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Bell 525 Vertical Fin / Aft Fuselage and Tailboom Composite / Metallic Hybrid Certification Fatigue Testing

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ICAF International Committee on Aeronautical Fatigue and Structural Integrity

38th Conference & 31st Symposium of the International Committee on Aeronautical Fatigue and Structural Integrity
Delft, The Netherlands, 26-29 June 2023

National Research Council Canada | Conseil national de recherches Canada

BELL

Canada

Background
Bell 525 Relentless

- **Bell 525 Relentless is Bell's largest commercial helicopter to date - announced in 2012**
- **Super medium helicopter, targeting oil and gas, corporate, SAR, public safety, troop transport markets.**

Specification	B525
PAX	16-20
MTOW	9752 kg
Range	1000+ km
Speed	165 kn

Background
Bell 525 Relentless

- **Bell 525 Relentless is Bell's largest commercial helicopter to date - announced in 2012**
- **Super medium helicopter, targeting oil and gas, corporate, SAR, public safety, troop transport markets.**
- **First introduction of fly by wire into civil rotorcraft**
- **First flight 2015, certification with FAA to FAR 29 soon**

Specification	B525
PAX	16-20
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Background

Bell 525 Fatigue Test Objectives

- **Test Goals:**
  - Evaluate the damage tolerance of composite Principal Structural Elements (PSE) structures with intrinsic flaws and impact damages;
  - Determine the fatigue strength of metallic PSE structures to determine a replacement time based on crack initiation time in an as-manufactured component;
  - To perform strain surveys under static load conditions to collect strain, displacements and load reactions data to validate the airframe Finite Element Model (FEM);
  - To demonstrate residual strength of the structure to the post fatigue test static requirements;
  - To provide substantiating data to show compliance to the applicable CFR Part 29 requirements

- **Full Scale Tests Required:**
  - Others
  - **Aft Fuselage / Tailboom Fatigue Test ← Carried out by NRC**
  - **Aft Tailboom / Vertical Fin Fatigue Test ← Carried out by NRC**

Background

Bell 525 Structural Arrangement

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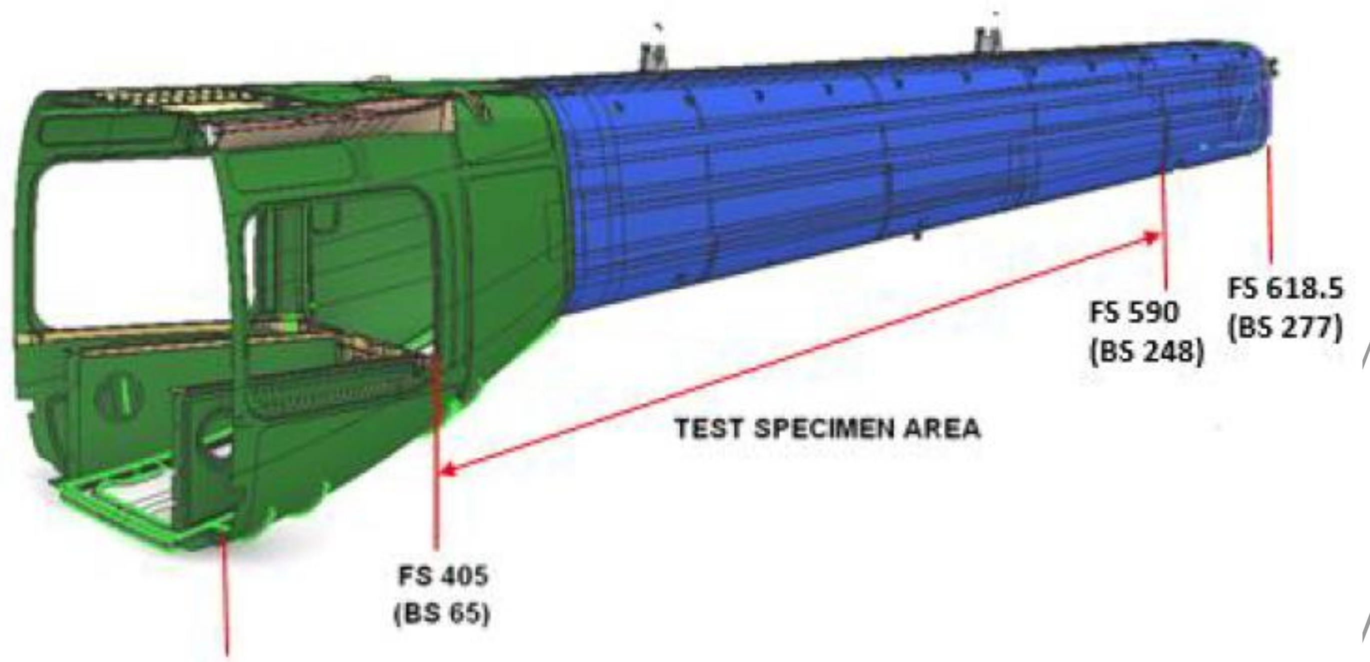
Bell 525 Fatigue Test Articles

