James Webb Space Telescope (JWST) Integrated Science Instruments Module (ISIM) Electronics Compartment (IEC) Conformal Shields Composite Bond Structure Qualification Test Method
-Extended Abstract-

NASA Structures, Loads & Dynamics, and Mechanical Systems (SLaMS)
Young Professional (YP) Forum 2015

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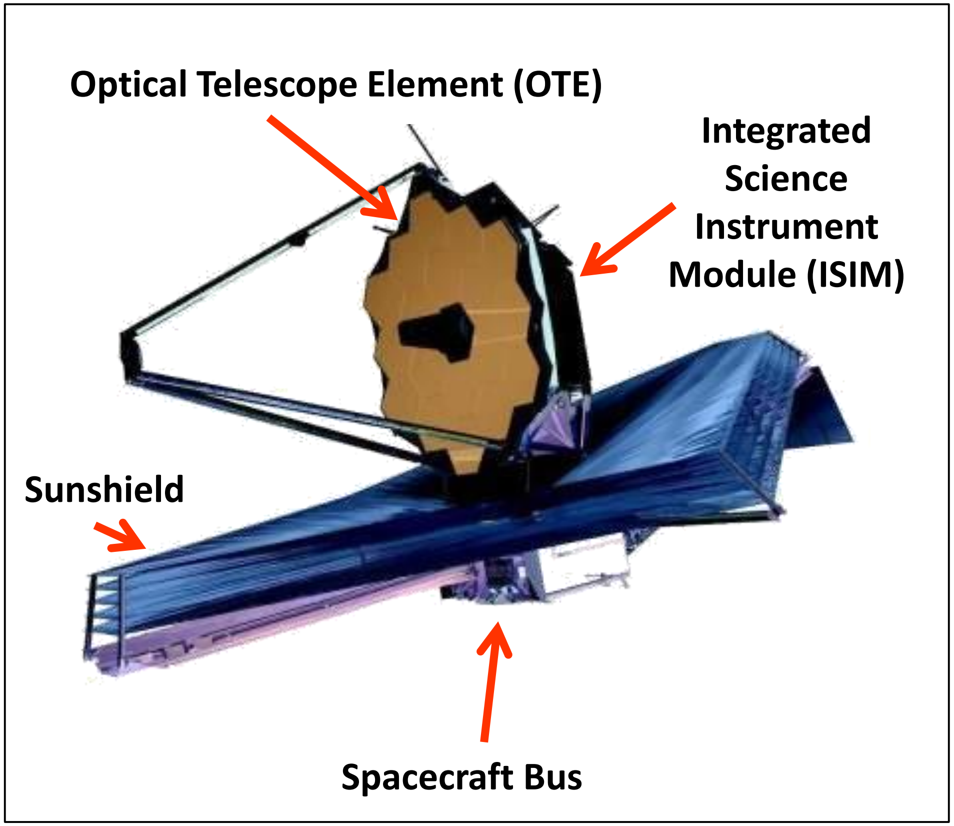
Overview

- **IEC Conformal Shields Frame Description**
- **Purpose of Testing the Structure**
- **Thermal Verification of Bonded Frames**
  - Bond Failure Results
  - Improved Test Method
  - Bond Repairs
  - Repaired Bonds Test & Results
- **Conclusions**

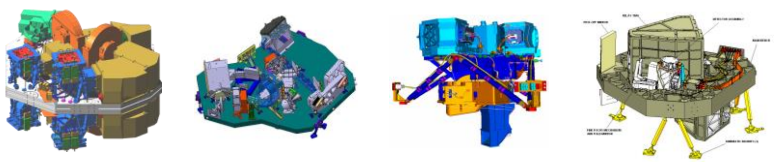
Description of IEC Conformal Shields Structure

The IEC Conformal Shields Frame is a structural component of the James Webb Space Telescope (JWST)



JWST Mission Objective

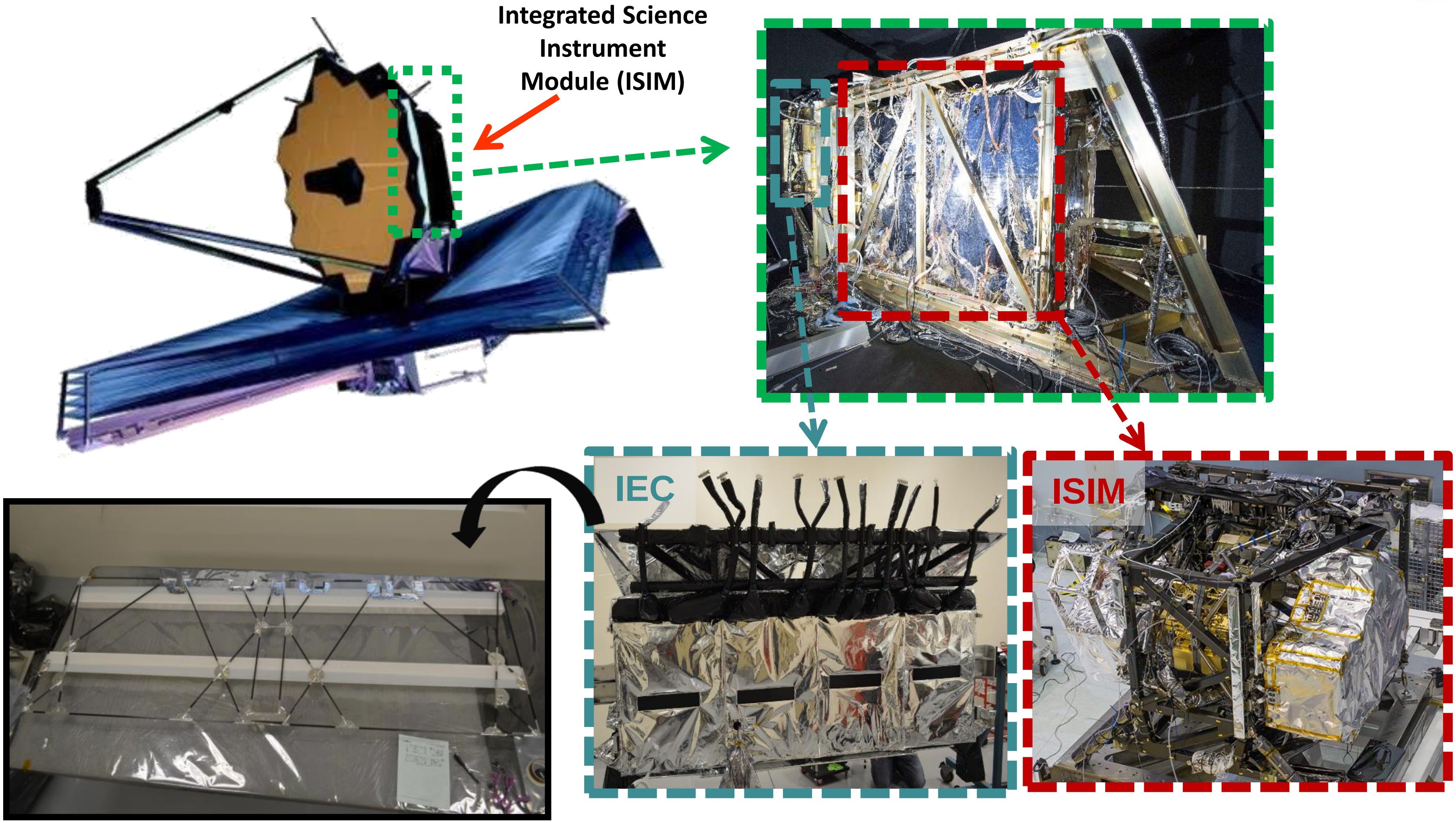
Study the origin and evolution of galaxies, stars & planetary systems:
Optimized for infrared observations (0.6 – 28 μm)



Four Science Instruments (ISIM)

