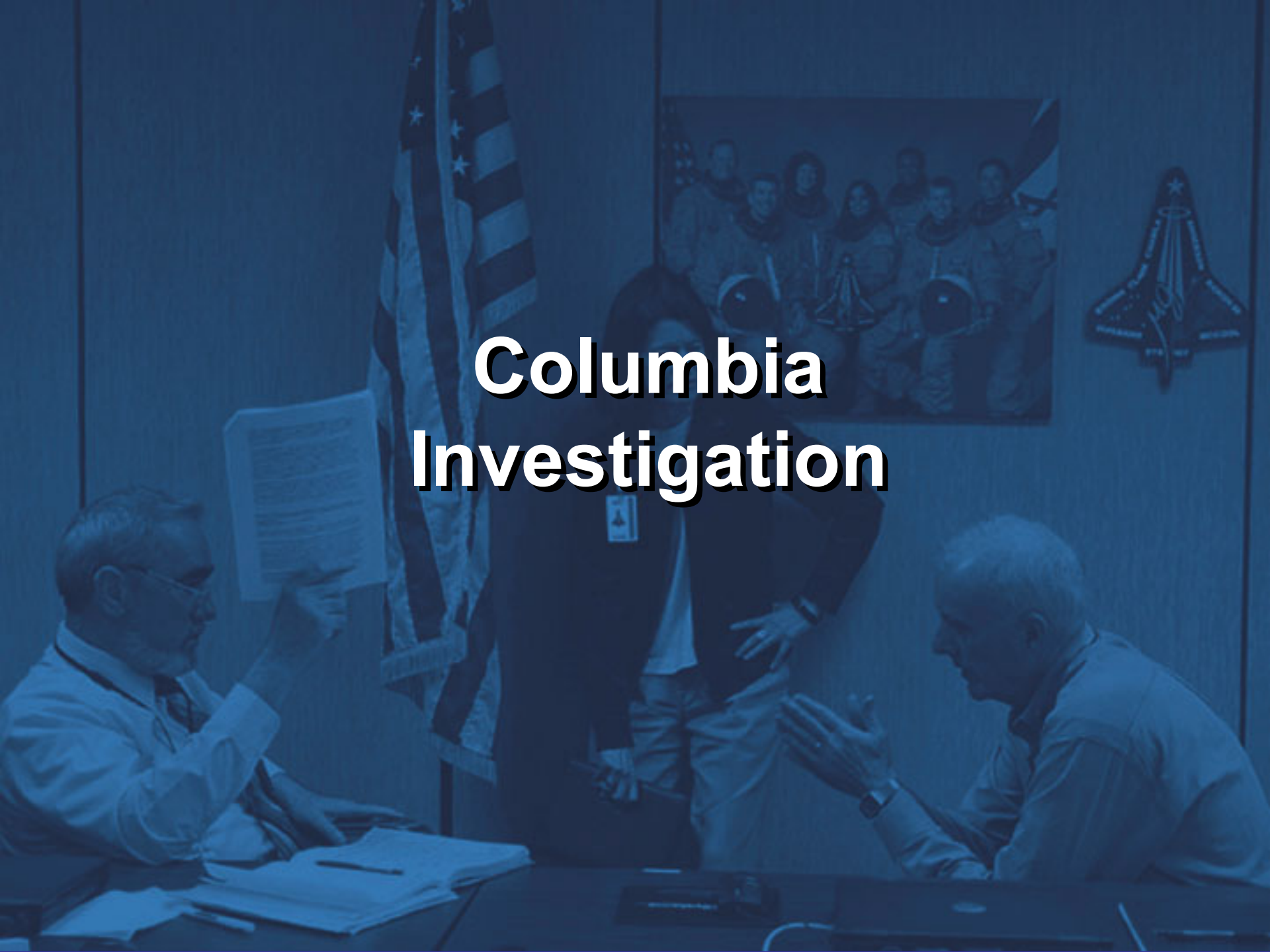
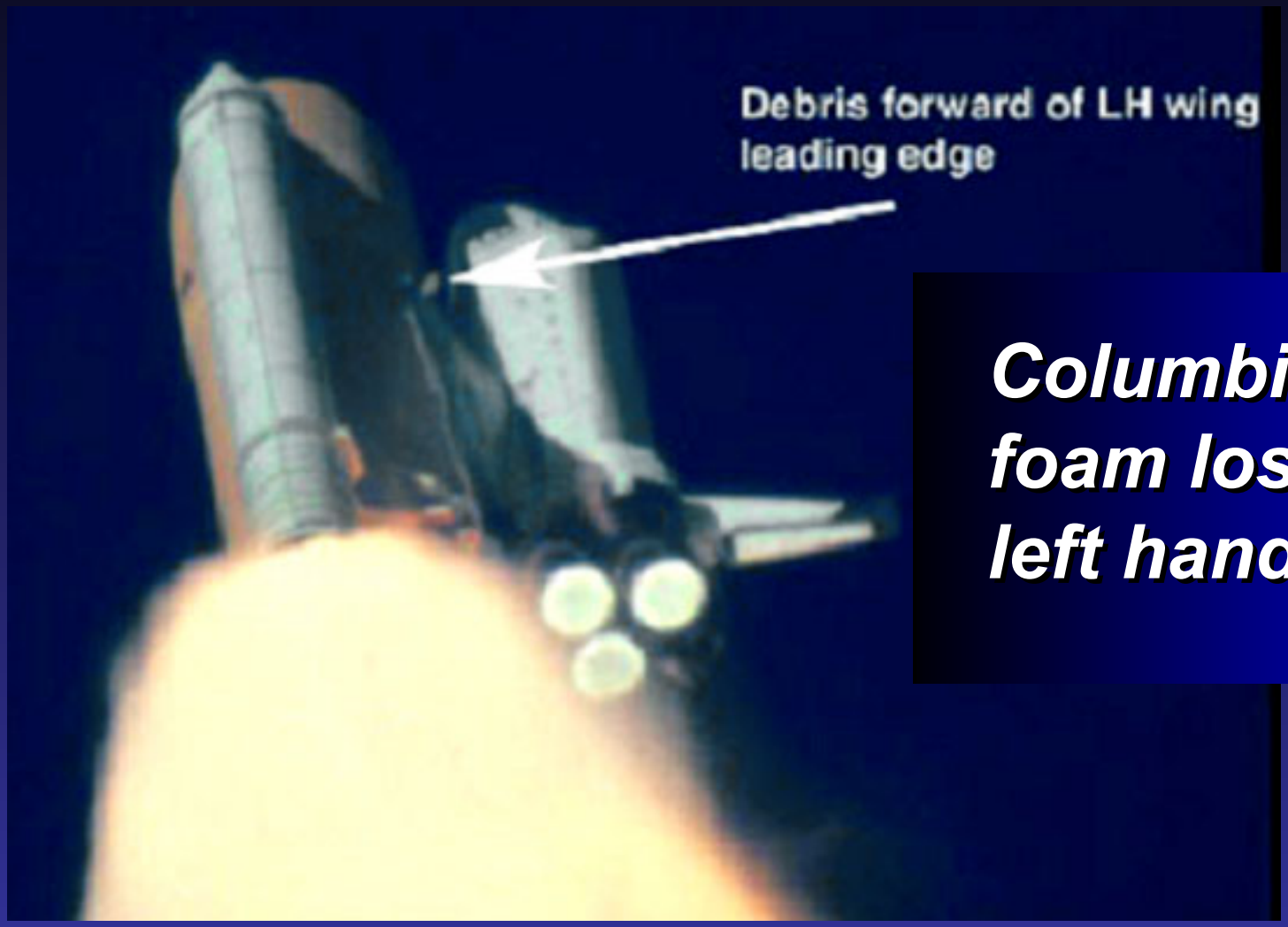
Return to Flight Status

Neil Otte


Columbia
Investigation

Columbia Investigation Overview

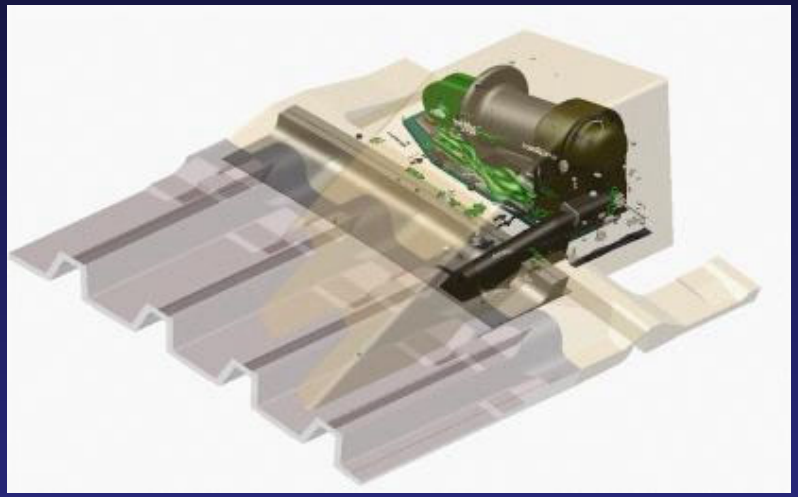


Columbia hit by foam lost from left hand bipod

Columbia Investigation Overview

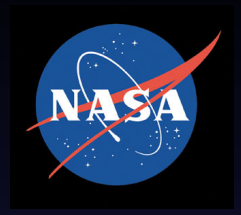
Major Findings

- *Design verification and process validation did not encompass all material and processing variability or adequately address all failure modes*
- *Quality Control verification of the manual spray application process did not preclude process variations affecting the part integrity*
- *Available acceptance testing / inspection techniques were not capable of rejecting ramps with adverse "as-built" features which could threaten the TPS integrity*



Shuttle, and therefore External Tank, must consider debris as a critical environment