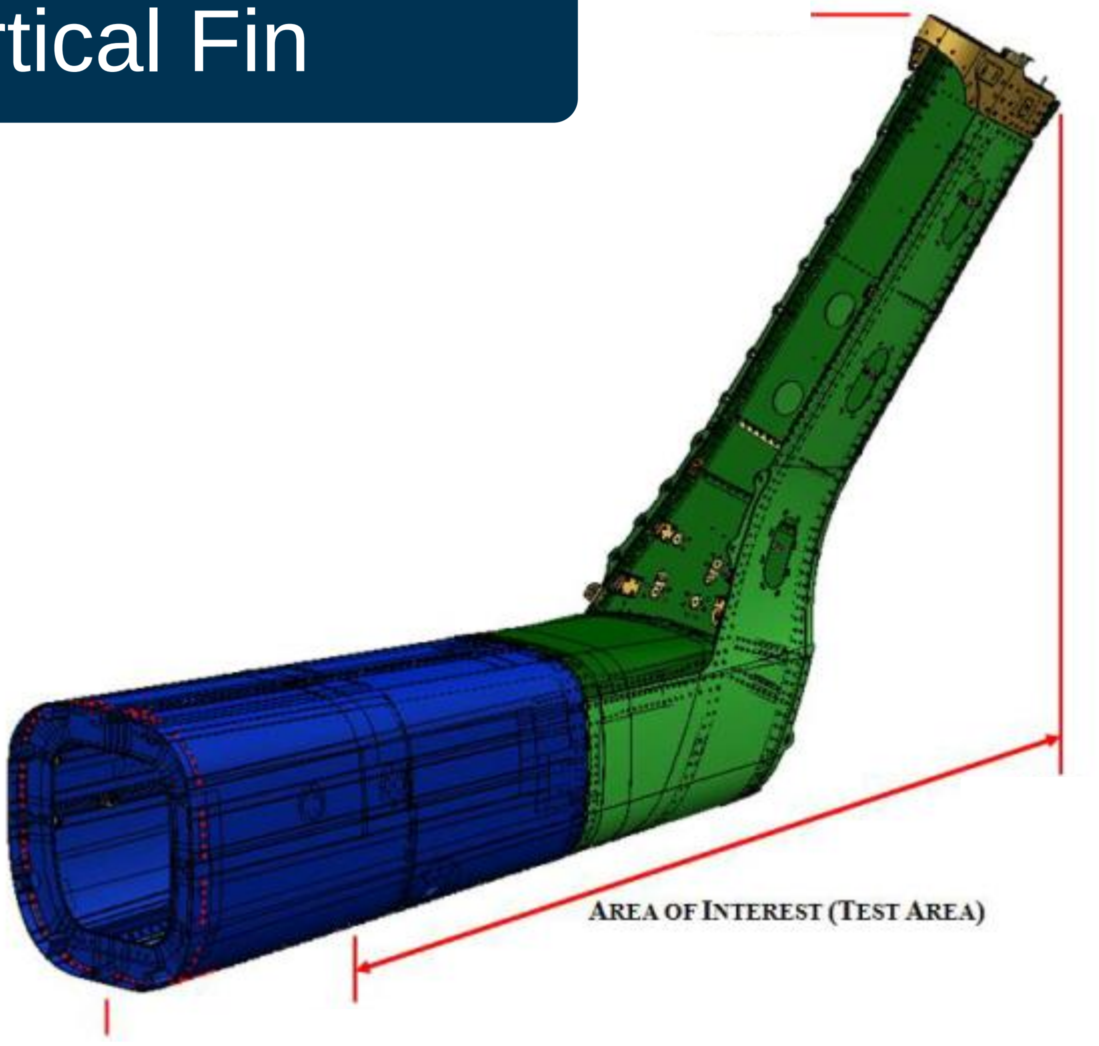
Aft Fuselage / Tailboom Test



Background

Bell 525 Fatigue Test Objectives

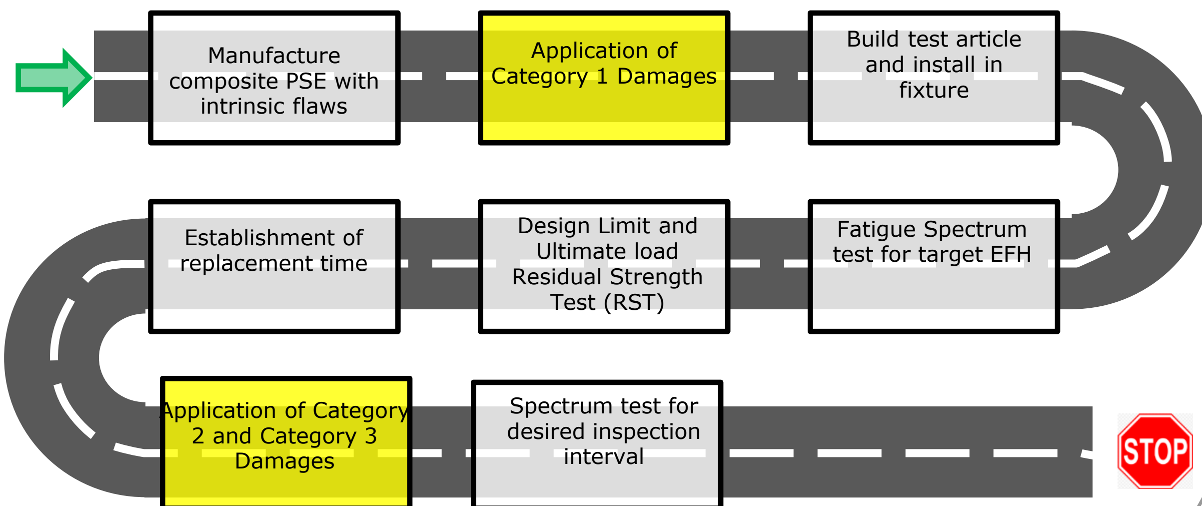
Aft Tailboom / Vertical Fin



Background

Bell 525 Fatigue Test Composite Certification Approach

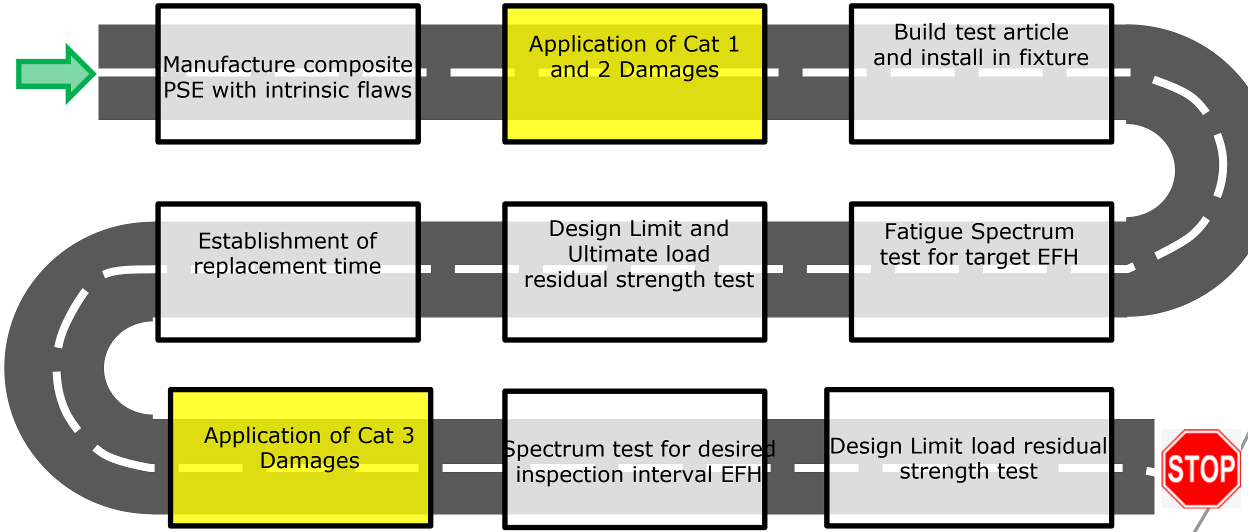
- **Requirement:**
  - Demonstration of catastrophic failure due to static or fatigue loads be avoided throughout operational life or prescribed inspection intervals, while considering intrinsic or discrete manufacturing defects or accidental damage
- **Threat Assessment of PSE's and Intrinsic Flaws incorporated at build, along with Impact**
- **Aft Fuselage / Tailboom Approach – Clear Cat 1 (BVID) with Cycling add Cat 2 / 3 and Establish Inspection Interval**



Background

Bell 525 Fatigue Test Composite Certification Approach

- **Requirement:**
  - Demonstration of catastrophic failure due to static or fatigue loads be avoided throughout operational life or prescribed inspection intervals, while considering intrinsic or discrete manufacturing defects or accidental damage
- **Threat Assessment of PSE's and Intrinsic Flaws incorporated at build, along with Impact**
- **Aft Tailboom / Vertical Fin Approach – Some Cat 1's were Classified as Cat 2 and inspection interval established during cycling, Cat 3 introduced and tested for inspection interval**