- Near Infrared Camera (NIRCam)
- Near Infrared Spectrograph (NIRSpec)
- Mid-Infrared Instrument (MIRI)
- Fine Guidance Sensor (FGS)

Description of IEC Conformal Shields Structure

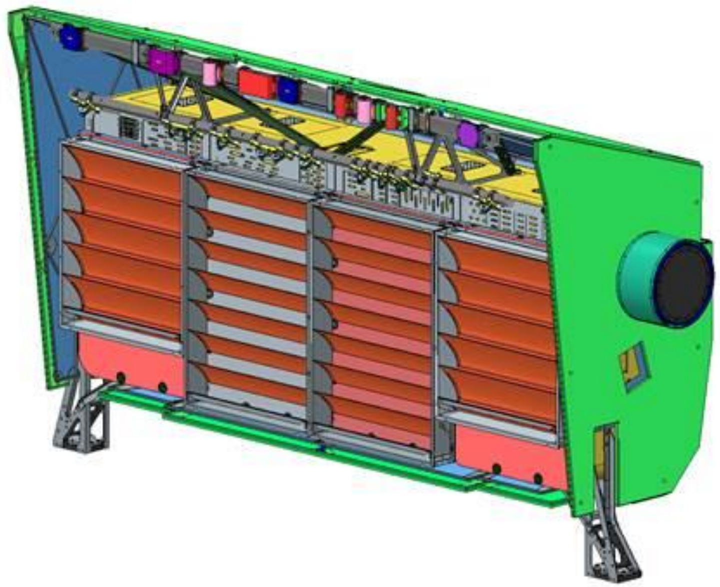


The function of the bonded composite frames is to provide the structure on which multi-layer insulation (MLI), called Conformal Shields, mounts

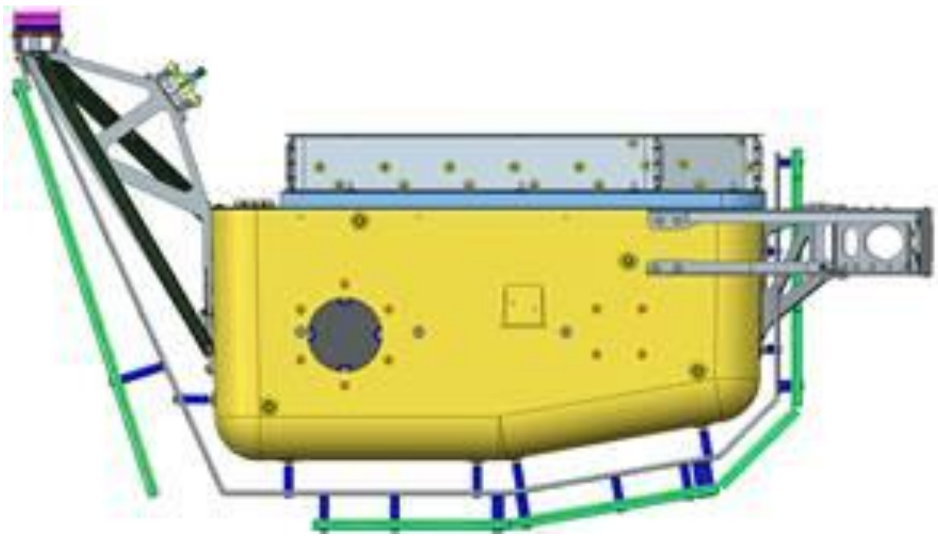
Description of IEC Conformal Shields Structure

Conformal shields structure is <u>critical to the thermal function of the IEC</u>:

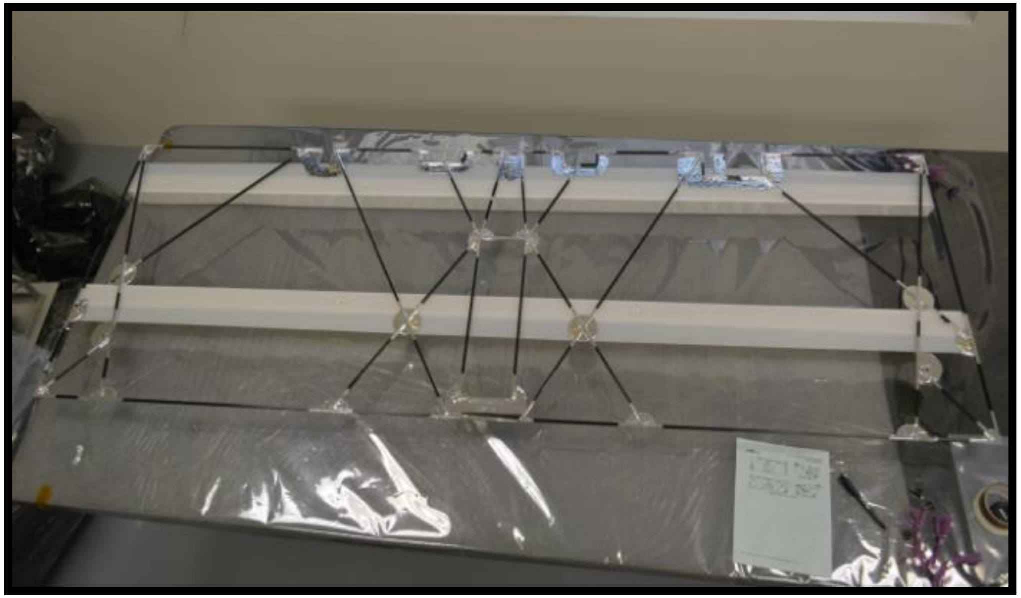
- **IEC is a room temperature heat source in the middle of critically sensitive, tennis court size observatory**
- **Heat must be directed away from sensitive cryo-instruments**



IEC flight configuration



Description of IEC Conformal Shields Structure



Frames construction

- 1/4'' OD carbon fiber square tubes
- 1/16'' thick carbon fiber gussets

Bonded joints

- Hysol EA 9394
- Excess adhesive squeezed out

Purpose for Testing IEC Conformal Shields Frame

- **Verifies bonded joints fulfill Mission Assurance Requirements per JWST-RQMT-002363**
  - MAI-405: If the use of adhesives is planned, proper adhesive selection for the <u>operating environment</u>, surface preparation, bond line thickness, and component configuration shall be made and indicate positive margins with an ultimate factor of safety (FS) of 1.5 with analysis.
  - MAI-406: All bonded interfaces shall be <u>strength test verified</u>.
- **Reduce risk of in-flight bonded joints failure**

→ **<u>OPERATING ENVIRONMENT</u>: EA 9394 needs to be evaluated for cryo-susceptibility**

Need to confirm flight temperatures to perform thermal vacuum testing

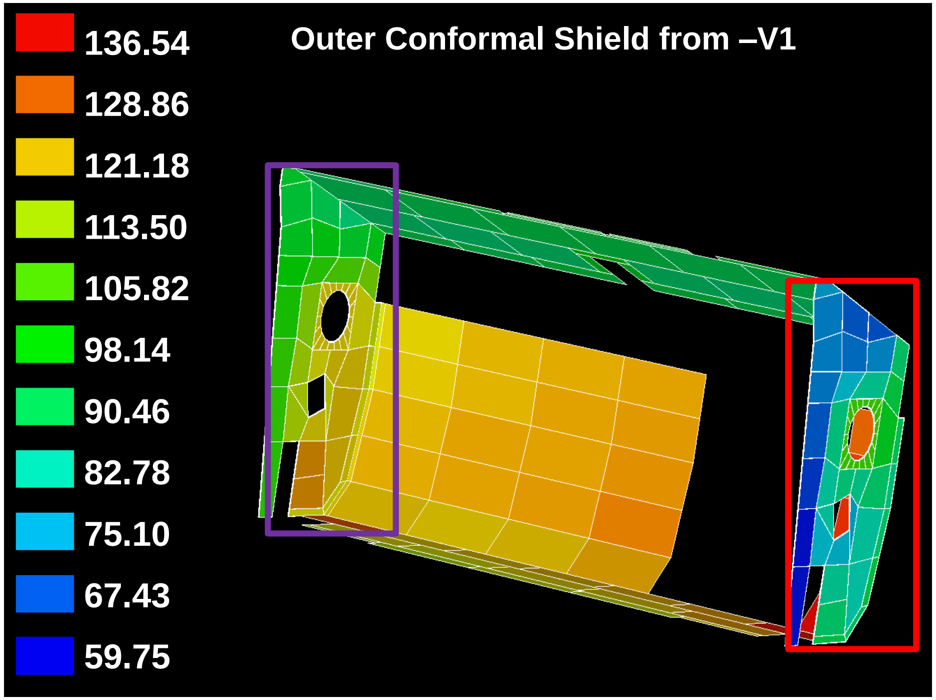
→ **<u>STRENGTH TEST</u>: An equivalent flight load needs to be determined**

