

Structural Analysis, Modeling, and Testing of Multi-Nut Joint for TriTruss Structure

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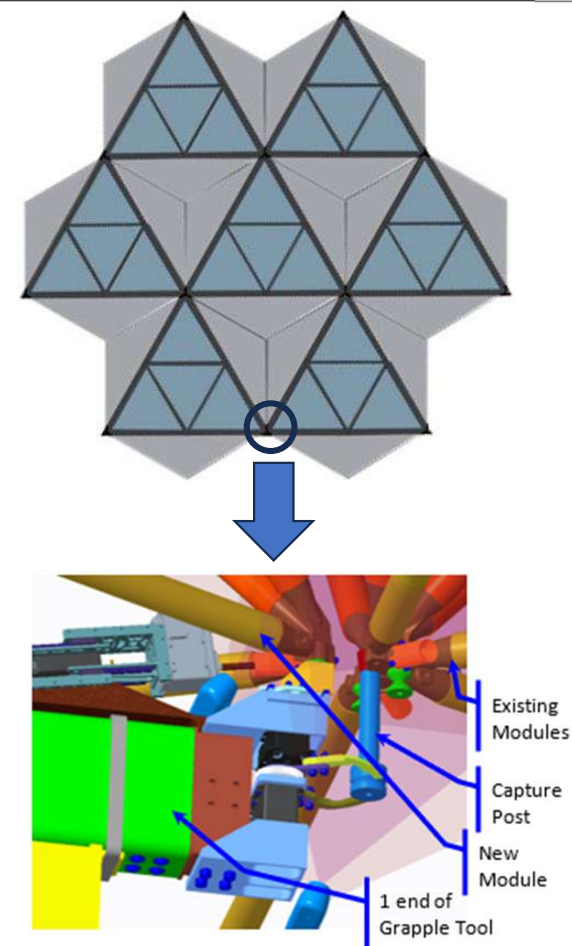
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 - TriTruss and Multi-nut
 - Objective of structural testing and analysis
- Multi-nut test and analysis
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- Summary