CAIB Recommendations for External Tank



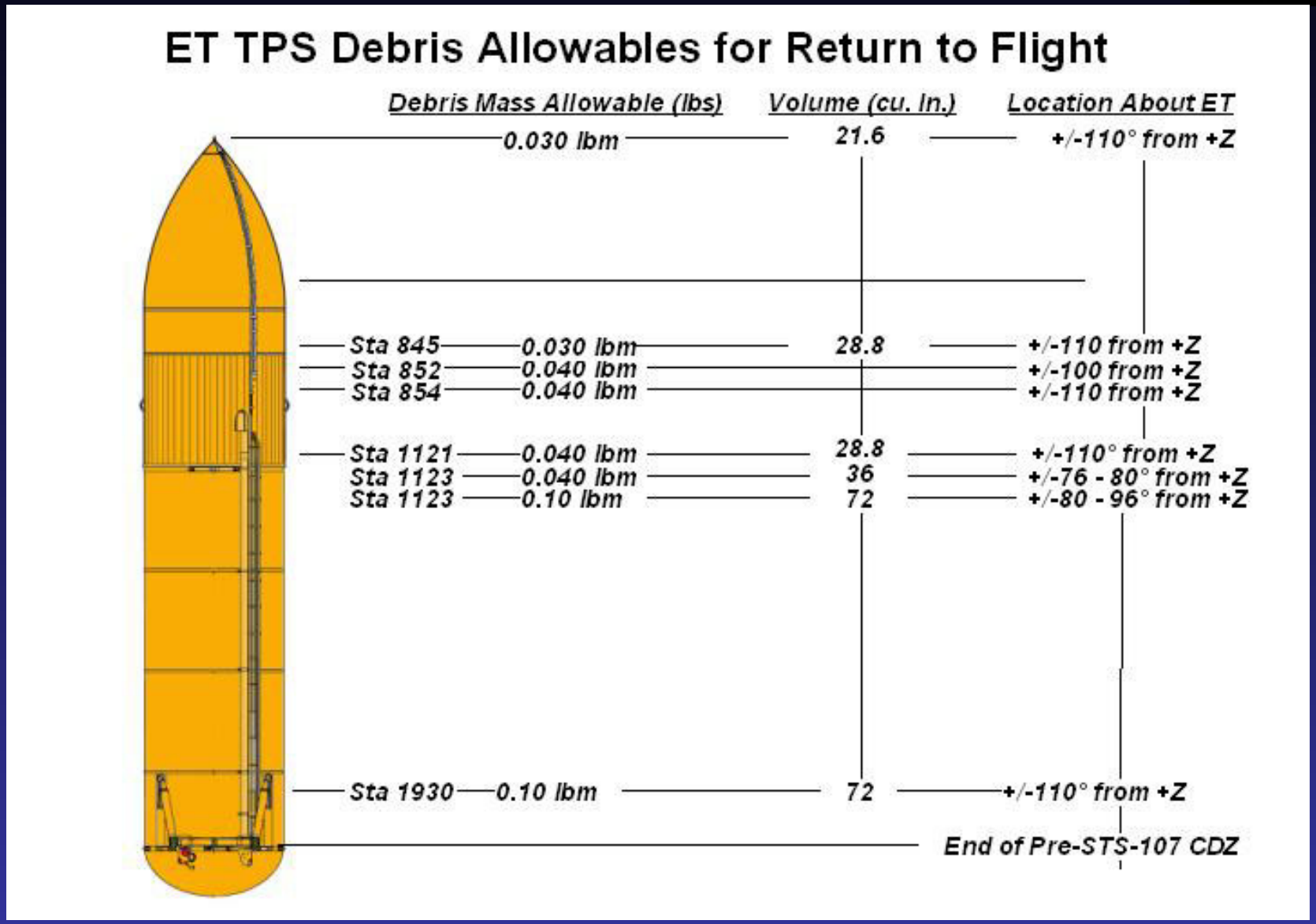
Thermal Protection System *R.3.2-1: Initiate an aggressive program to eliminate all External Tank Thermal Protection System debris-shedding at the source with particular emphasis on the region where the bipod struts attach to the External Tank.*

Imaging *R3.4-2: Provide a capability to obtain and down link high-resolution images of the ET after it separates. R3.4-3: Provide a capability to obtain and down link high-resolution images of the underside of the Orbiter wing leading edge and forward section of both wings' TPS.*

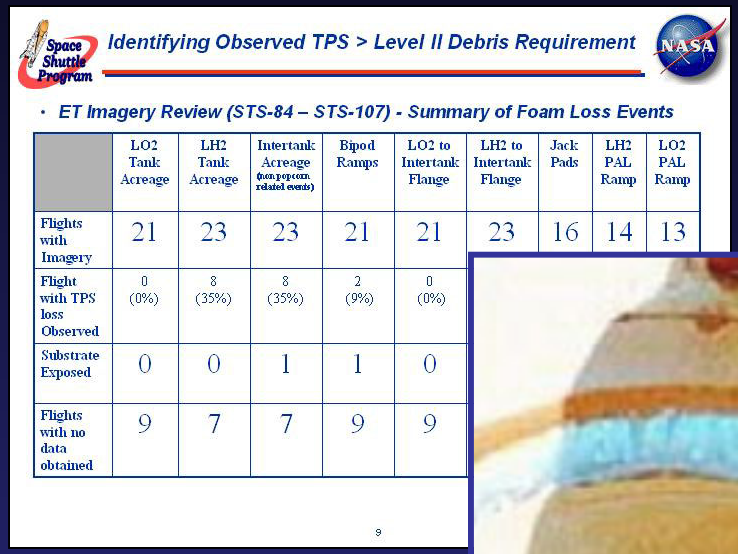
Closeouts *R.4.2-3: Require that at least two employees attend all final closeouts and intertank hand-spraying procedures.*

External Tank is complying with all CAIB recommendations

Preliminary Debris Requirements



Flight History Used to Determine Areas of Redesign Necessary for Tank



Space Shuttle Program

Identifying Observed TPS > Level II Debris Requirement

- *ET Imagery Review (STS-84 – STS-107) - Summary of Foam Loss Events*

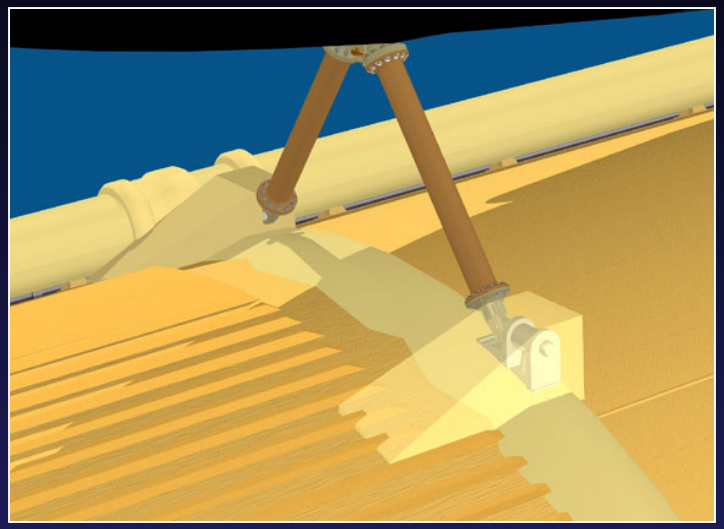
	LO2 Tank Acreage	LH2 Tank Acreage	Intertank Acreage (non popcorn related events)	Bipod Ramps	LO2 to Intertank Flange	LH2 to Intertank Flange	Jack Pads	LH2 PAL Ramp	LO2 PAL Ramp
Flights with Imagery	21	23	23	21	21	23	16	14	13
Flight with TPS loss Observed	0 (0%)	8 (35%)	8 (35%)	2 (9%)	0 (0%)				
Substrate Exposed	0	0	1	1	0				
Flights with no data obtained	9	7	7	9	9				

9

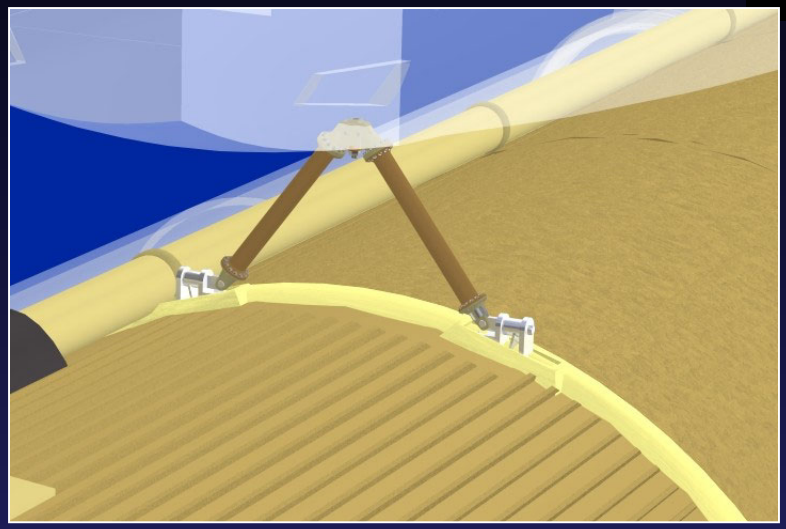
Efforts underway to address areas with known violations of new debris requirements