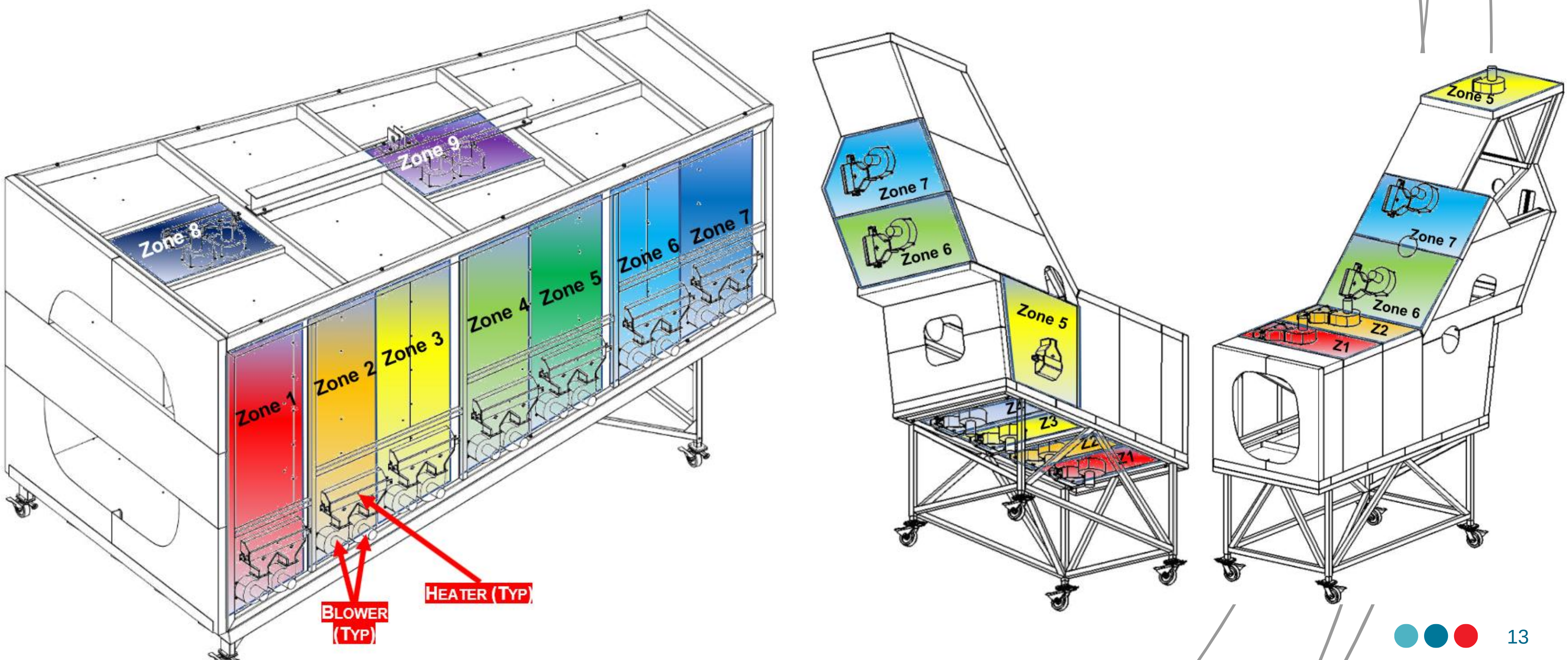


Background
Hybrid Material Certification Challenges

- **Load Spectrum**
  - Composites damage tolerance with embedded flaws / impacts requires high peak loads
  - Metallic damage tolerance peak loads are clipped to avoid non-conservative notch tip-plasticity
- **Environment at Empennage – Hot / Wet**
  - Turbine exhaust impinges directly on entire area
  - Combined with worst case ground environmental condition leads to challenging LEFs
  - Typically handled with Load Enhancement Factors (LEFs)
  - Unacceptably high LEFs required for this area – would risk non-representative damage to metallic components

Background
Hybrid Material Certification Challenges

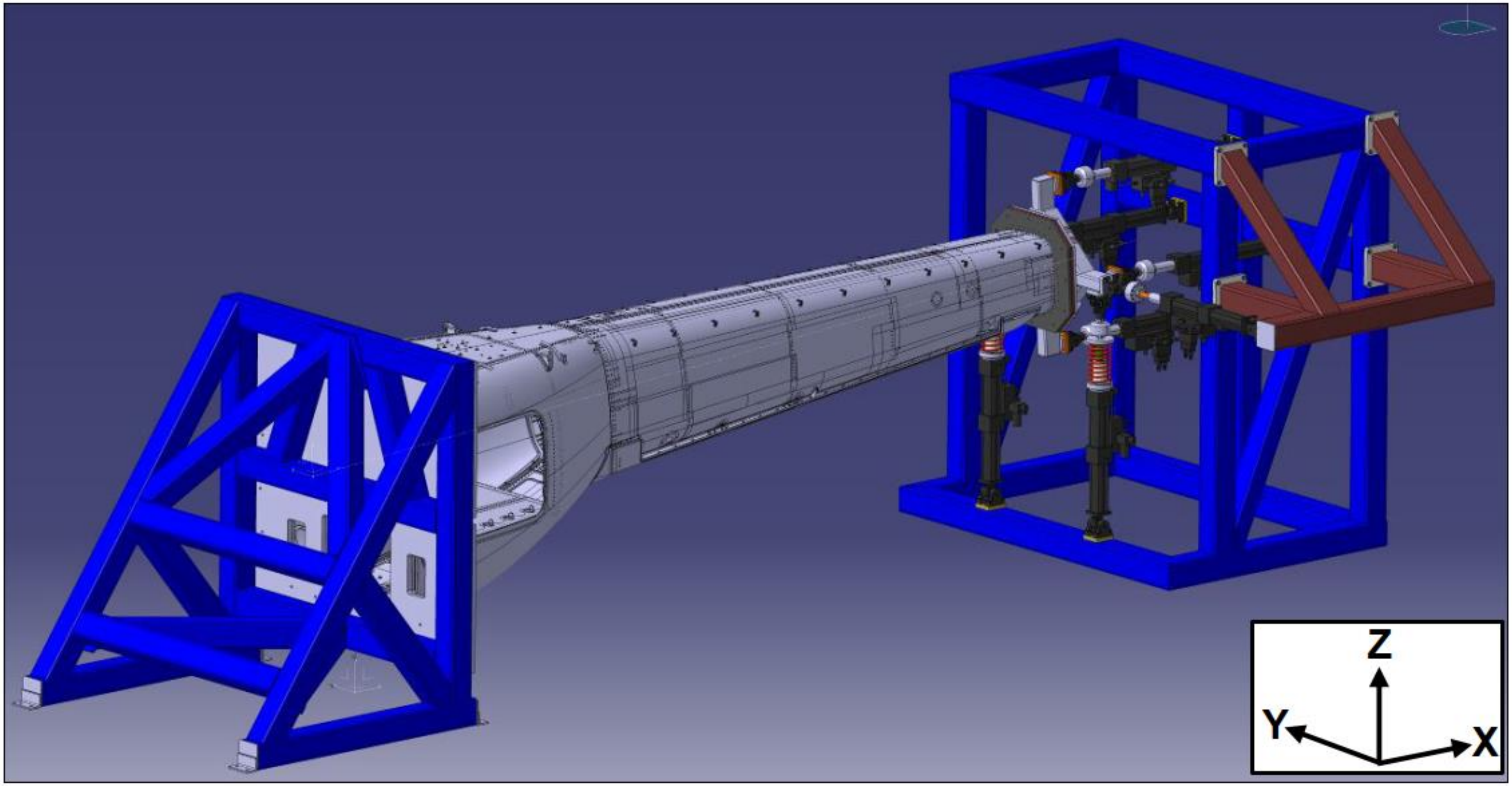
- **To avoid extremely high LEFs to account for service environment**
  - Run articles in hot / dry with adjustment to hot / wet with small LEF
  - Use environmental enclosures and run hot dry – NRC built / designed multizone closed-loop design