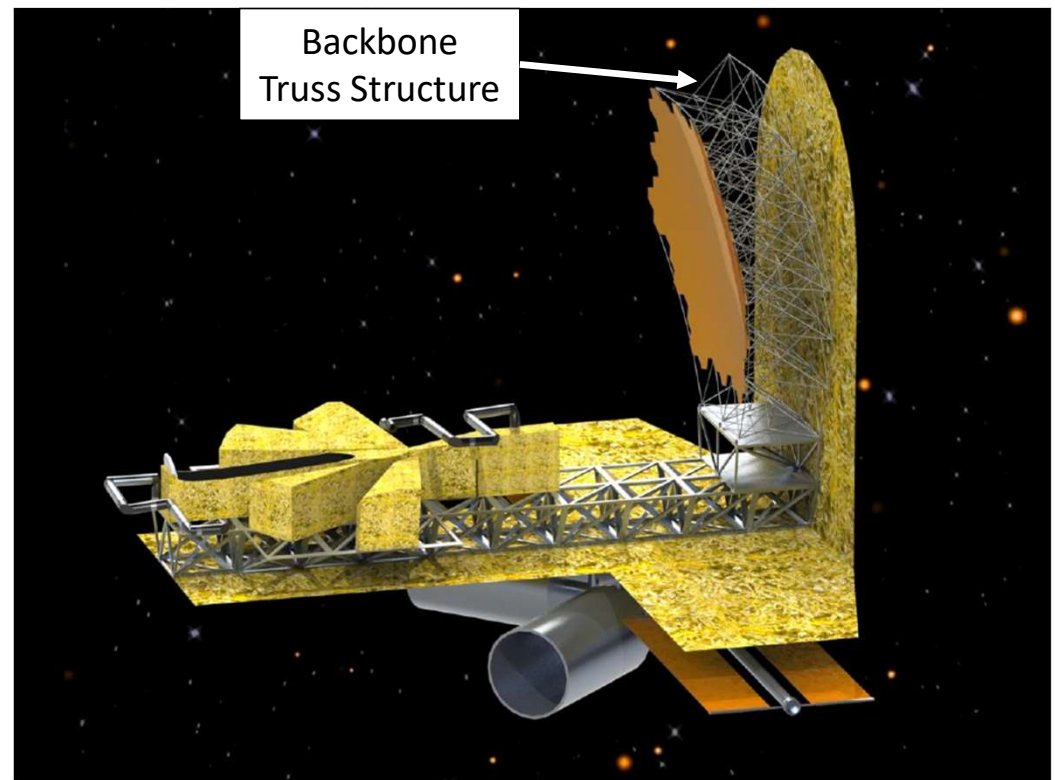




PASS Project Background

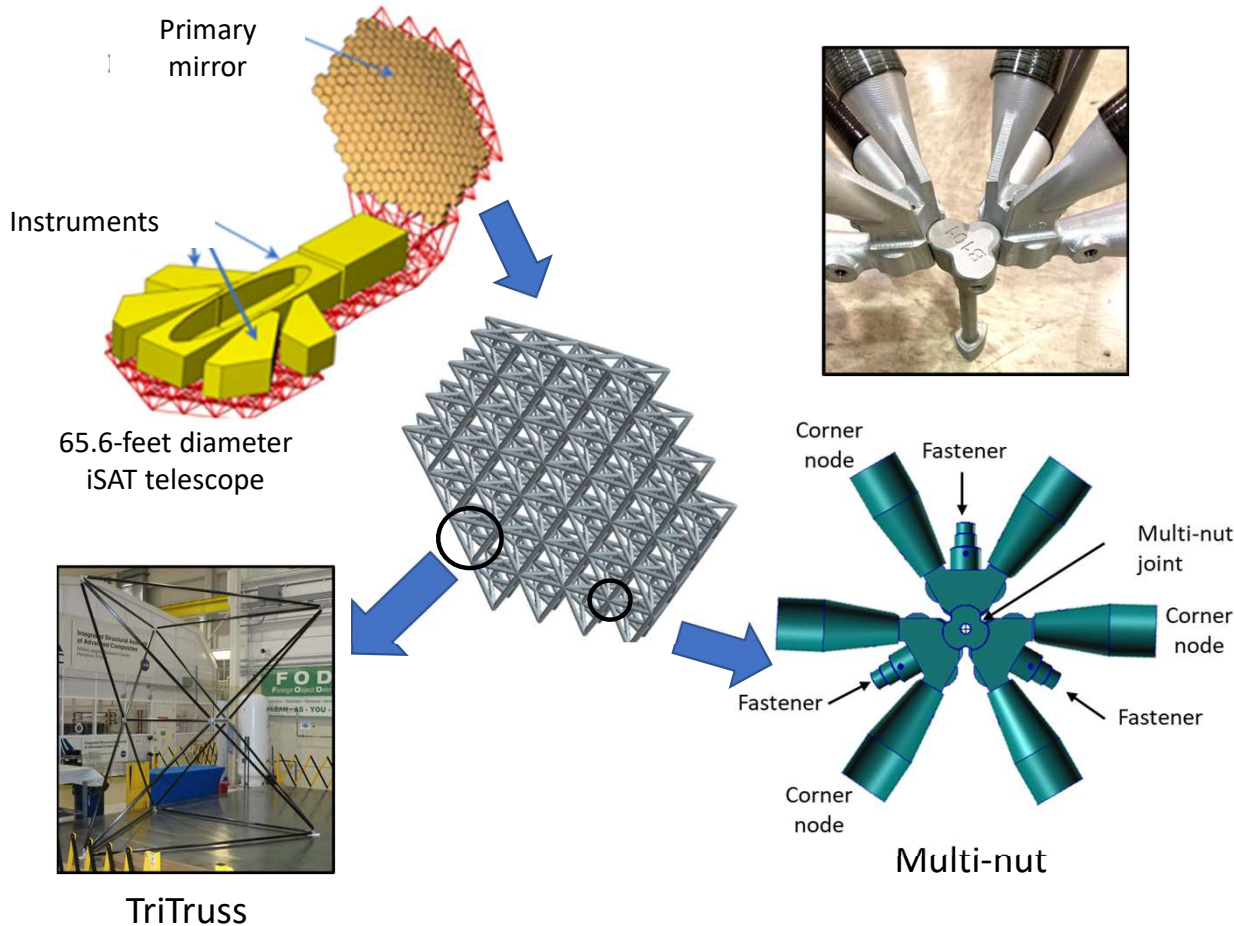


- NASA Precision Assembled Space Structure (PASS) project
 - Design reference mission: in-Space Assembled Telescope (iSAT)
- 2019 NASA iSAT study found that in-space assembly is likely the only way to achieve > 15-m aperture space telescope
- PASS project will perform ground demonstration of 20-m diameter backbone truss structure