External Tank
Animated Overview

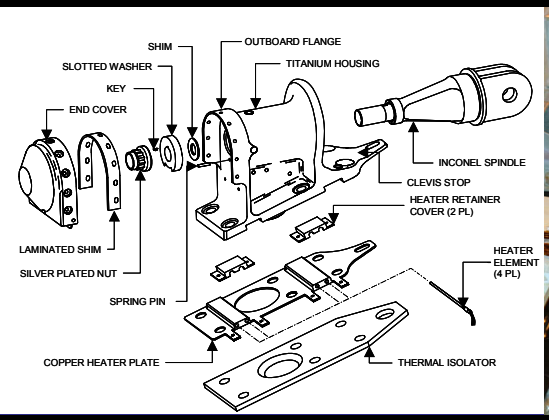
Bipod Redesign Overview

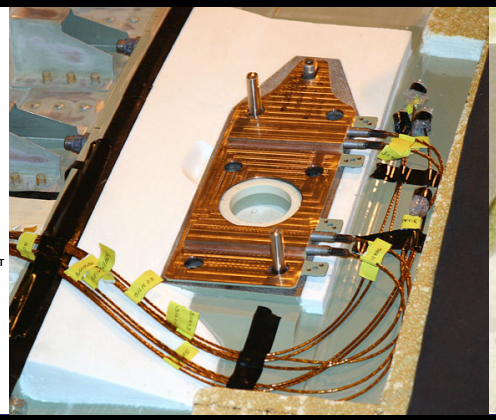


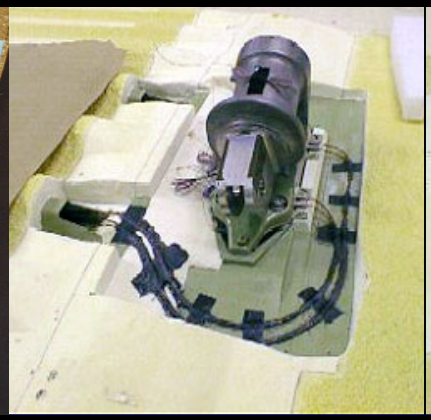
Was



Now







We have simplified and added controls to the foam application process

Bipod Redesign Foam Processing

Flat Panels	Full Scale Production Mockups	Flight Hardware

DEVELOPMENT

Basic Process
- Requirements Met
- Equipment Specified
- Basic Skills Developed
- Process Enhancement Test Plan

ENHANCEMENT

Refined Process
- Variables Eliminated/ Understood
- Variation Reduced
- Verification Test Plan

VERIFICATION

Verified / Locked Down Process
- Parameters Verified
- Spray Sched Defined
- PPD/MPP Defined
- Validation Test Plan

VALIDATION

Process Demonstrated
- Repeatability Proven
- Part Specific Certified Personnel

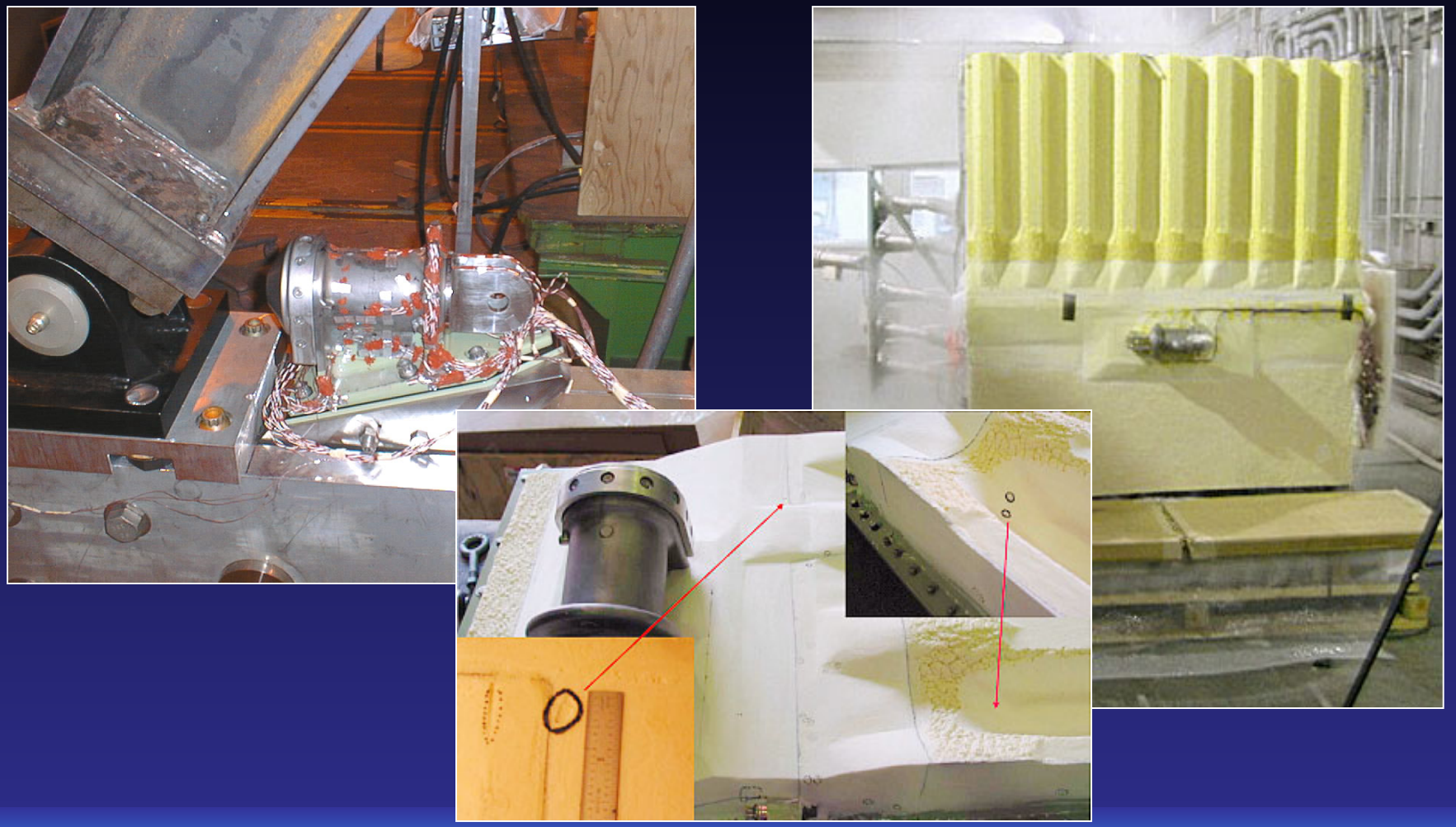
PRODUCTION

Same Sprayers Throughout

Statistically Significant Number of Data Points

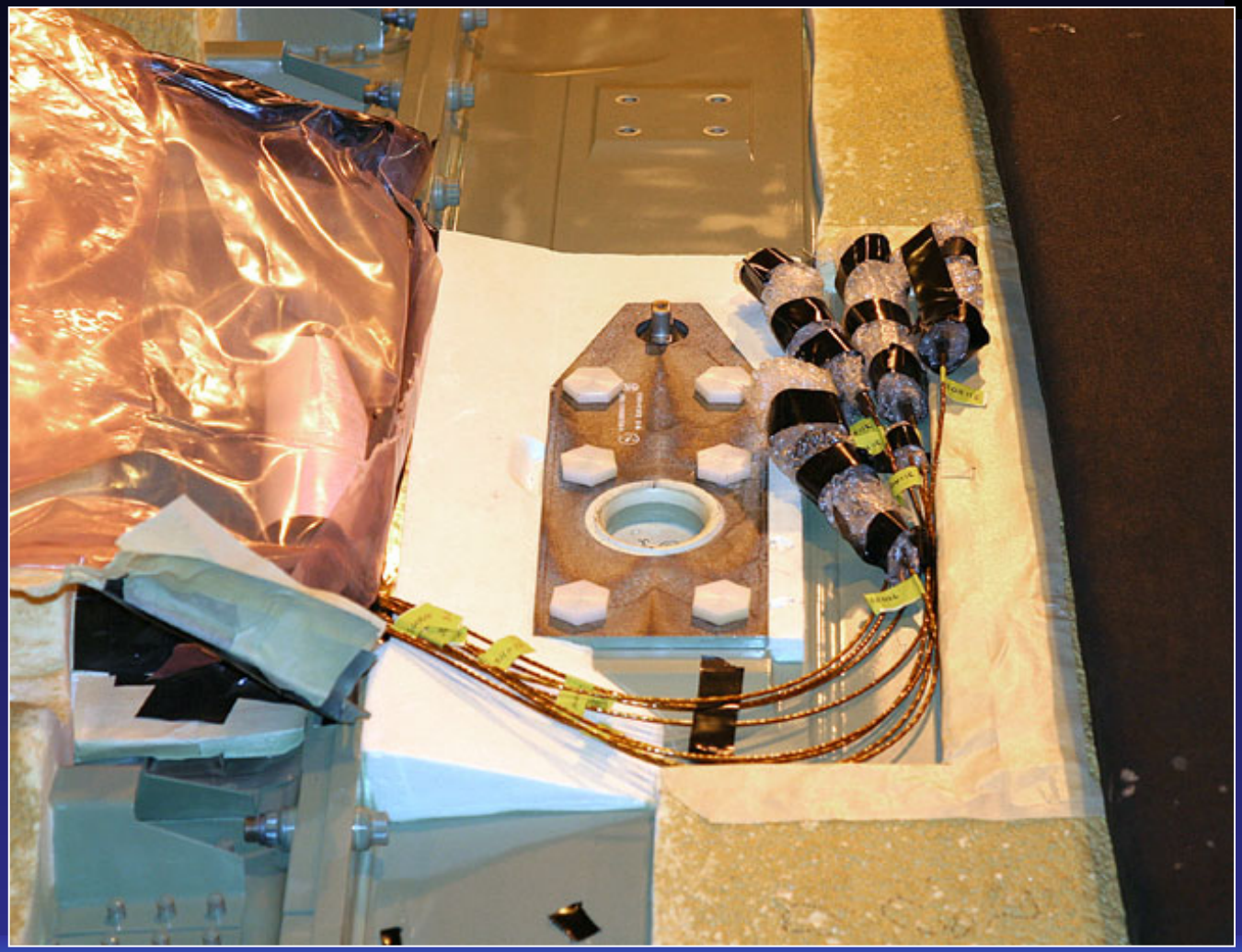
New foam applications on bipod are far superior to pre-Columbia