TEST DETAILS

Test Details

Aft Fuselage / Tailboom



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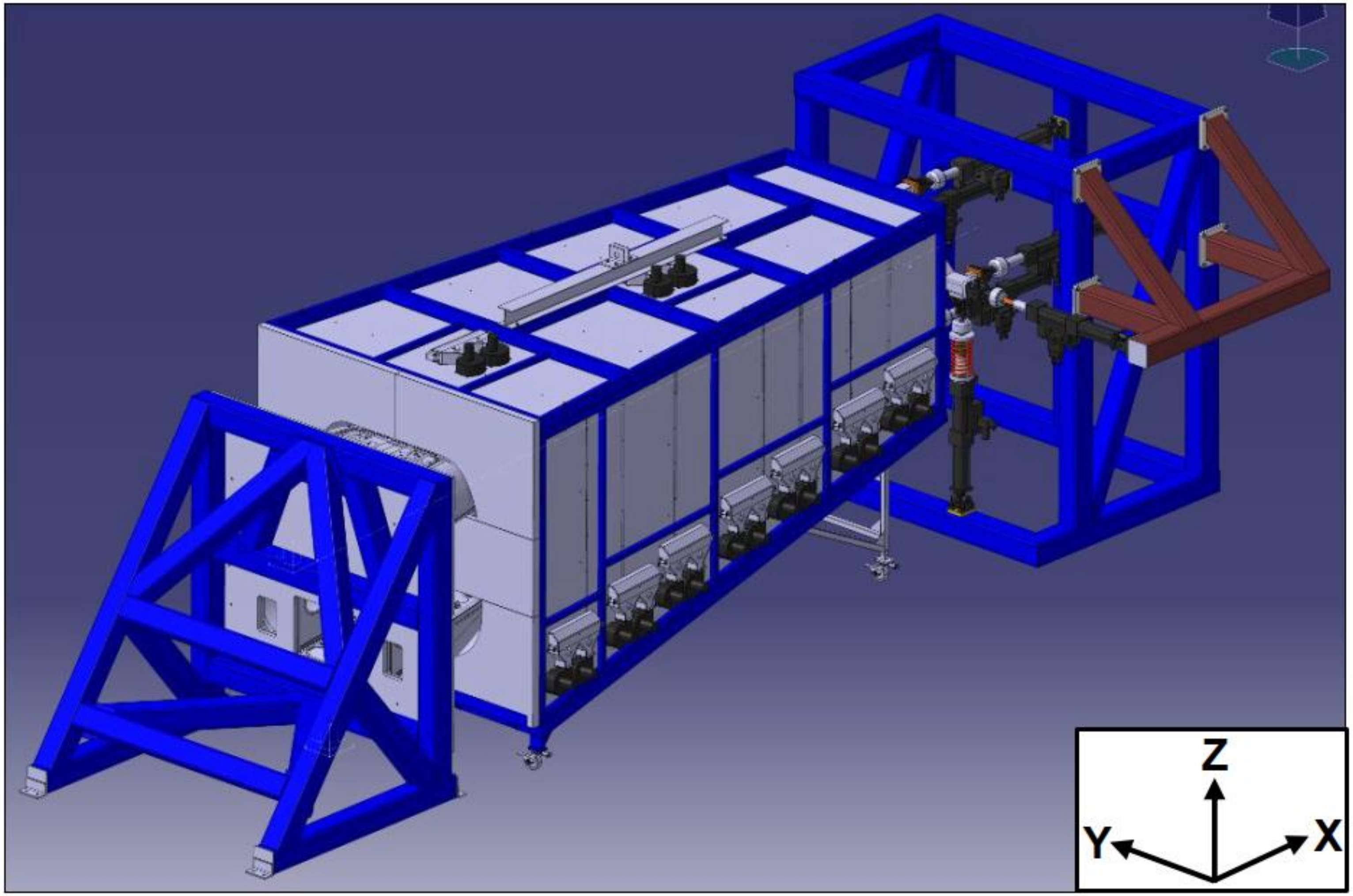
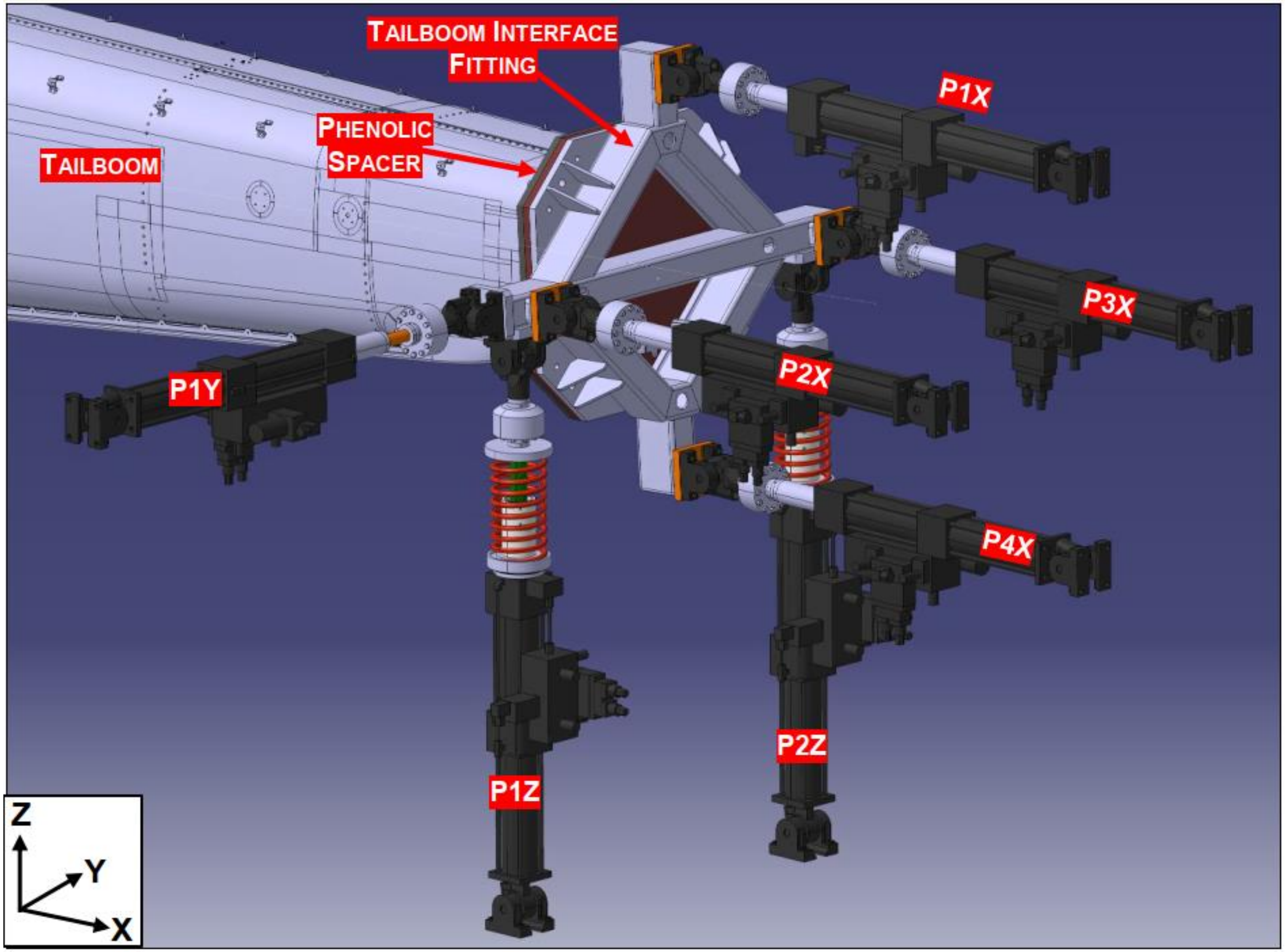