TriTruss and Multi-nut



- The TriTrusses are made of carbon fiber composite tubes, connected to aluminum (6061-T6) corner nodes by epoxy
- The TriTrusses are connected via bolted connections at the multi-nuts
- The multi-nuts are threaded steel parts with a stem feature for drawing the parts together for alignment
- Three TriTrusses can be attached at each multi-nut
- Each node has a different multi-nut geometry, which is necessary for the global geometry of the doubly-curved surface

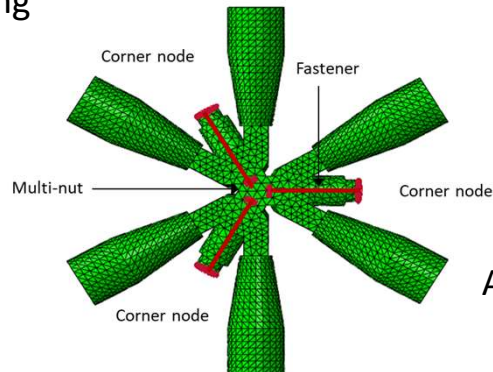
Precision Assembled Space Structure (PASS)



Objective of Structural Testing and Analysis

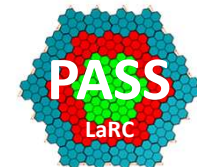


Testing

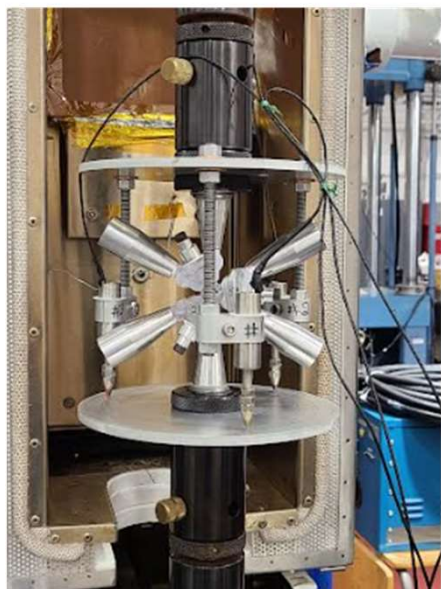


Analysis

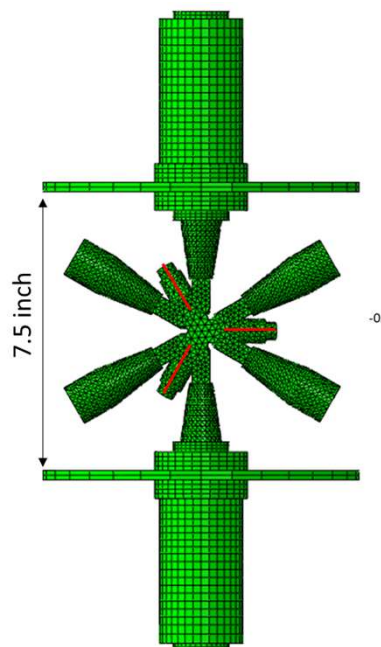
- Evaluate the multi-nut joint for axial and bending performance and provide reference data
- Determine the installation torque value of the attachment fastener to achieve linear load-displacement response in the operation load range
- Determine an axial stiffness (equivalent EA) and bending stiffness (equivalent EI) over the two corner nodes and multi-nut joint based on the axial test results
- Provide multi-nut joint performance results to validate Finite Element Model (FEM) of a multi-nut joint