Bipod Redesign Certification



Bipod redesign will be fully certified

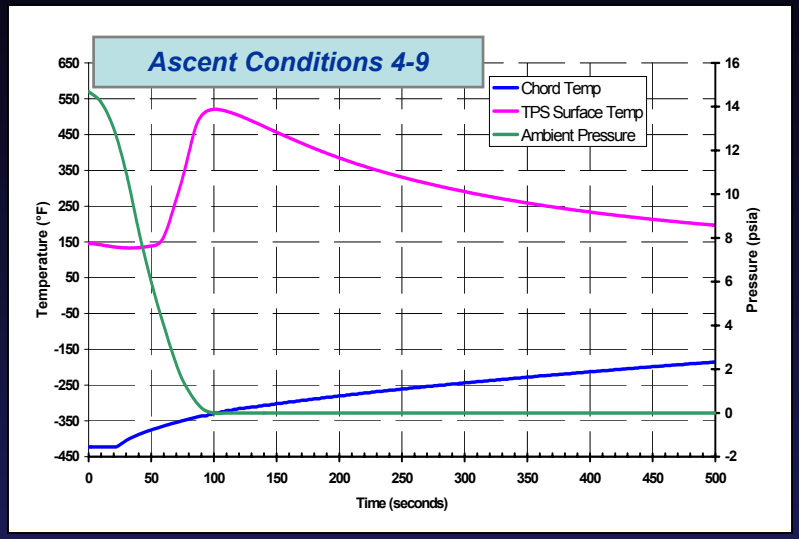
Bipod Redesign Status



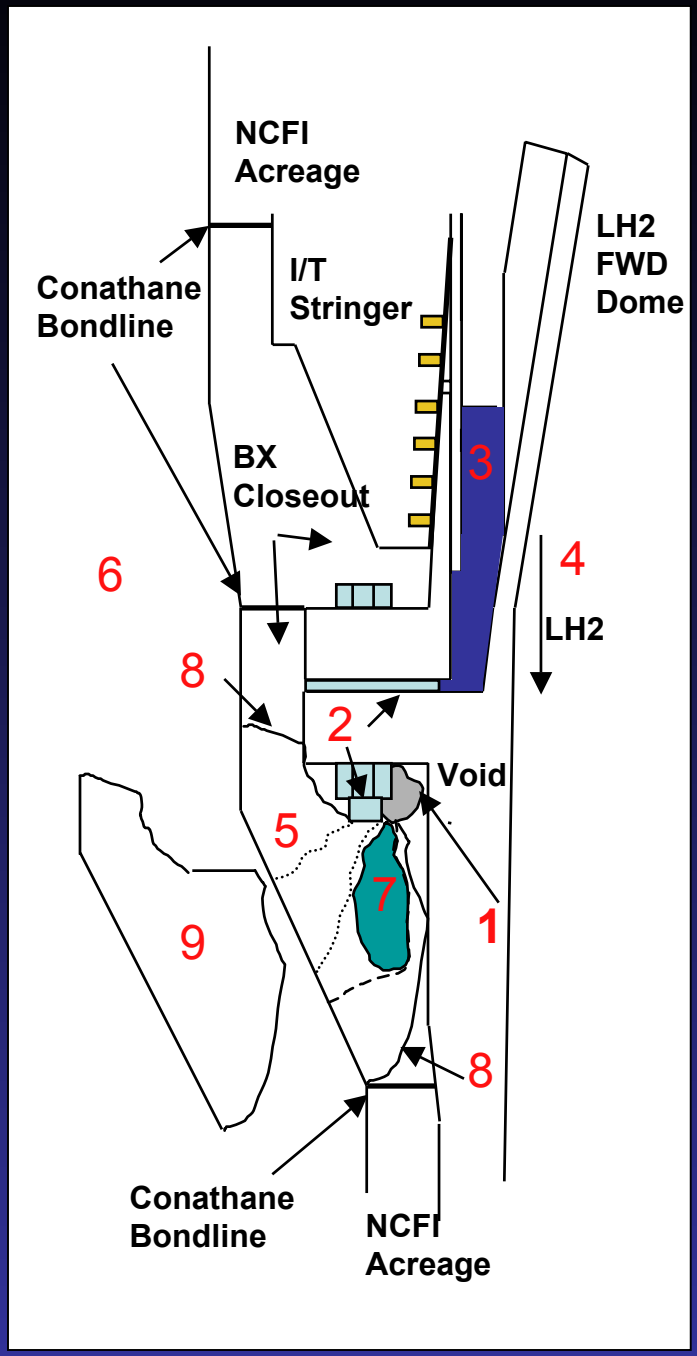
We have begun retrofitting External Tank


Bipod Video

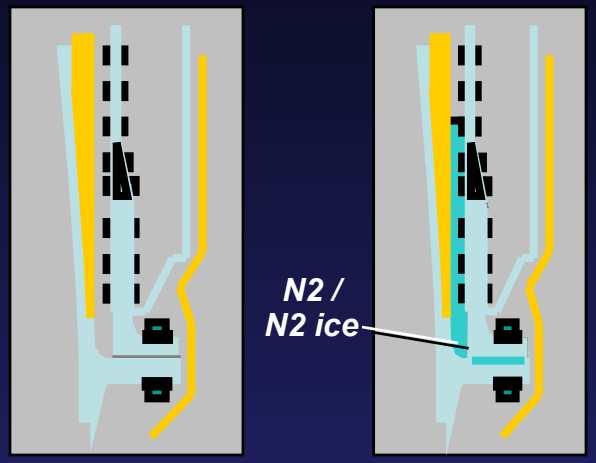
Flange Foam Loss



1. *LN2 begins to form in voids as LH2 level approaches flange*
2. *Flange temps rapidly fall to form SN2 in leak paths blocking flow*
3. *LN2 and SN2 begins to accumulate in Y joint during hold*
4. *During ascent LH2 level drops, flange temps begin to rise*
5. *LN2 begins to gasify causing foam to crack*
6. *Ascent heating weakens outer layer of foam*
7. *LN2 enters crack and begins rapid gasification*
8. *Crack rapidly propagates to substrate, conathane, flange*
9. *Divot produced due to weak outer layer and LN2/GN2*

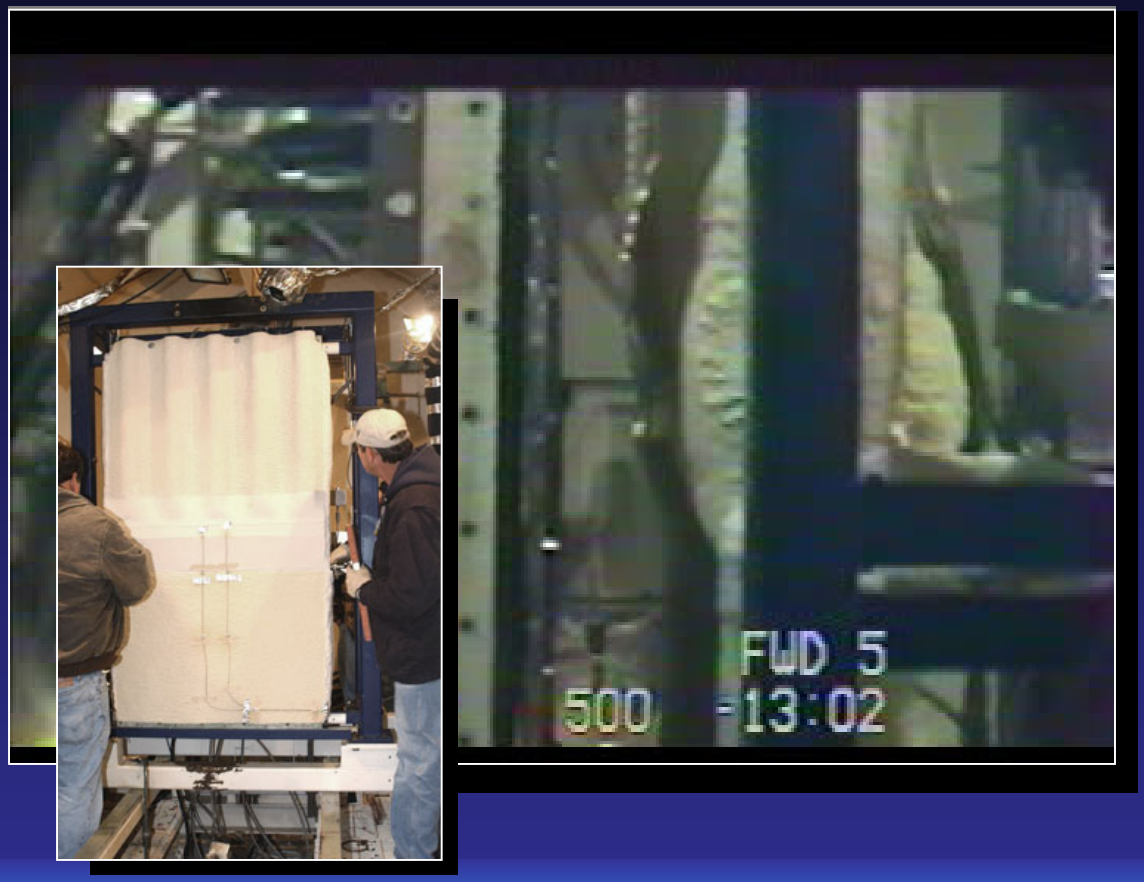


Flange Redesign Required Development of Test Bed to Find Root Cause of Foam Loss



Intertank "Y-joint" (Warm)

Intertank "Y-joint" (Cryo)