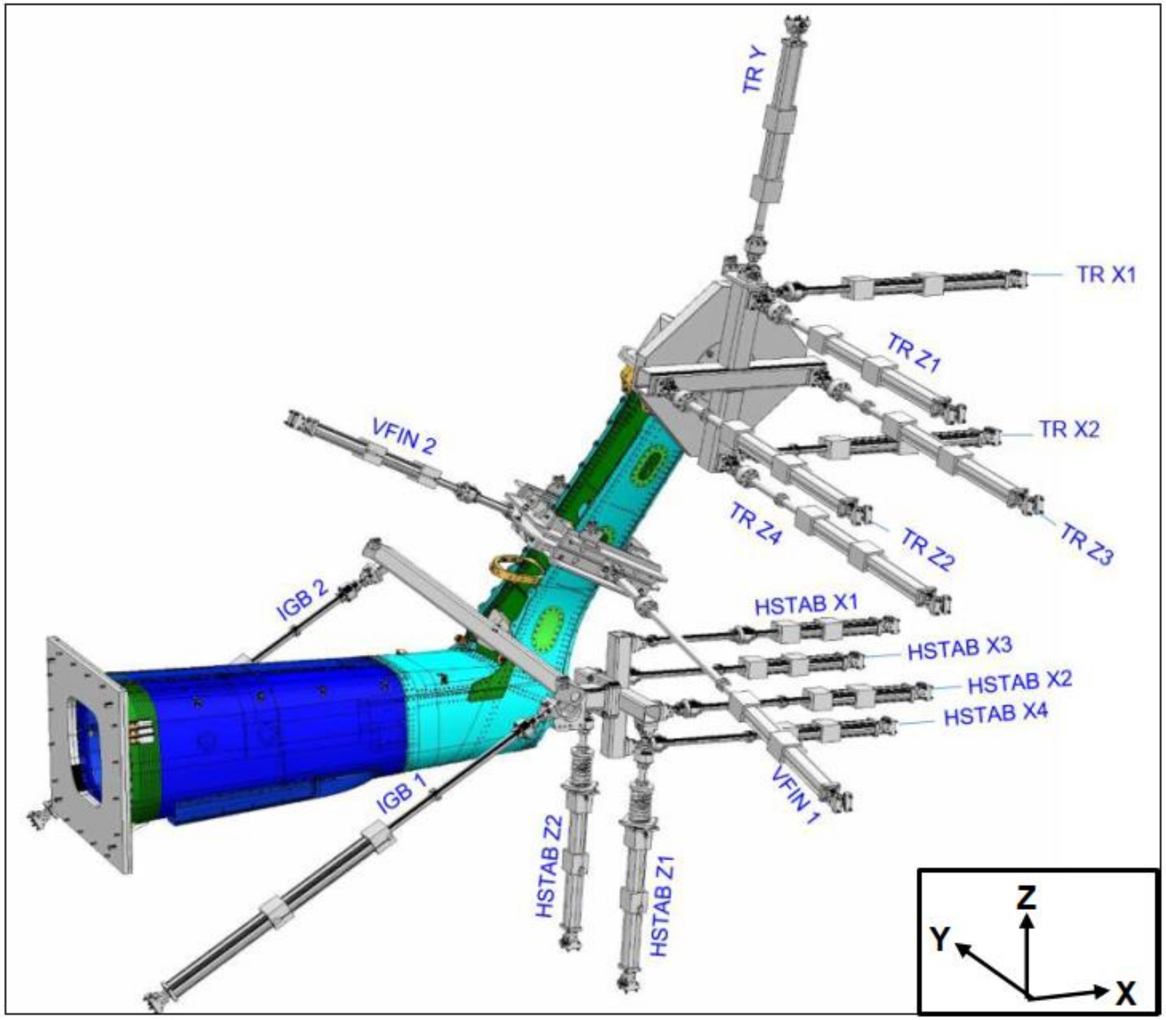
Test Details

Aft Fuselage / Tailboom



Test Details

Aft Tailboom / Vertical Fin



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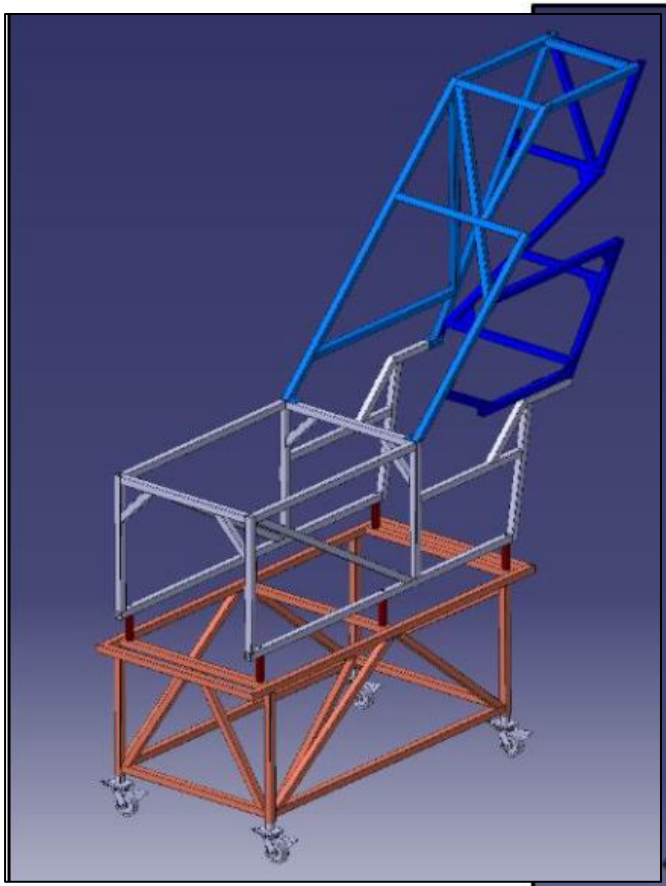