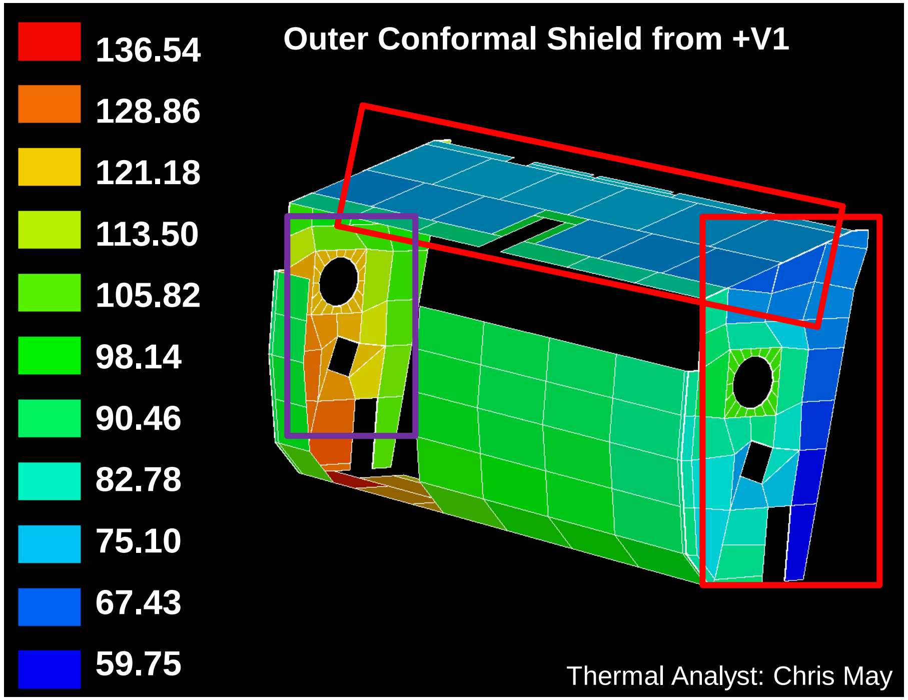
Pull test to 1.4 flight loads (per NASA-STD-5001A)

Thermal Verification of Bonded Frames

Thermal test requirement is based on JWST observatory thermal model:

- **Achieve protoflight levels: 10K margin over flight operational temperatures per General Environmental Verification Standard (GEVS); GSFC-STD-7000**
- **Achieve -162°C (111K) on 17 frame structures & -190°C (83K) on 3 frame structures**



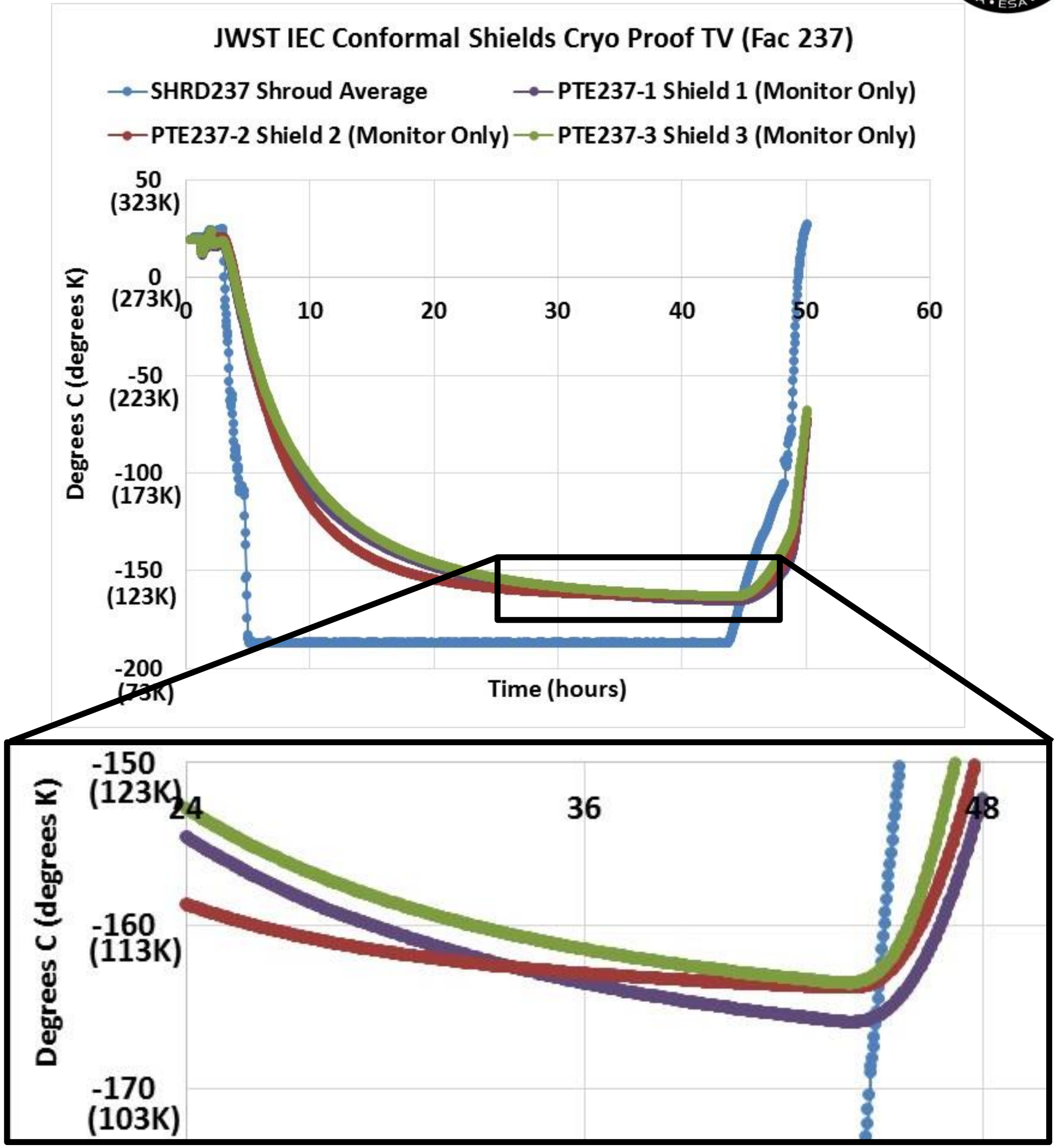


Outer layer of the MLI predicated to lower temperatures (59.75K)

But, inner side of the MLI correlates to actual frame temperature (~93K)