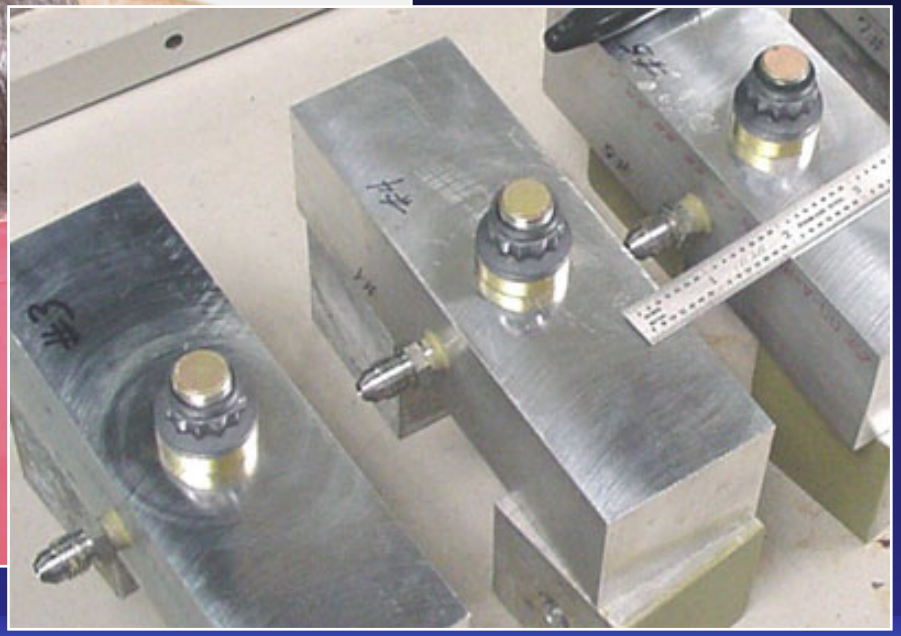


We have determined how and why the flange foam was being lost

Redesign Elements of the Flange

Crew of STS-114 Examine Flange Mods

Reversed Bolts

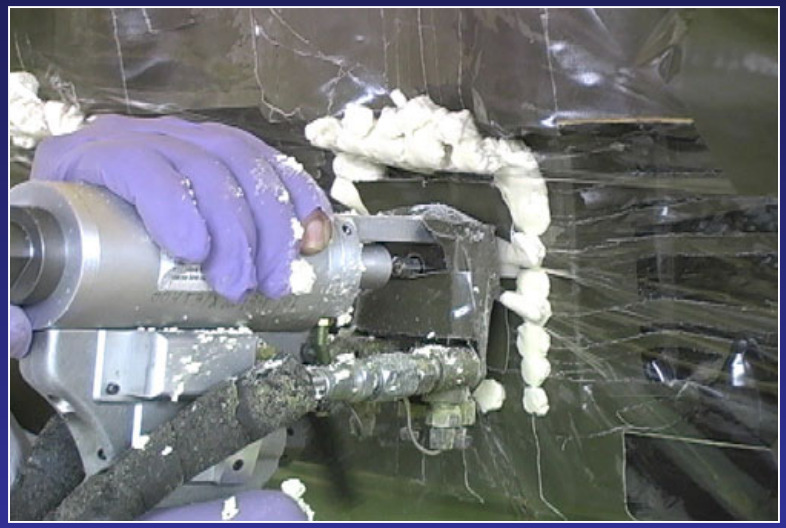


We are addressing contributors to foam loss on the flange (voids and leak path)

Redesign Elements of the Flange

Flange Stringer Injection

Upper Flange Spray

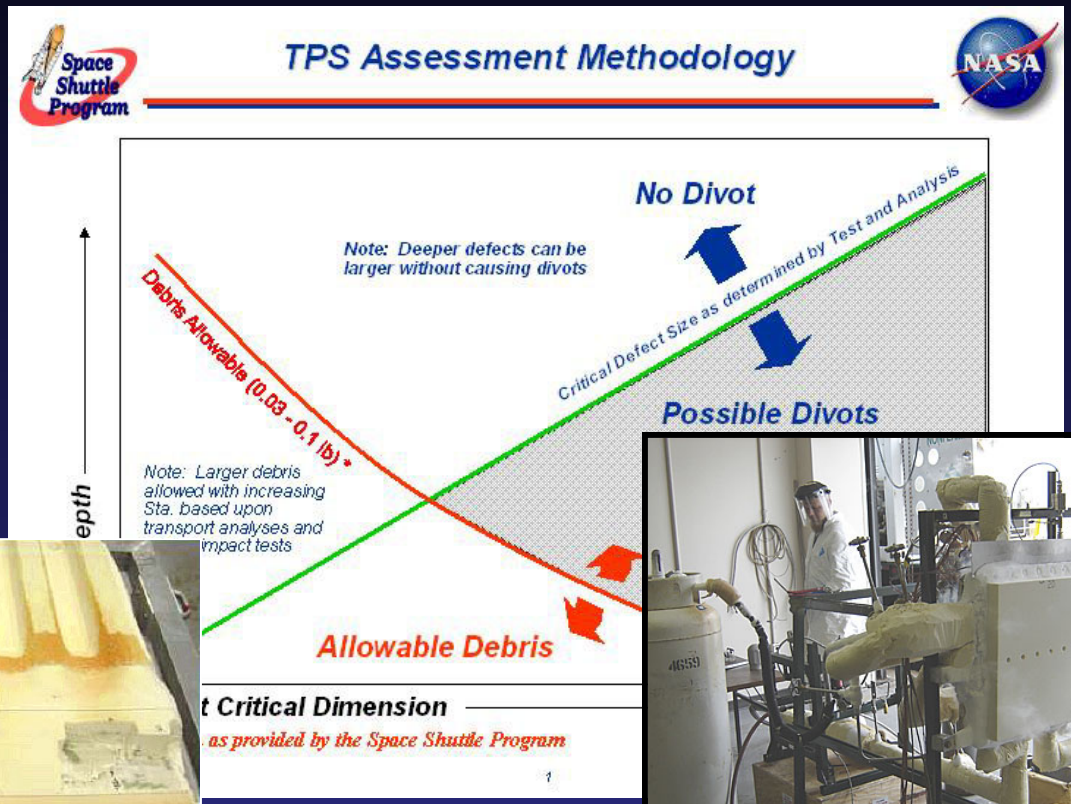


Thrust Panel Injection

Lower Flange Spray

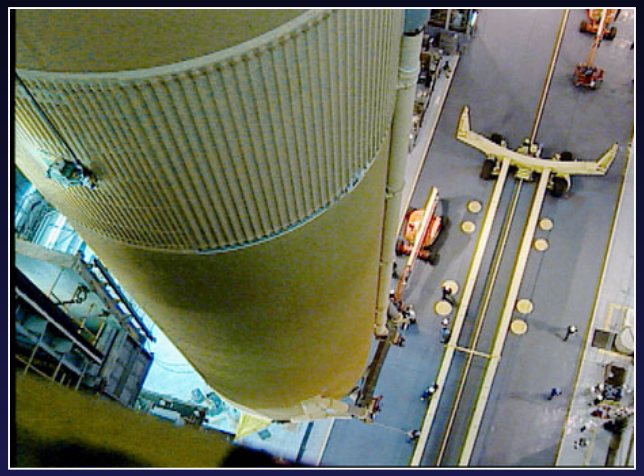
Characterizing Divoting Foam Loss

Thermal Vac Test

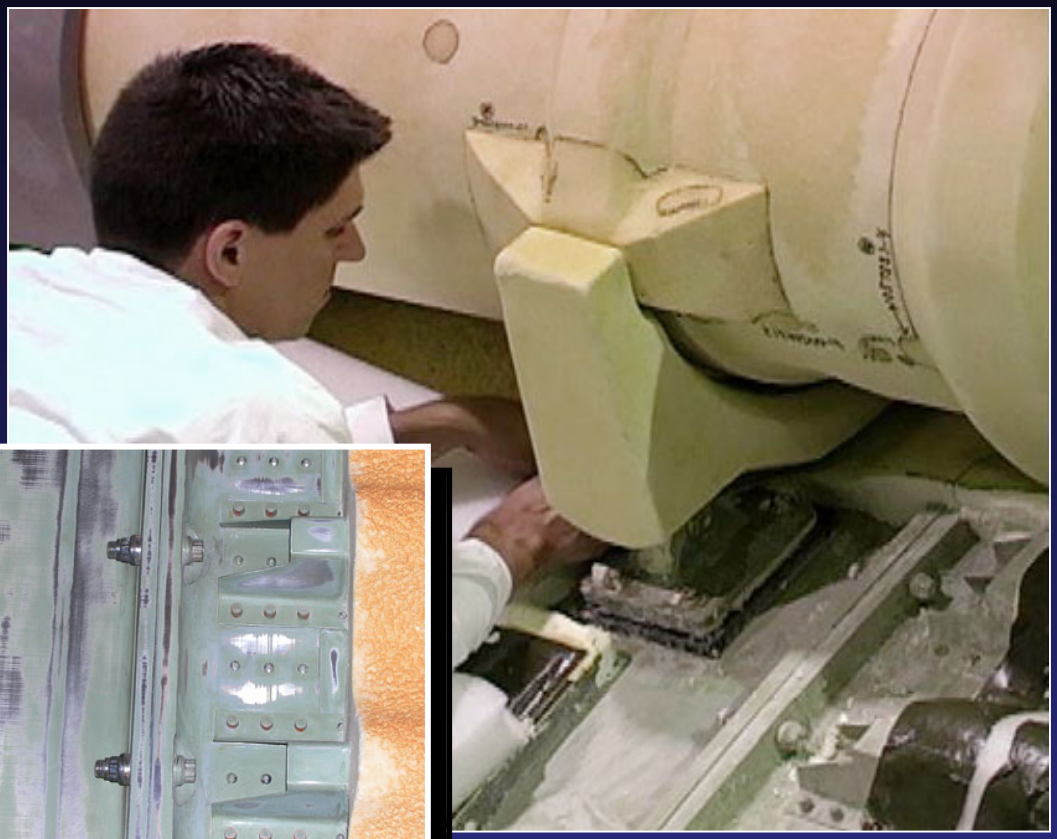


Our understanding of the divoting foam loss mechanism has increased dramatically and we continue to aggressively test