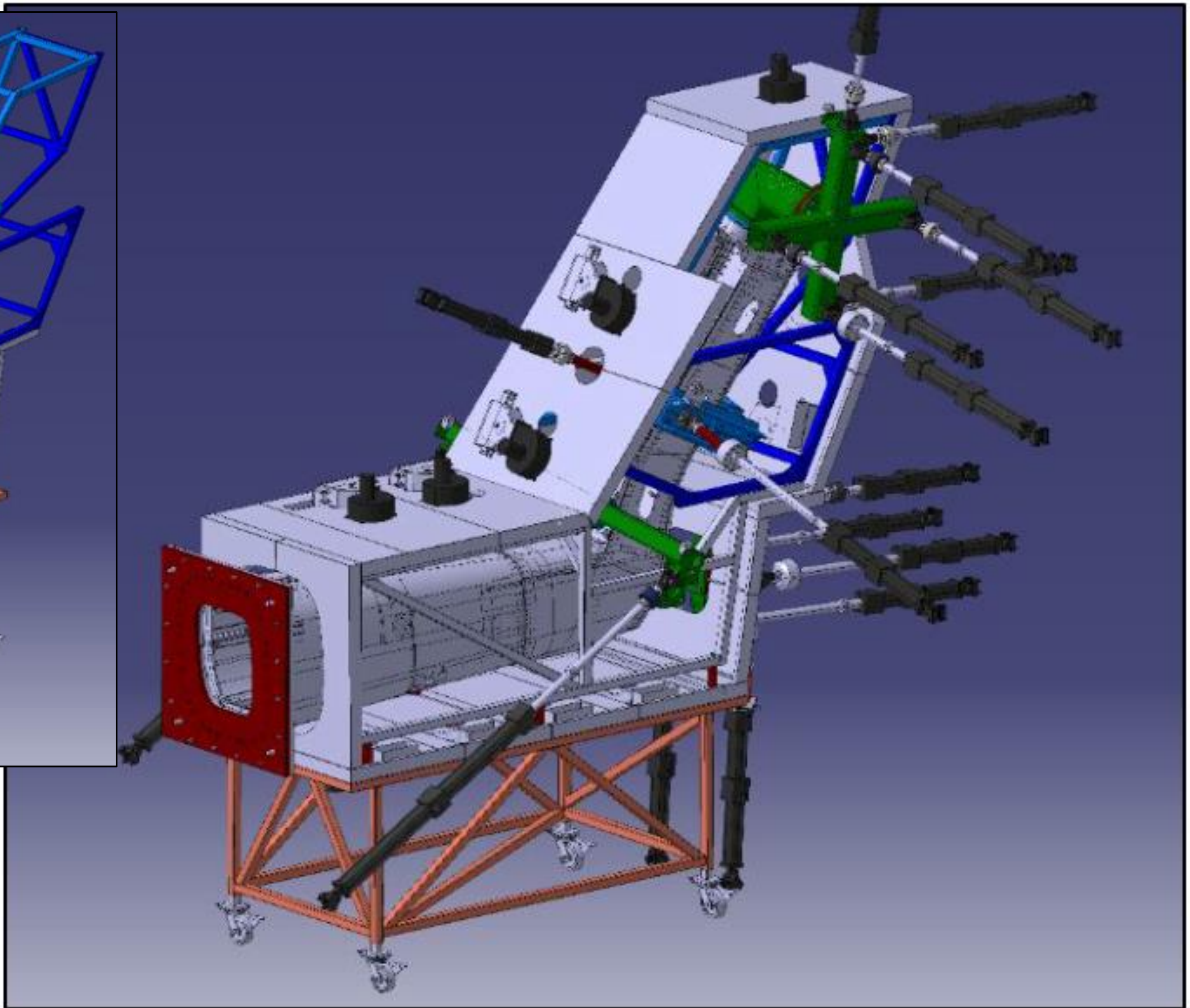

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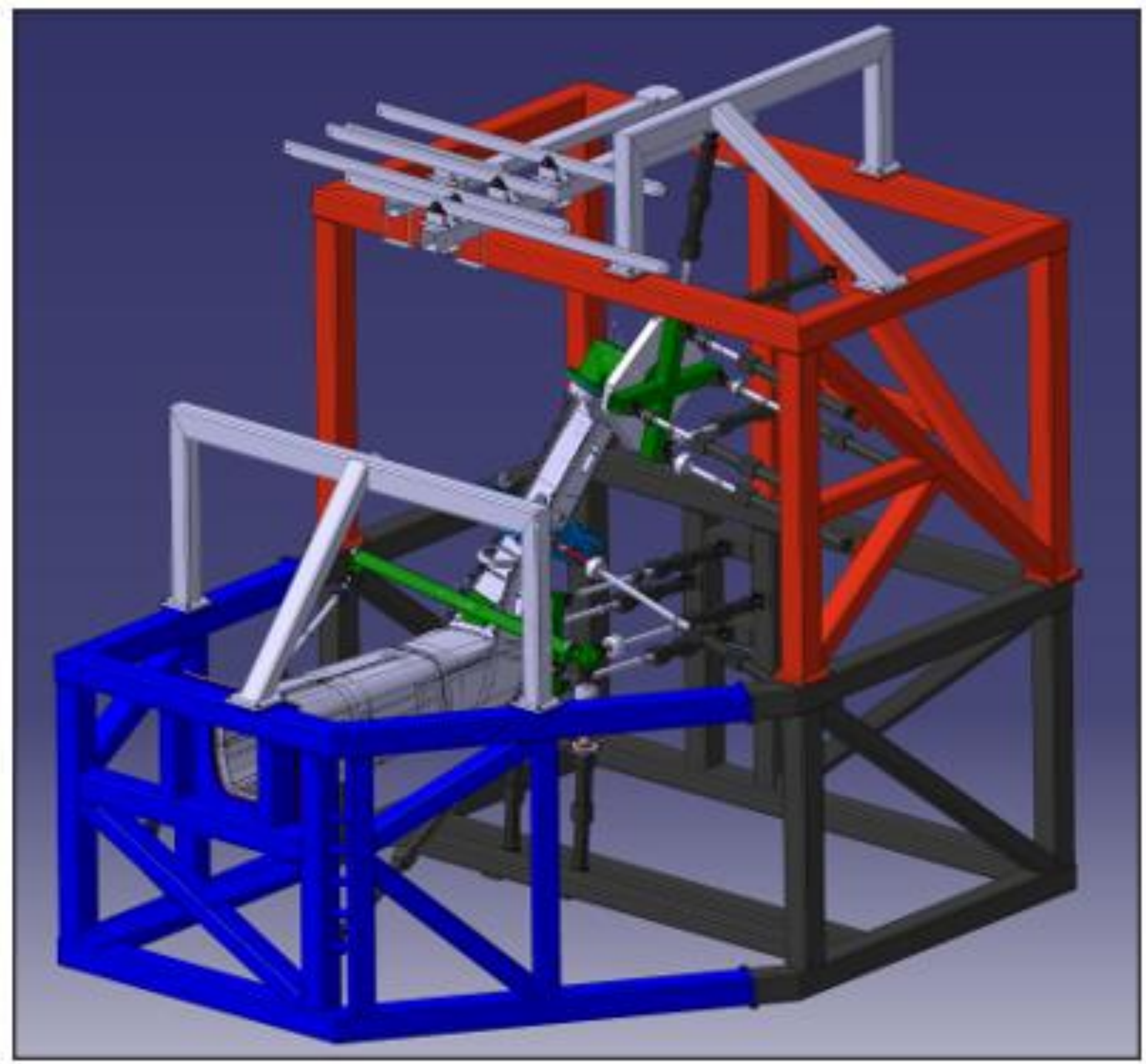