Thermal Verification of Bonded Frames

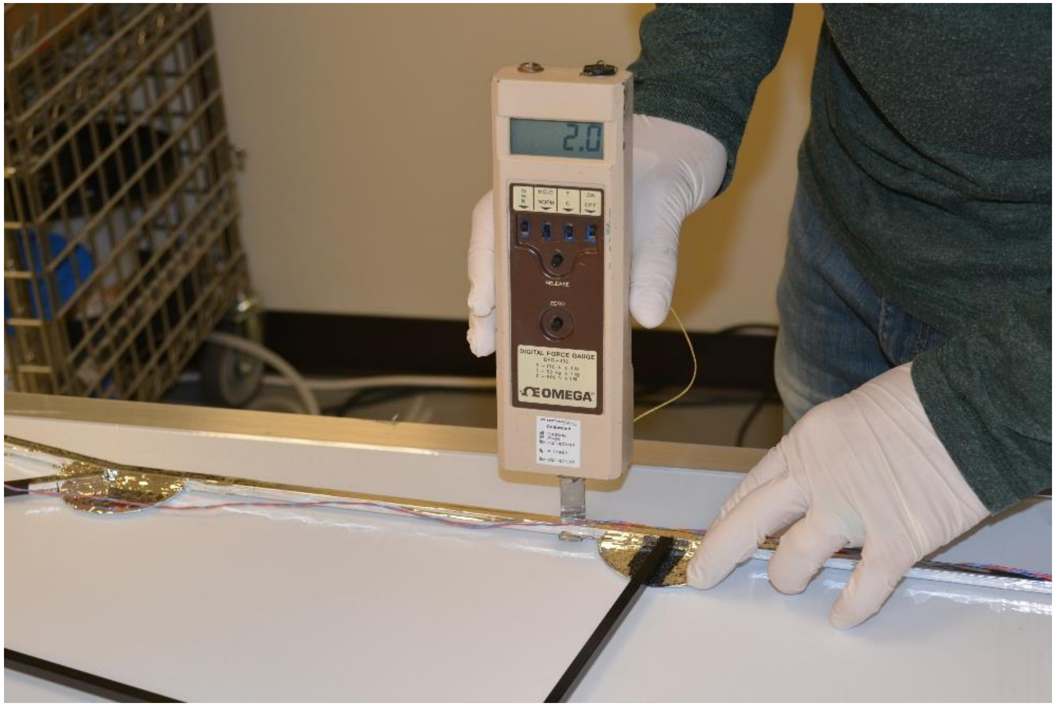
NASA GSFC Chamber 237 thermal vacuum chamber in flooded LN_2 shroud environment



LN_2-flooded shroud at -187°C (86K) achieved -166°C to -163°C (107K to 110K) on frames

Bond Workmanship Pull-Test Results

Post-cryo pull tests (2 lbs) performed at 2 locations for each frame section



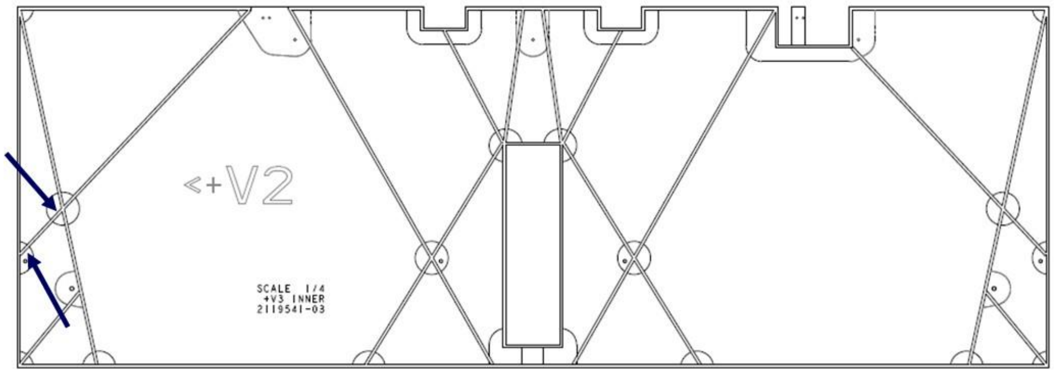
Pass/Fail Criteria – Failed if bond weakening is indicated by:

- **Sudden decrease in load during pull test**
- **Visual inspection**

Bond Failure Results

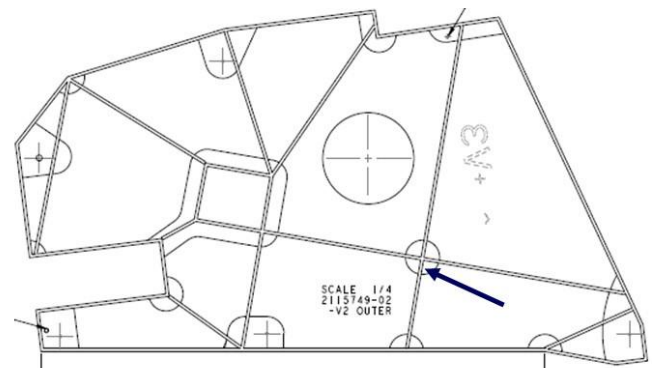
Bond failures occurred in a total of 6 locations on 3 of the structures

+V3 Inner Conformal Shield
2119541-03
Post Cryo Bond Failure Locations (x2)

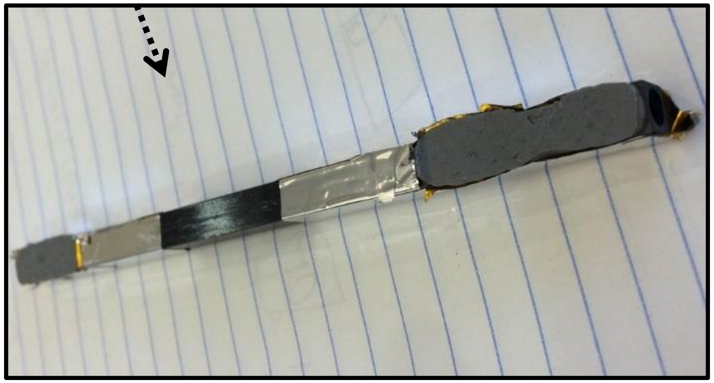


111K temp req'd

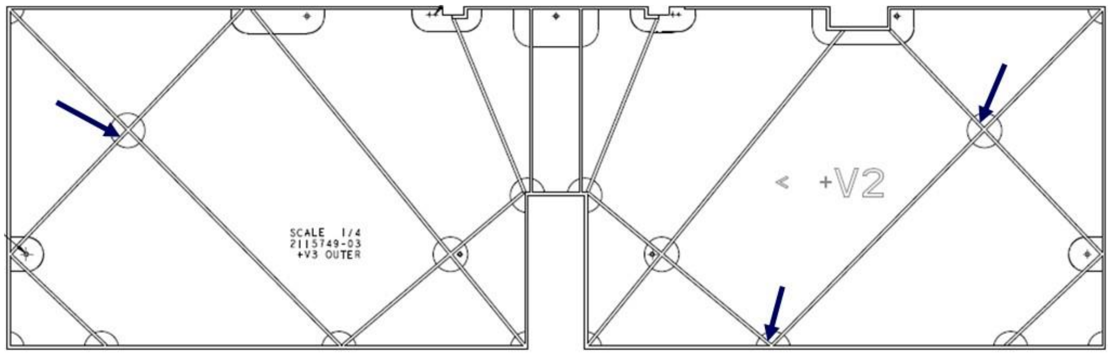
-V2 Outer Conformal Shield
2115749-02
Post Cryo Bond Failure Location (x1)