Current Status of Flange

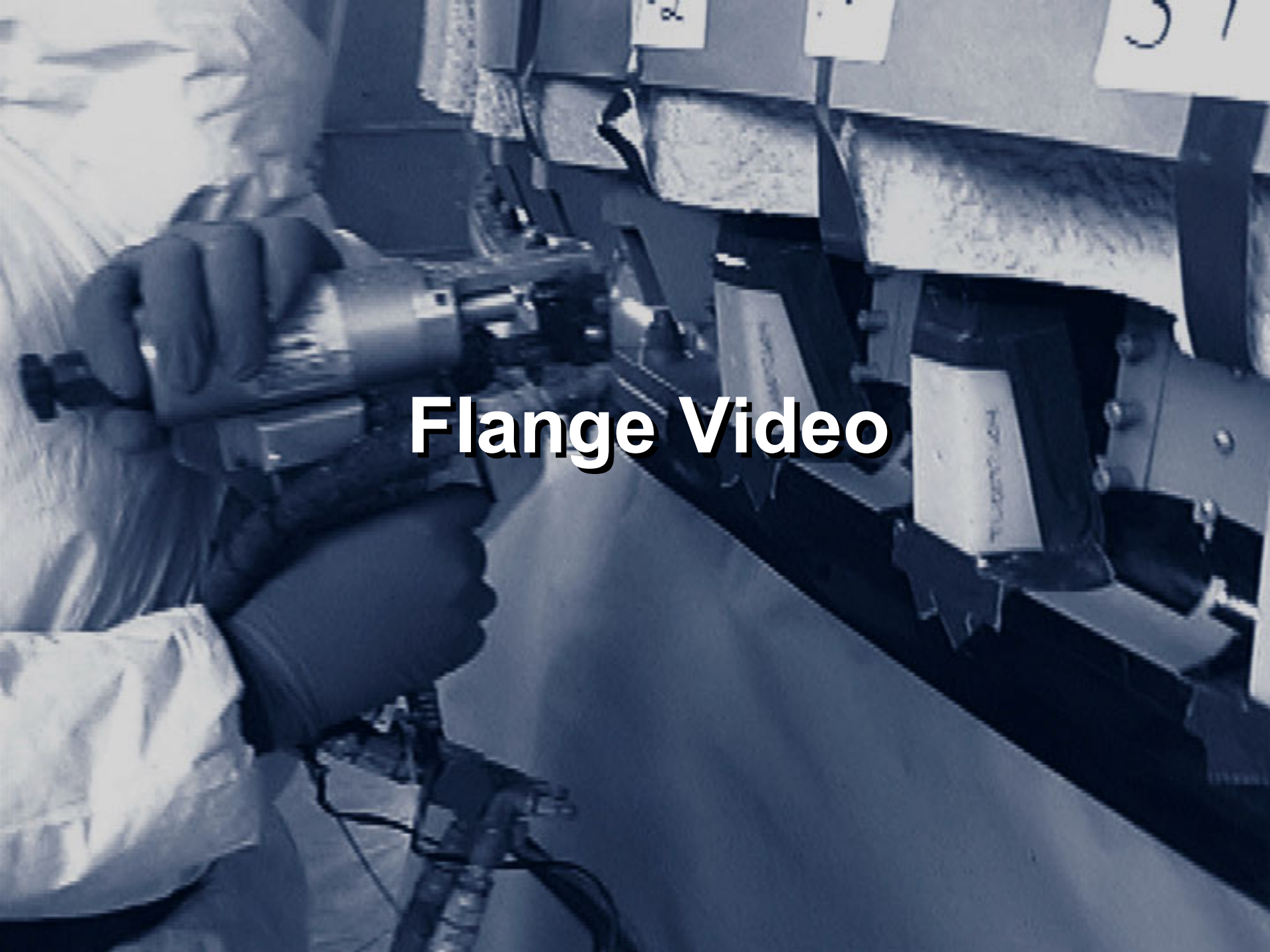


ET Vertical in Cell A

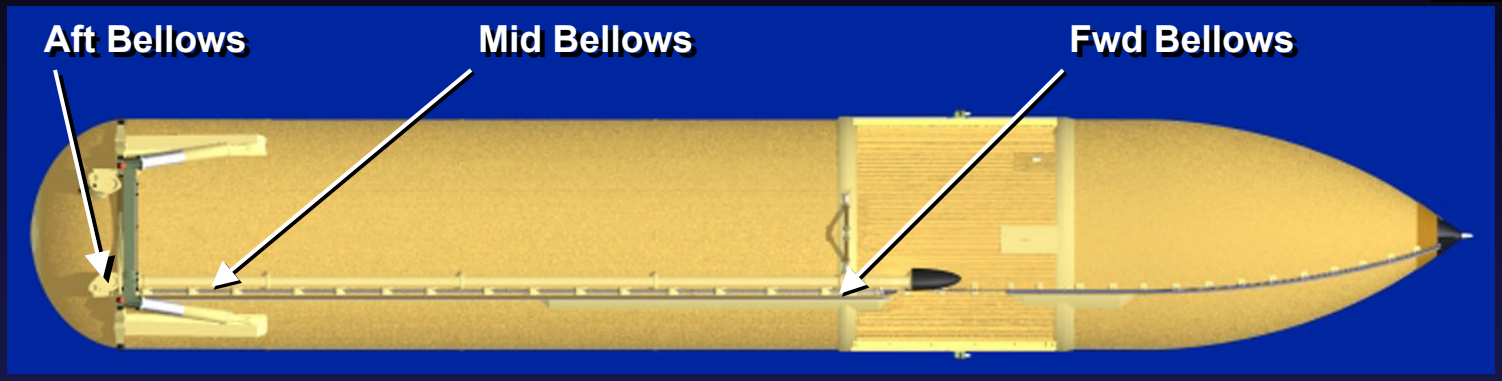


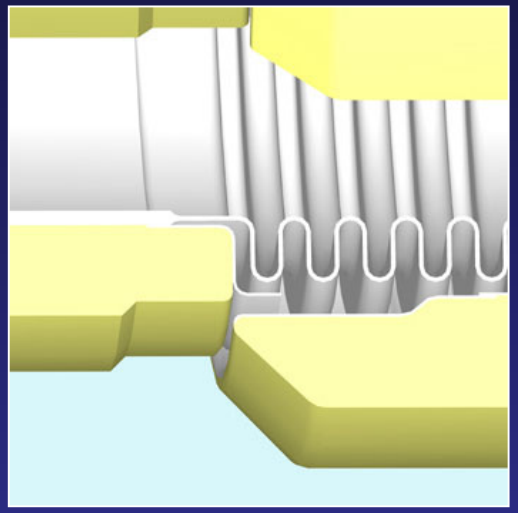
Flange Runs Beneath Feedline

The manufacturing flow for retrofit External Tanks is radically different than for in-line production, but we are ready to proceed


Flange Video

Feedline Bellows

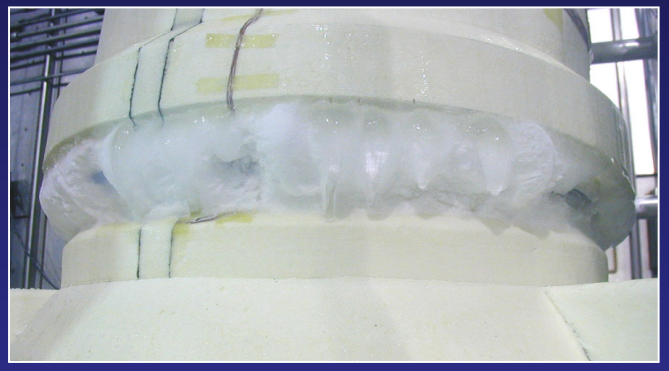


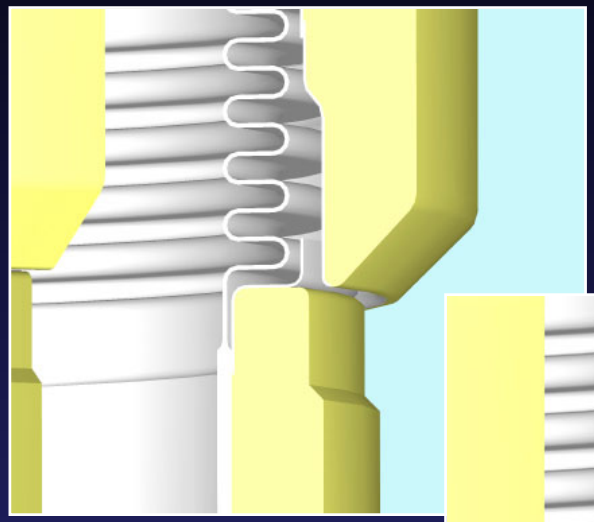


An additional debris source was identified for elimination

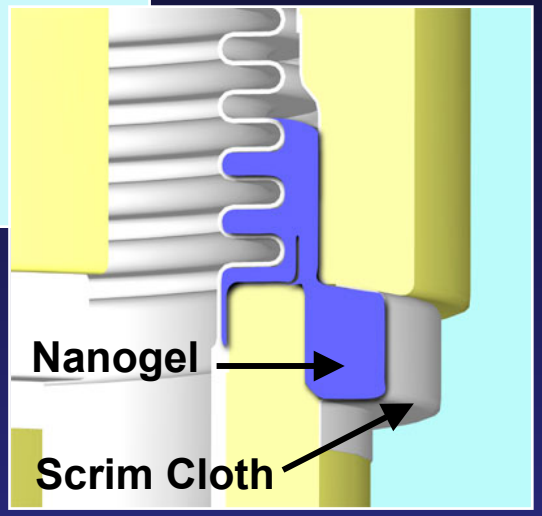
Feedline Bellows Testing and Redesign

Lower Feedline Bellows During Baseline Test at Eglin AFB





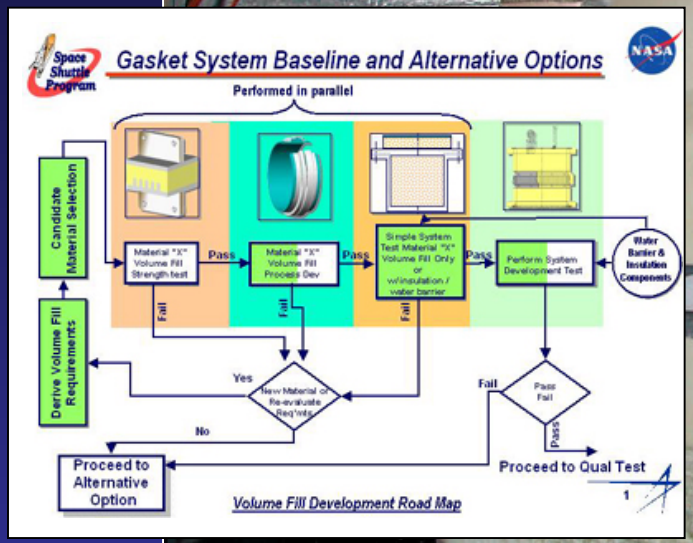
Cutaway View of Bellows Drip Lip Configuration with Retainer



