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


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

- 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
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 operating environment, 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 strength test verified.
- Reduce risk of in-flight bonded joints failure

→ OPERATING ENVIRONMENT: EA 9394 needs to be evaluated for cryo-susceptibility
   Need to confirm flight temperatures to perform thermal vacuum testing
→ STRENGTH TEST: 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
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)

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

111K temp req’d

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
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
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

**Mechanical Shop (Data Acquisition)**

- **Vaporizer**
- **Flex Line**
- **LUC box for the Frames**
- **Sensors & heater wires**

**LUC = LN₂ Unpressured Container**

- **Access port cover**
- **IEC Frames**
- **LUC lid**
- **Heater plate**

**LUC tub**

Fill LUC tub with GN₂, then LN₂

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

Actual Atmospheric LN$_2$ test set-up:
Atmospheric LN₂ 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

[Image of a component showing old and new bonds]
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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