83K temp req'd



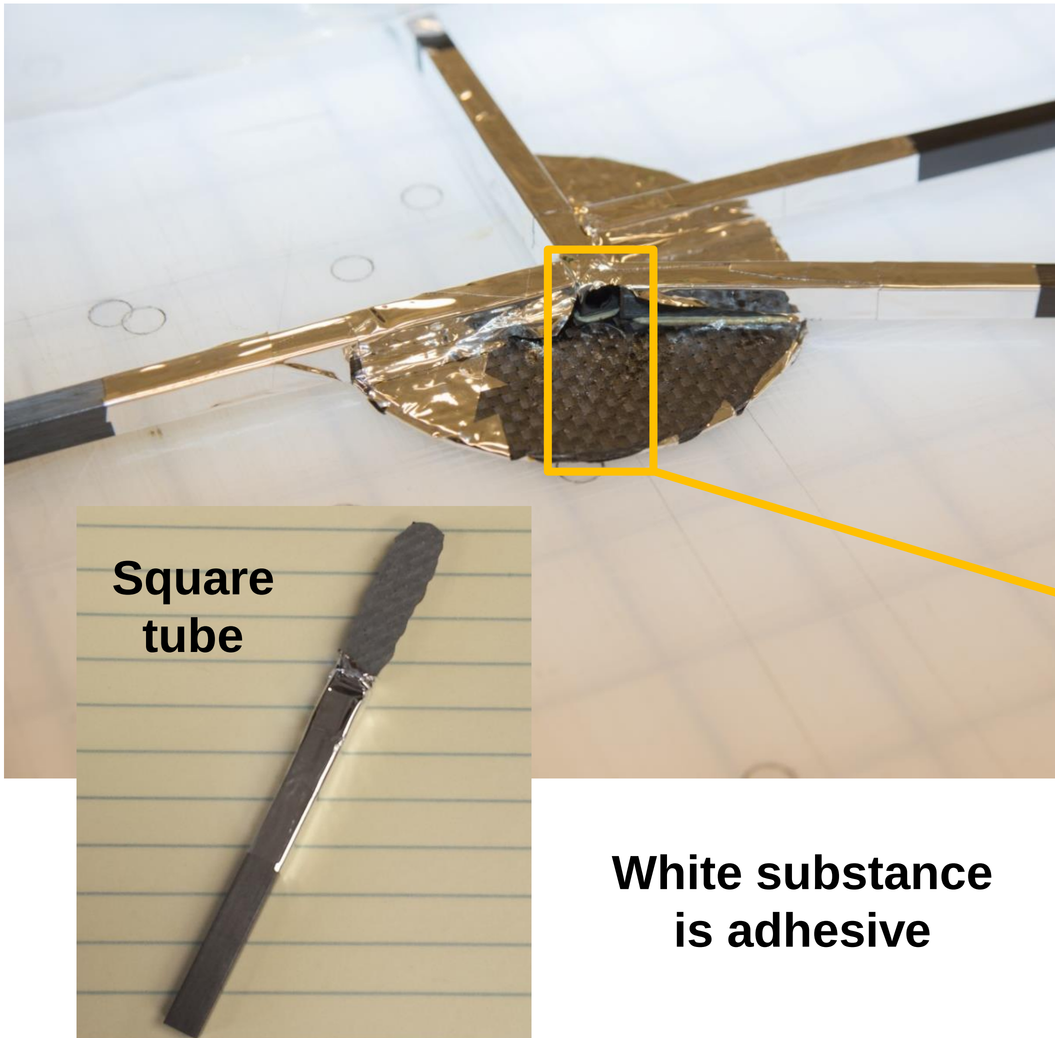
+V3 Outer Conformal Shield
2115749-03
Post Cryo Bond Failure Locations (x3)