Cutaway View of Bellows Drip Lip Configuration with Nanogel and Scrim Cloth Retainer

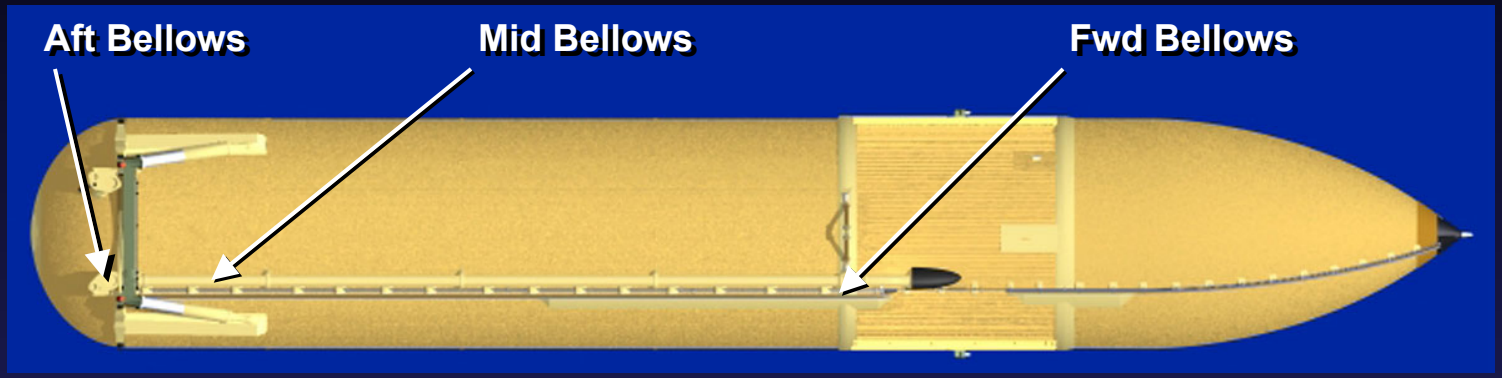
We have identified a two part design fix

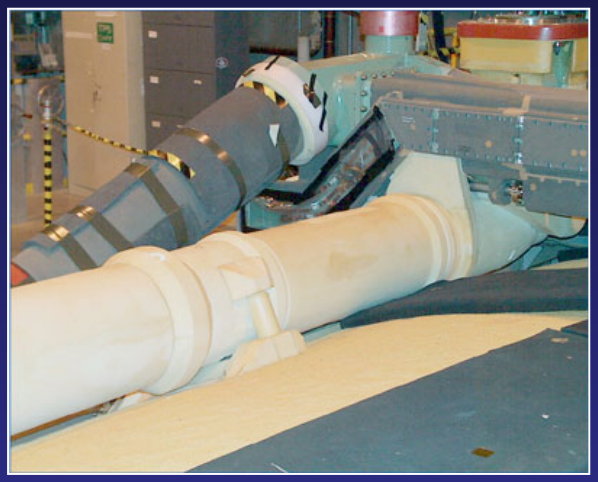
Certification of the Bellows Redesign



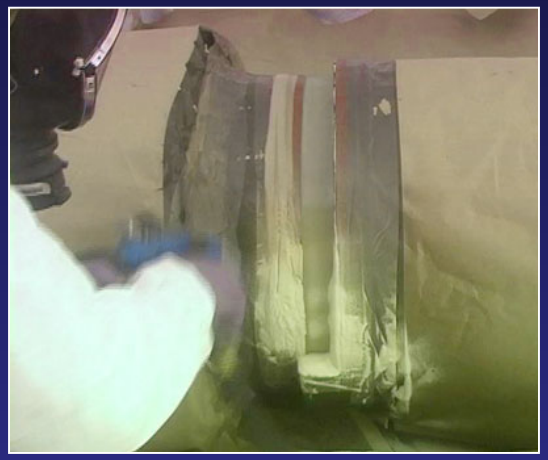
Bellows redesign will preclude ice and certification is in work