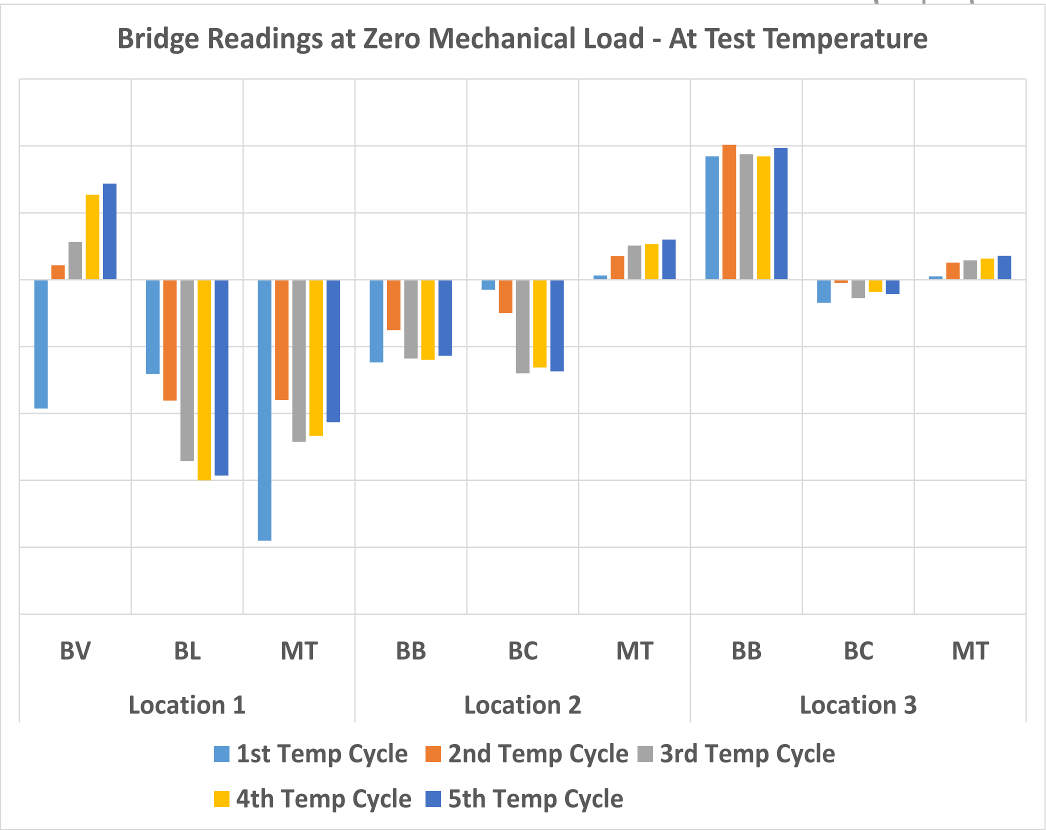
TEST CHALLENGES

Test Challenges
High Test Temperature Considerations

- **Commissioning**
  - Temperature soak times prior to loading defined in Test Plan, operationally verified via internal thermocouples
  - Heated chamber controller tuning to generate even temperature distribution (within a tolerance band of ±5.5 ºC)
  - Load evaluations conducted at room temperature followed by high-temperature
- **Instrumentation Temperature Compensation Plan**
  - Pre-calibrated and verified bending / shear bridges should have been self-temperature compensating
  - Quarter bridge strain gauges to be corrected post-test (“Golden Zero”)

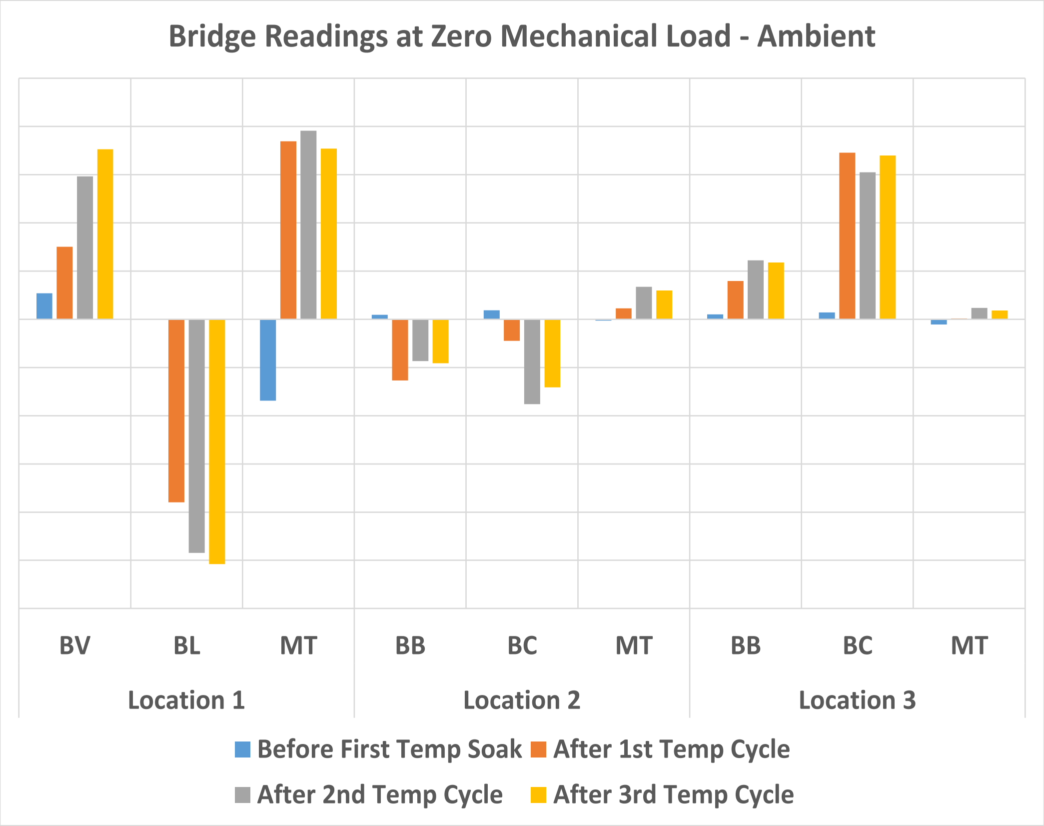
Test Challenges
High Test Temperature Considerations

- **Instrumentation Temperature Compensation Findings**
  - Quarter bridge strain gauge zero-g readings changed under temperature, as expected
  - Bending bridge readings changed under temperature, this was unexpected