83K temp req'd

Bond Failure Results

Failure at square tubes to gussets bond

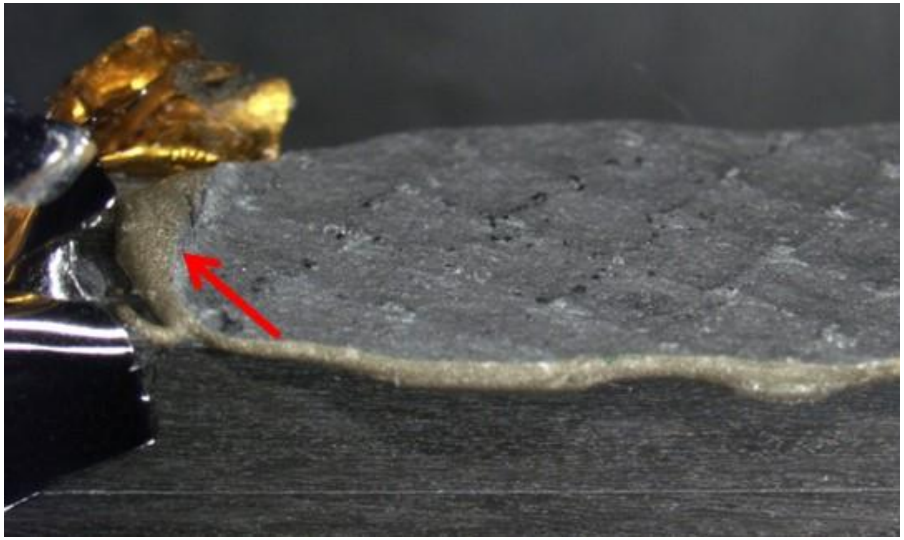


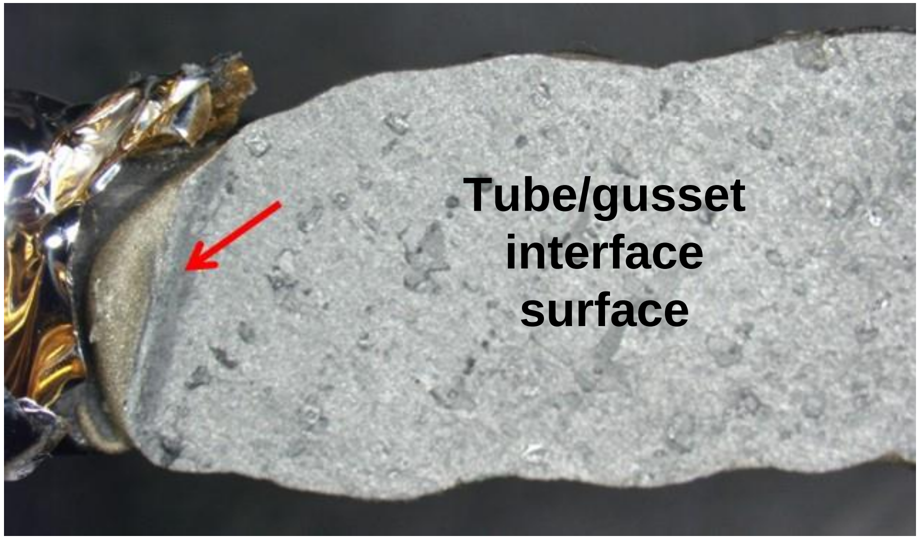
White substance is adhesive

Bond Failure Results

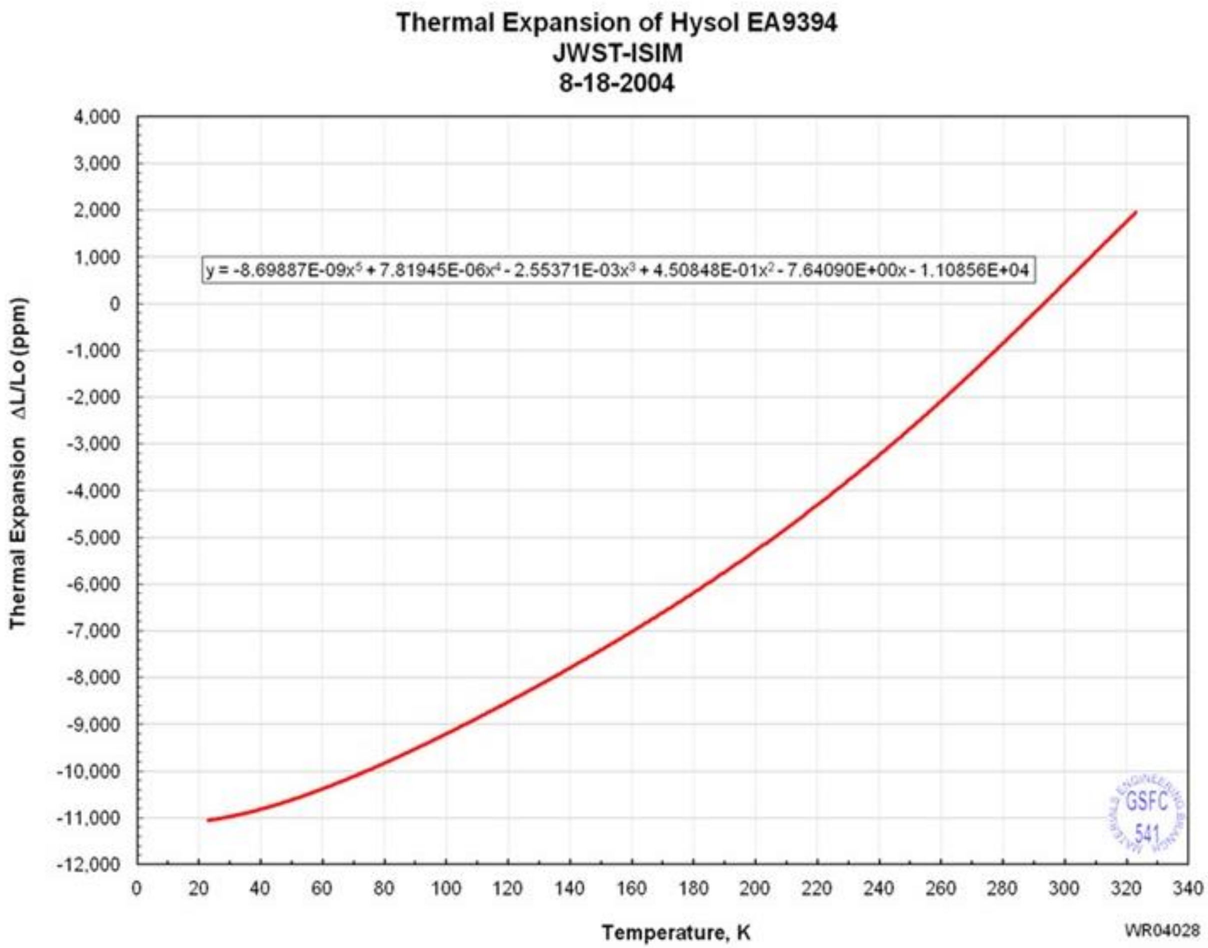
Failure Analysis

- Failure Mode: Adhesive failure due to stress concentration at fillets
- Large fillets were all around the bond line
- Crack started at the gusset edge fillet (arrows) & propagated





Improved Test Method for Re-Test

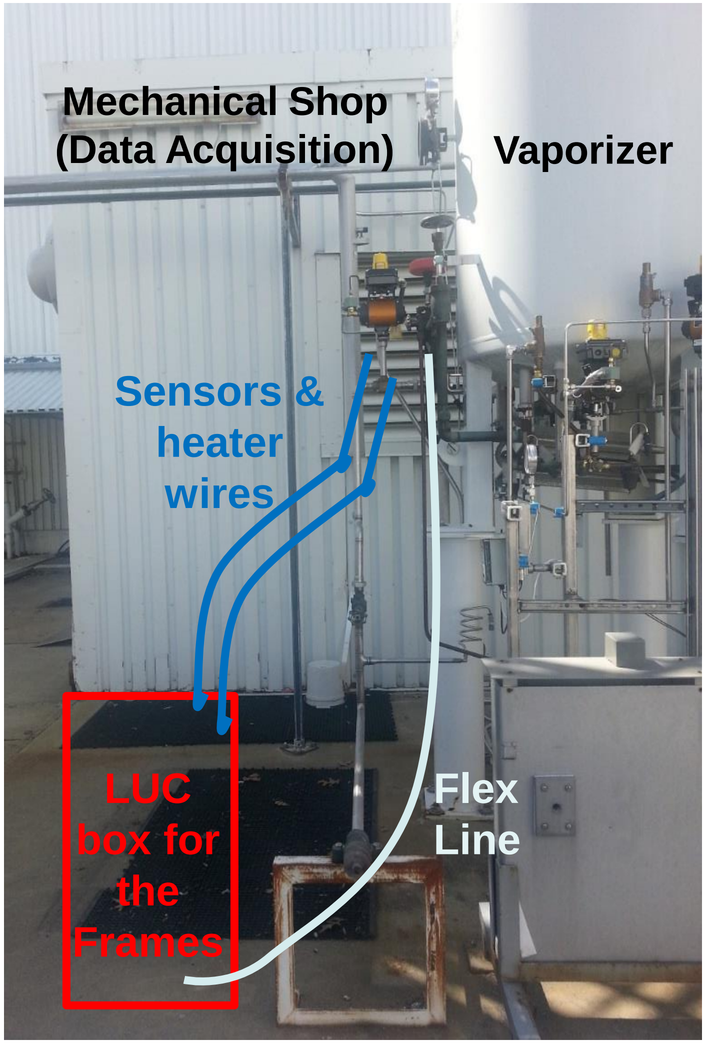


Why is it a big deal to go from 110K to 83K?

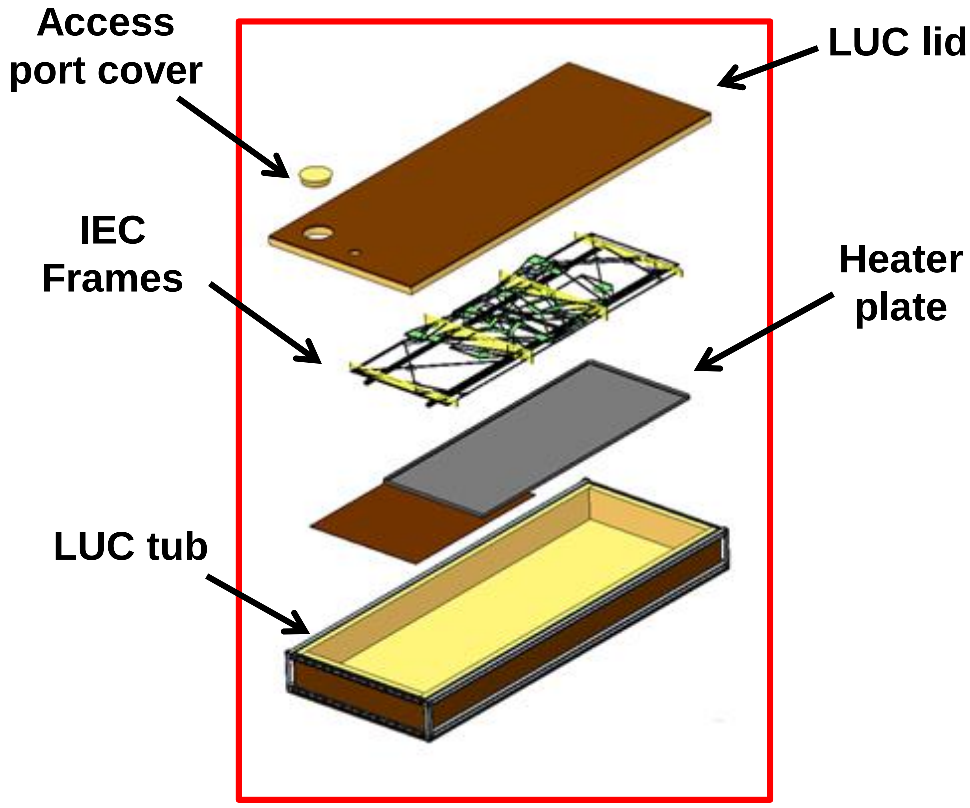
CTE data for EA 9394 indicates about 0.8% change in dimensions from 110K to 83K