Bellows Manufacturing / Process Validation Status





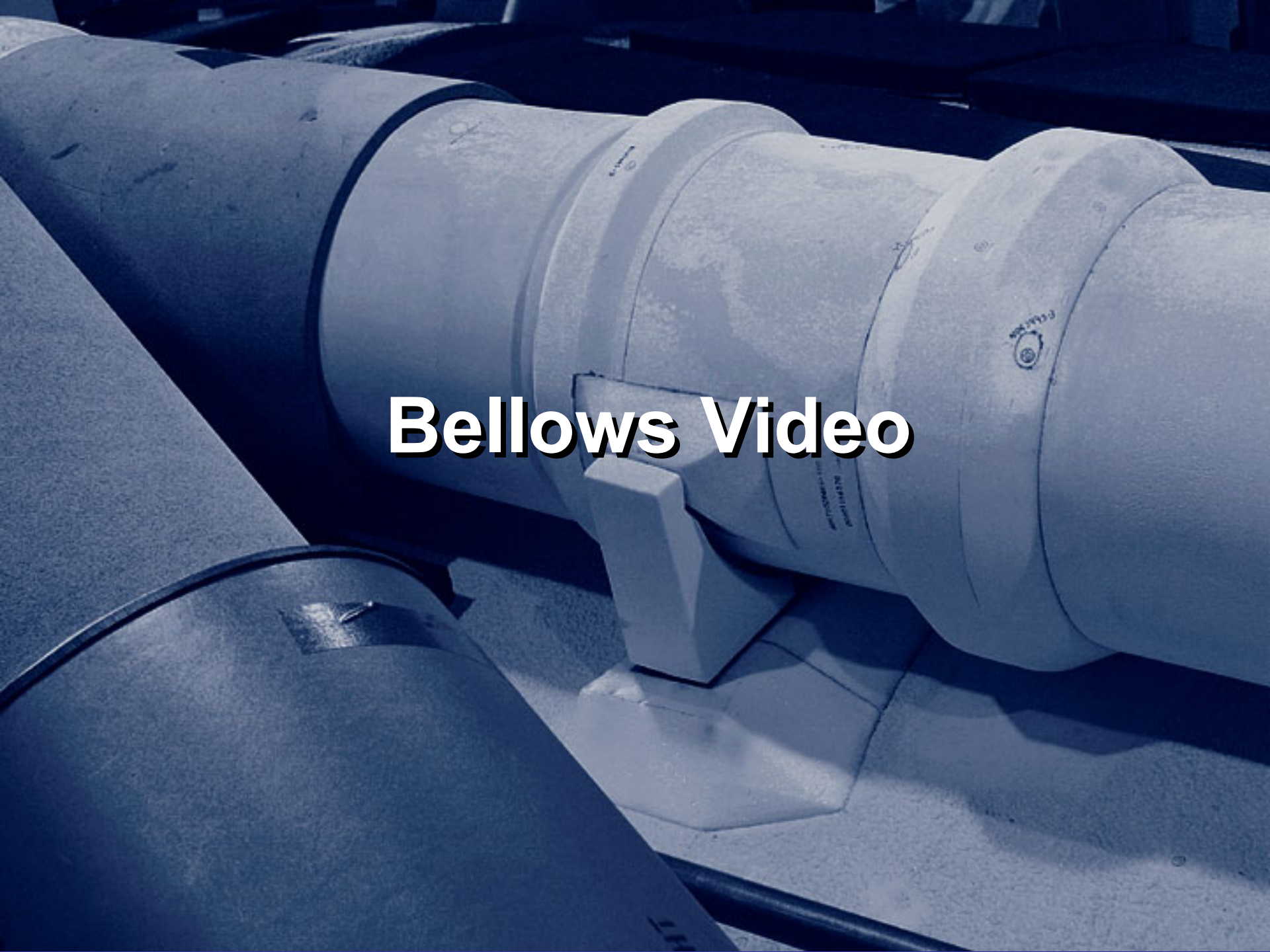
Aft Bellows



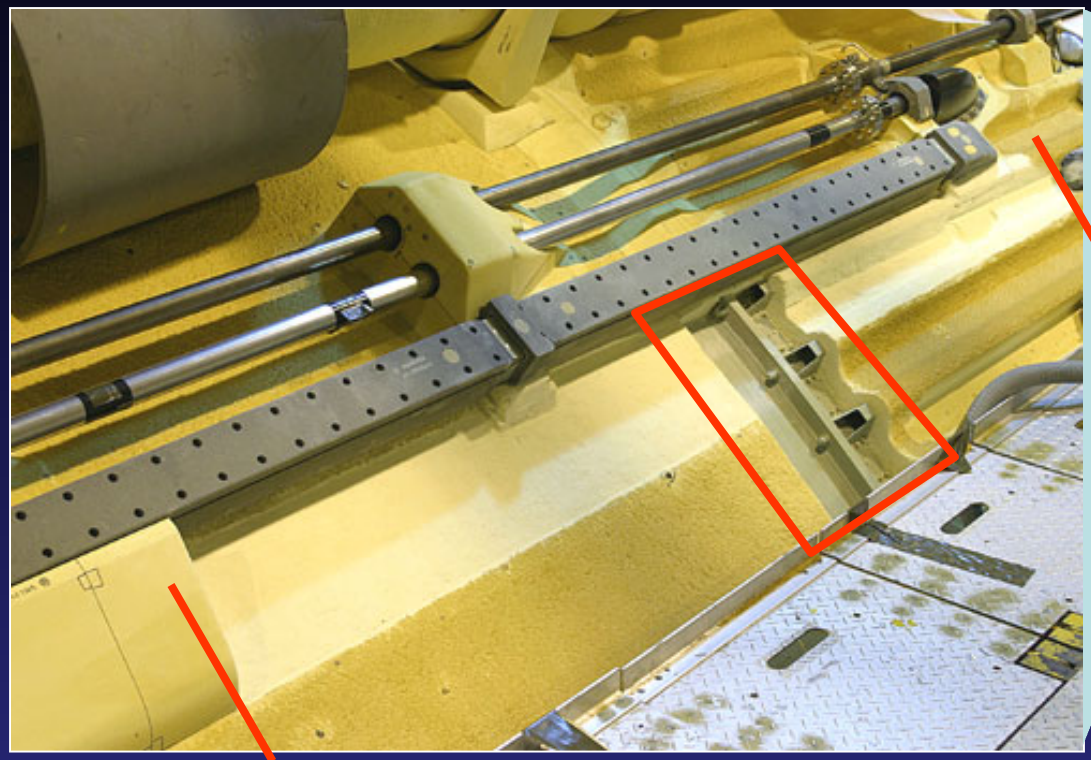
Bellows Spray

PDL Pour

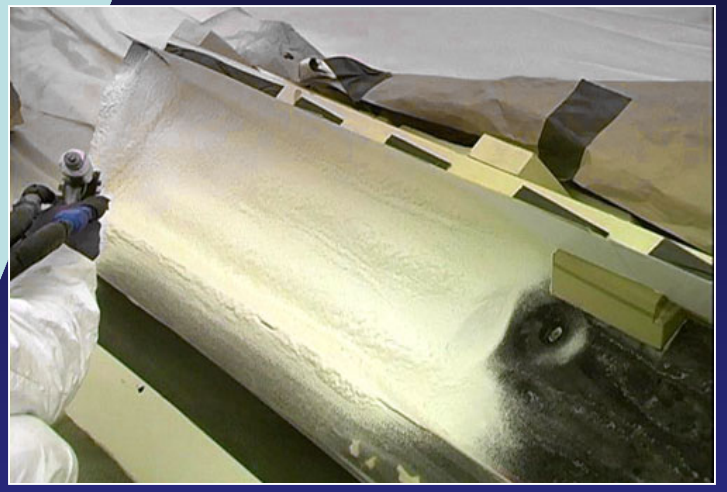
ET-120 retrofit processes are being validated


Bellows Video

PAL Ramp



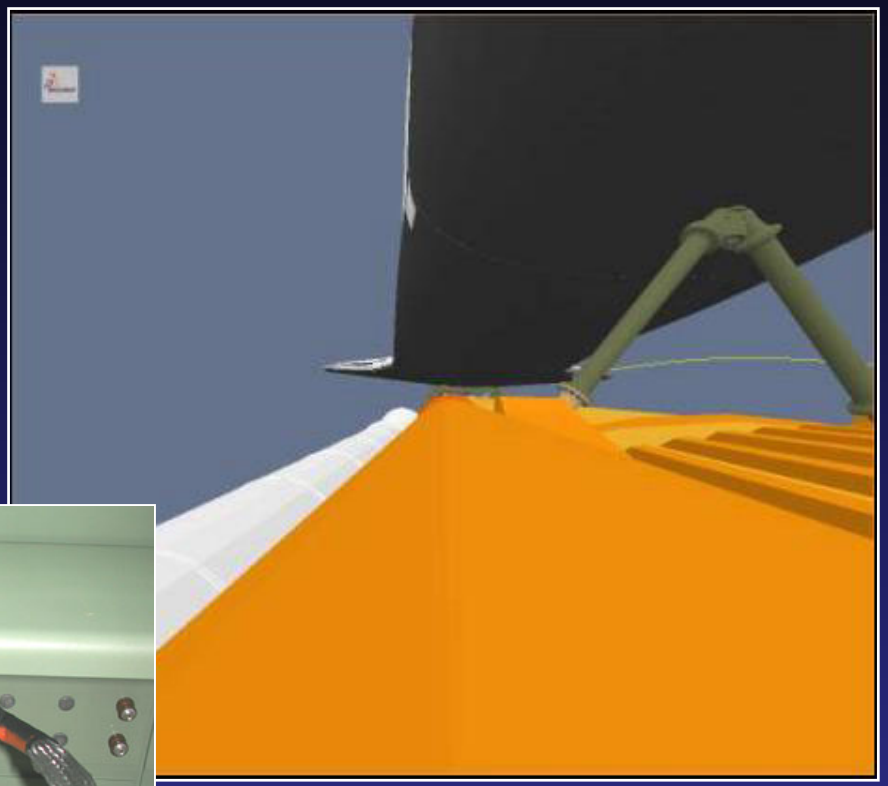
Ten Feet Section of Removed PAL Ramp
with Critical Area Shown in Red Box



PAL Ramp Spray

We have removed the PAL ramp over the flange and are refining the process to replace it

Enhanced In-Flight Imaging



Potential Field of View

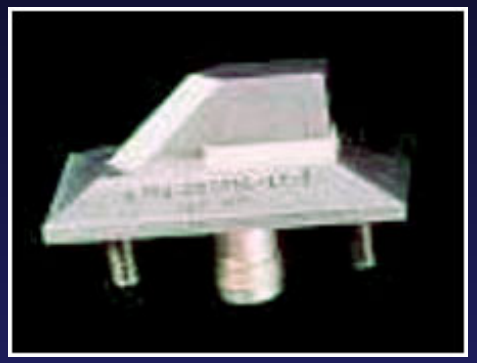
Internal View of Camera Installation

External Tank is supporting program imaging requirements

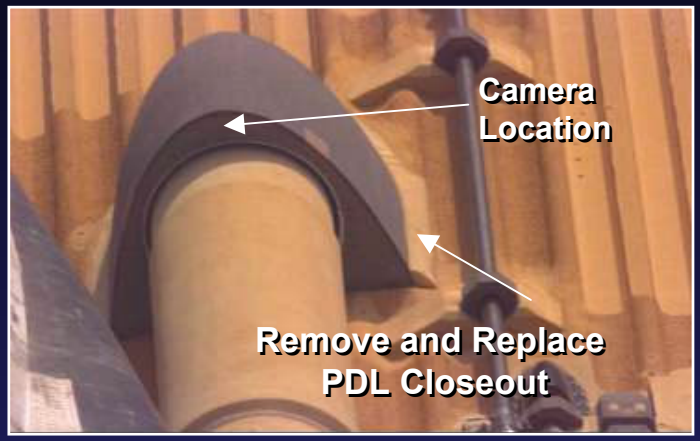
Enhanced In-Flight Imaging System

Interface at Ground Umbilical Carrier Plate
- On / Off
- Battery Charging / Monitoring

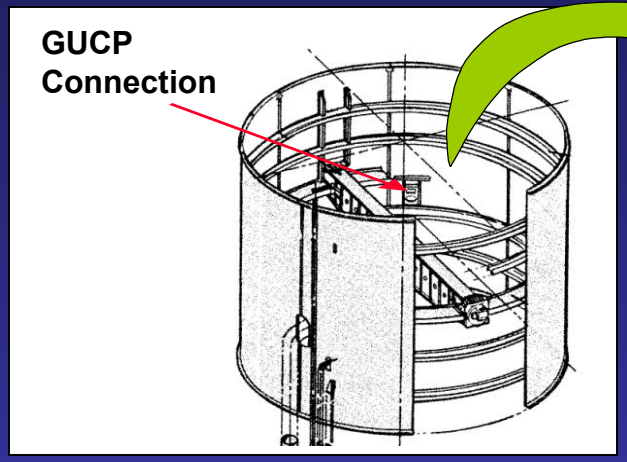
BX-265 Closeout



Two Antennas on -Z



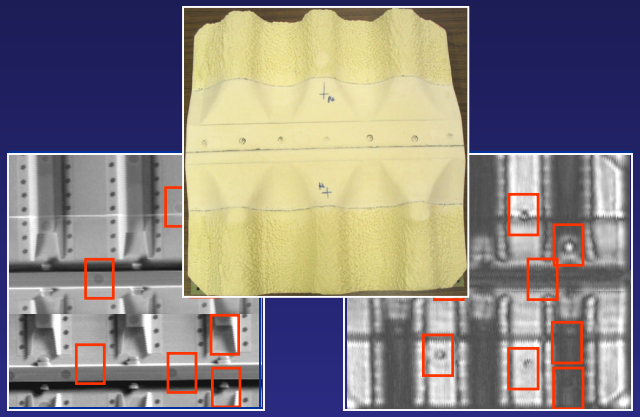
One Camera in LO2 Feedline Fairing

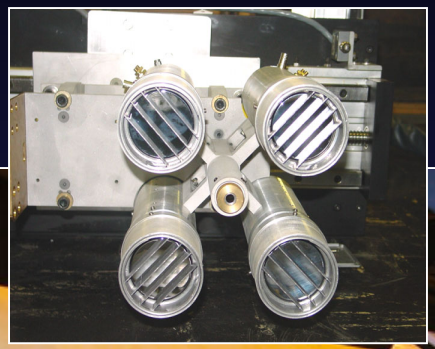


Electronics Box in Intertank

Non-Destructive Evaluation (NDE)

Terahertz





Backscatter

NDE is being aggressively developed but is not currently available for hardware acceptance

The External Tank will be ready to safely support the Crew of STS-114 and missions to follow!