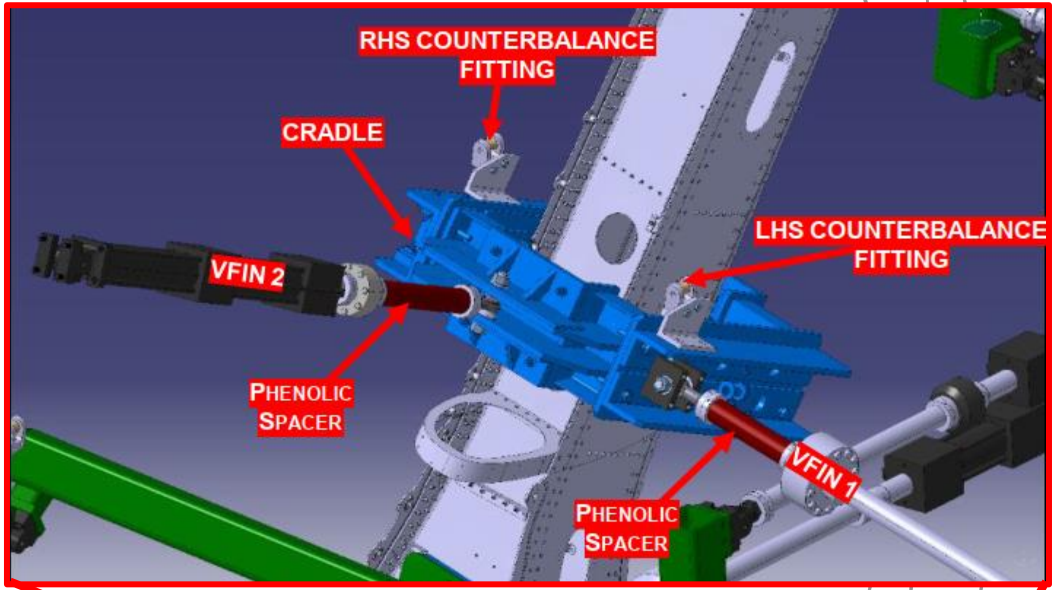
Test Challenges
High Test Temperature Considerations

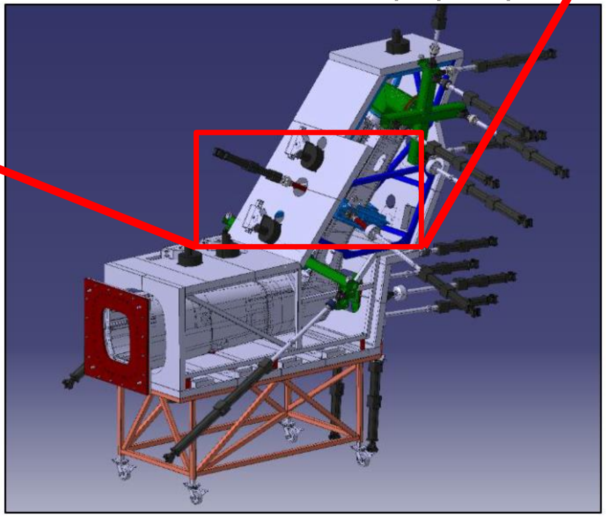
- **Instrumentation Temperature Compensation Findings**
  - Quarter bridge strain gauge zero-g readings changed under temperature, as expected
  - Bending bridge readings changed under temperature, this was unexpected
  - Change in bridge reading retained under return to ambient loading
  - Stabilization achieved after multiple, longer temperature soak cycles
  - Test schedule precluded disassembly and bridge recalibration, therefore, these were also compensated in-situ ("Golden Zero")



Test Challenges
High Test Temperature Considerations

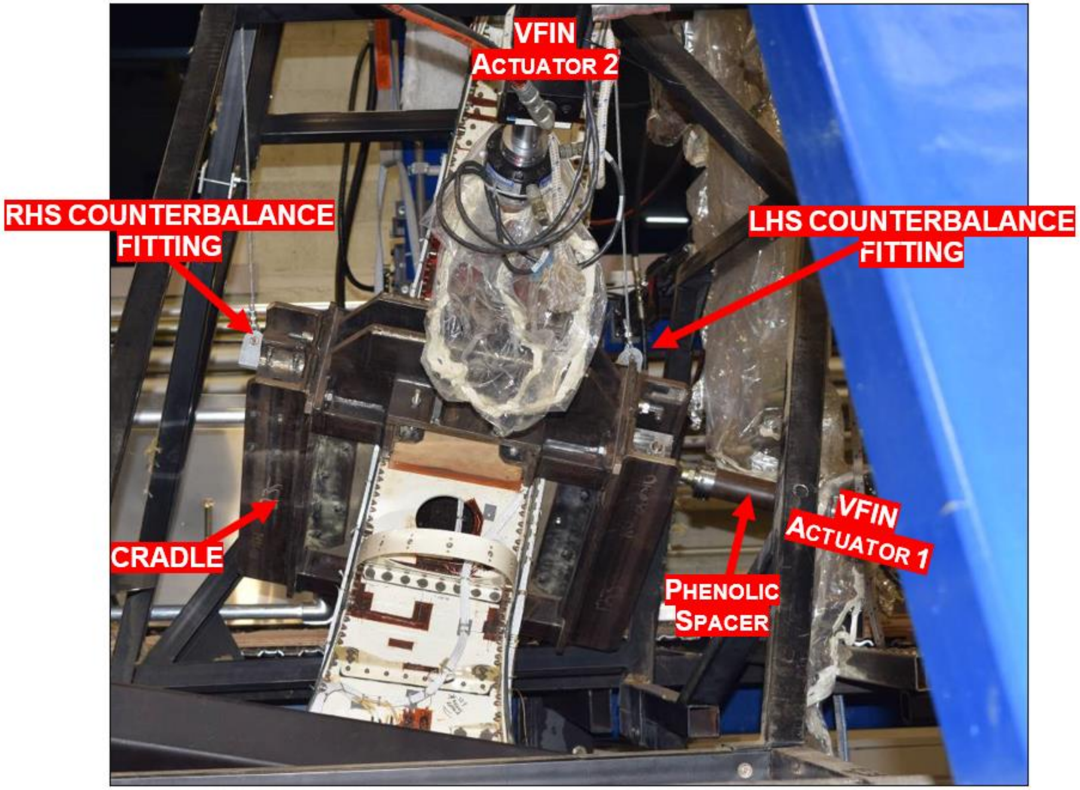
- **Vertical Fin Cradle Movement**
  - Vertical fin loaded via compression – compression cradle with elastomeric interface to skin
  - Compression friction fit needed
  - Cradle attachment torques validated during room temperature





Test Challenges
High Test Temperature Considerations

- **Vertical Fin Cradle Movement**
  - Vertical fin loaded via compression – compression cradle with elastomeric interface to skin
  - Compression friction fit needed
  - Cradle attachment torques validated during room temperature
  - Following thermal cycling, cradle position noted to have moved
  - Resolved by changing elastomer to lower CTE and increasing attachment torques to increase compression
  - Result was that cradle now moved excessively at room temperature – acceptable trade



THANK YOU

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