Since chamber shroud can only achieve -187°C (86K) and thermal requirement is to achieve 83K on the hardware → Need new method to achieve 83K

Improved Test Method



LUC = LN_2 Unpressured Container

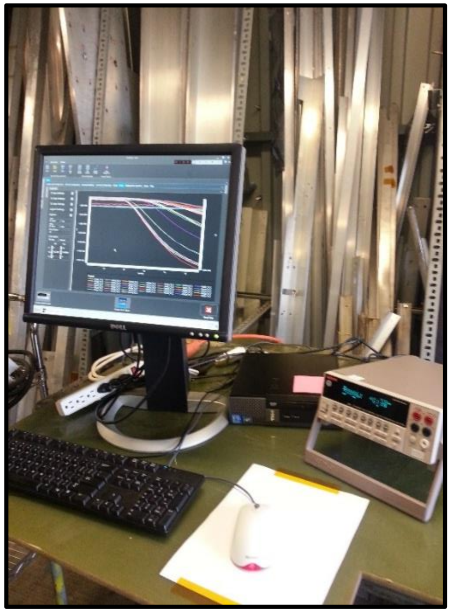


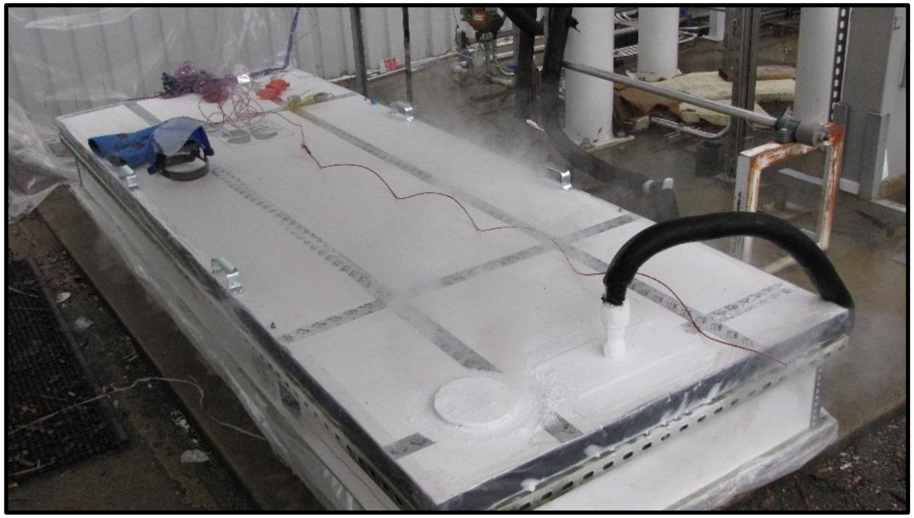
Fill LUC tub with GN_2, then LN_2

Must achieve 83K for frames with failed bonds + those with 83K requirement (total of 4 frames)

Improved Test Method

<u>Actual Atmospheric LN_2 test set-up:</u>

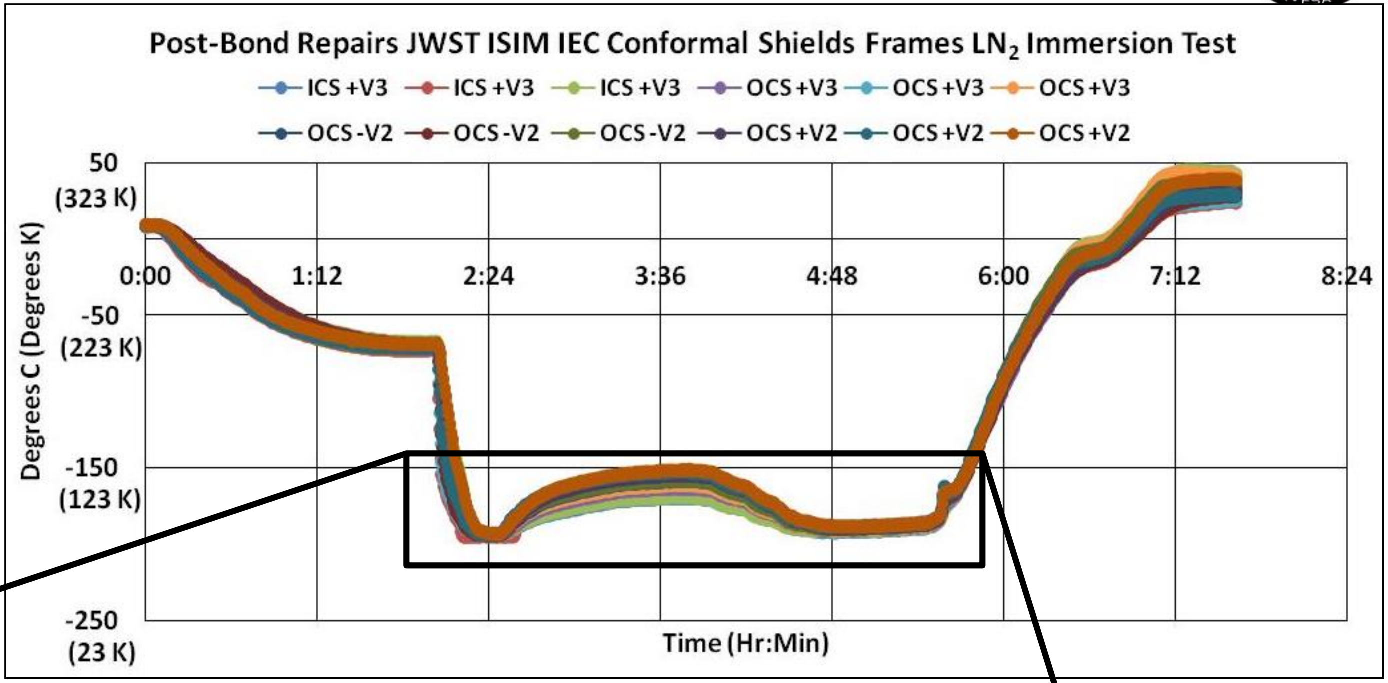


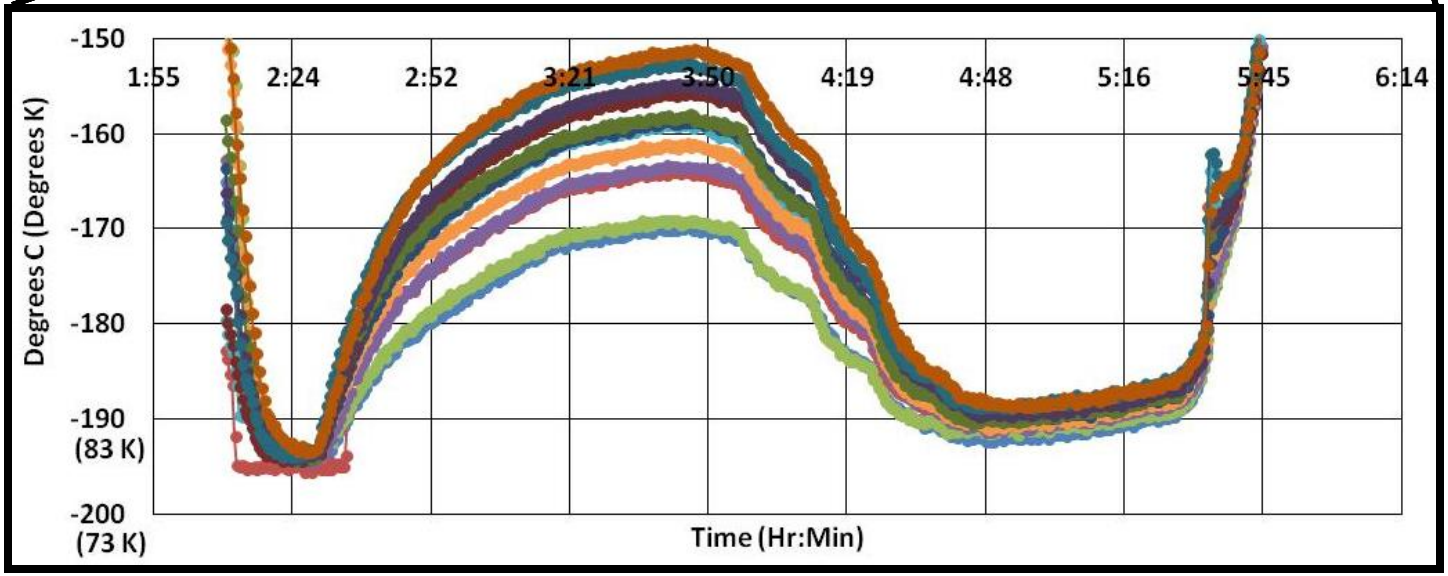


Atmospheric LN_2 Test Results

(1) Thermal test results: Achieved 78K-80K, exceeds protoflight levels

(2) Mechanical test results were also positive: NO NEW BOND FAILURES



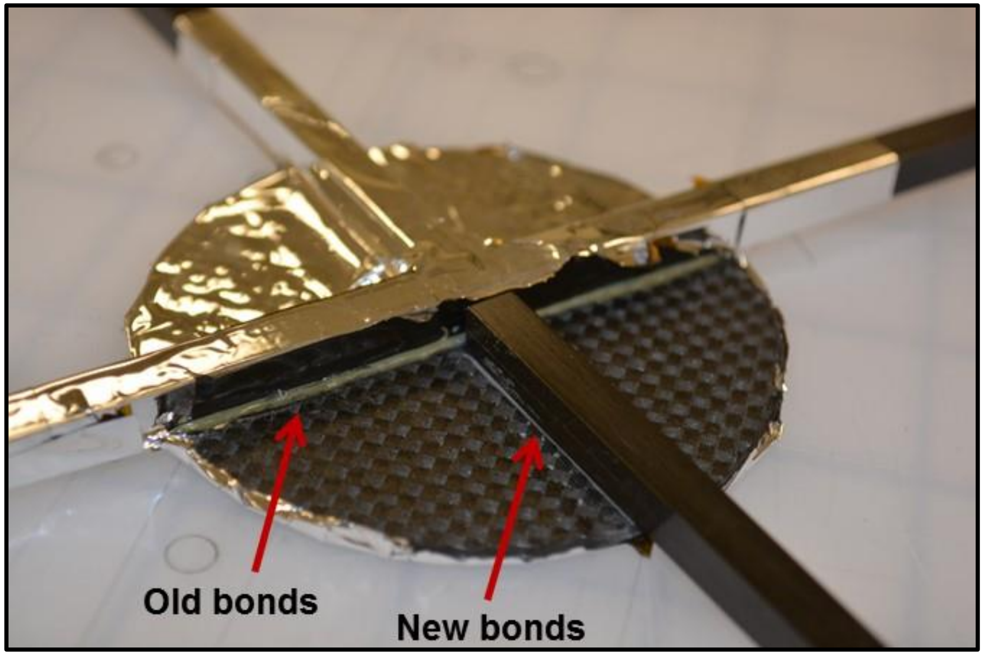


Bond Repairs

- Tubes replaced with new ones
- Bond line and squeeze out controls

⇩

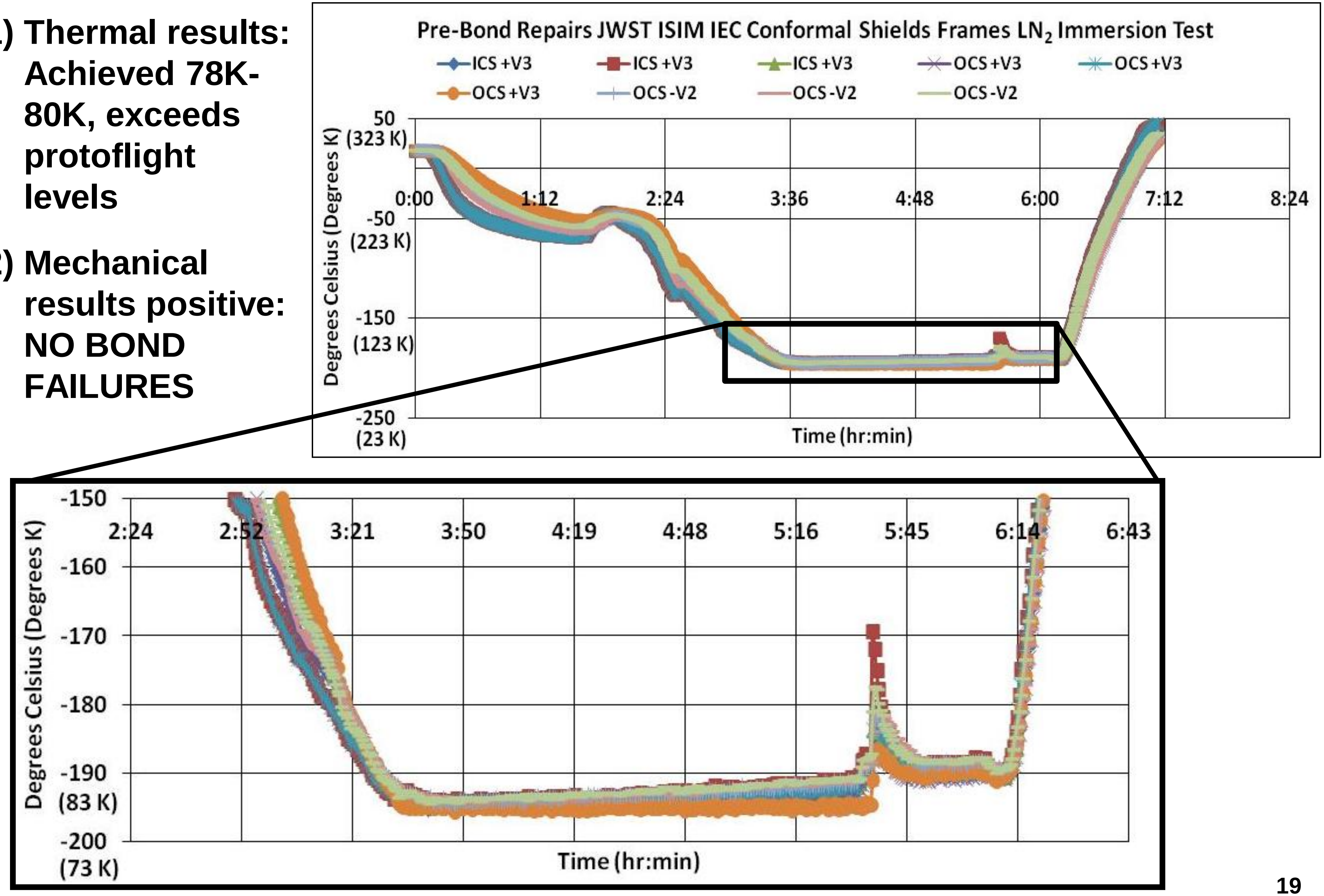
- Must re-test to qualify flight structure
- Cryo-test: Shields achieved 107K – 110K



Repaired Bonds Test & Results

(1) Thermal results: Achieved 78K-80K, exceeds protoflight levels

(2) Mechanical results positive: NO BOND FAILURES



Conclusions

- Bond integrity changes from ambient to cryo-conditions
- Must test all composite structures
  - Critical for mission assurance
  - Thermal & mechanical testing
- Perform “proof-of-concept” test runs on non-flight items
- Eliminate fillets during squeeze-out during bonding process
- Atmospheric LN_2 test method proved effective and efficient for achieving target test levels

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