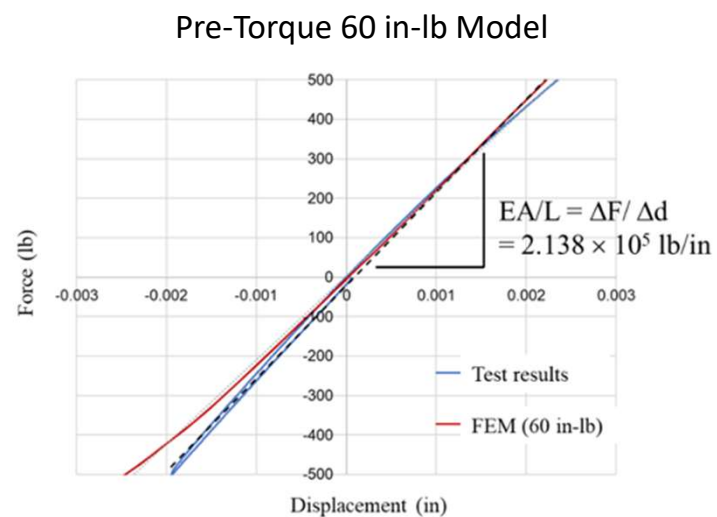
Multi-nut Axial Test and Analysis



Multi-nut axial test setup



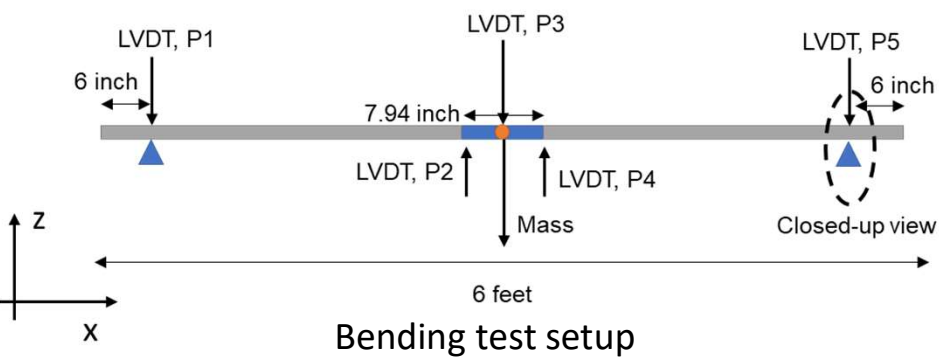
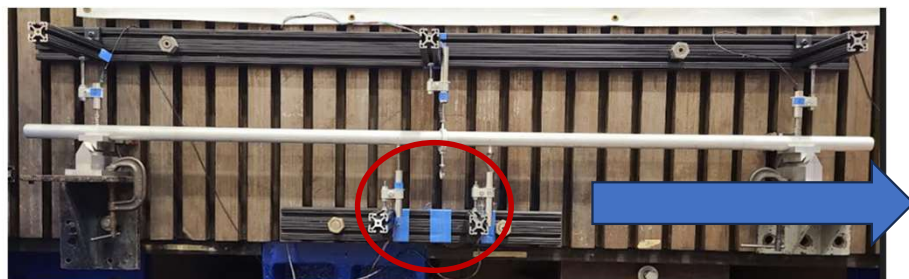
Finite element model



Test-analysis comparison results example

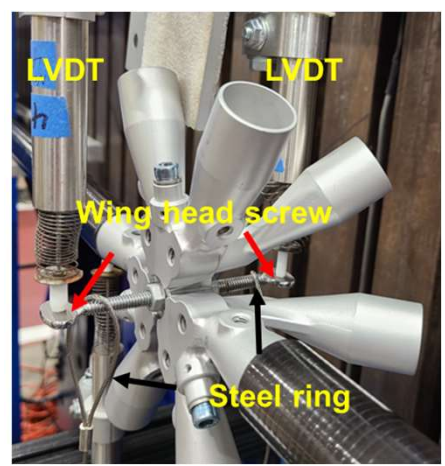
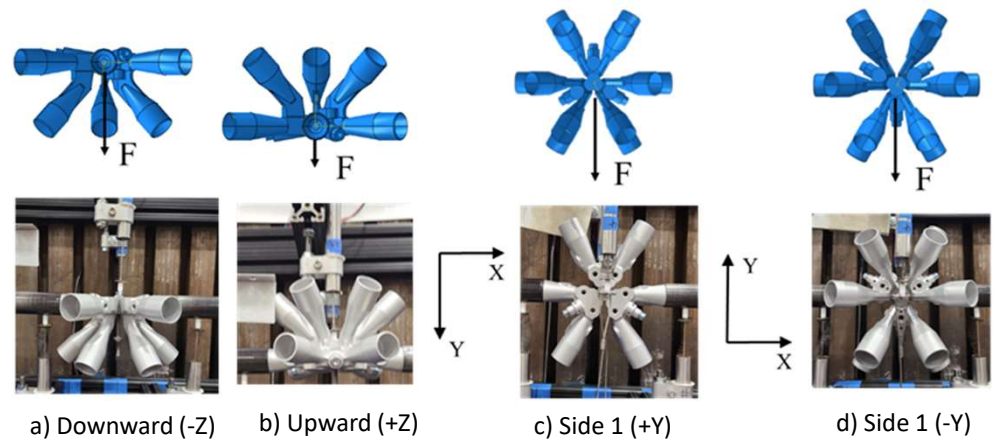


Multi-nut Joint Bending Test and Analysis



LVDT: Linear Variable
Differential Transformer

Precision Assembled Space Structure (PASS)

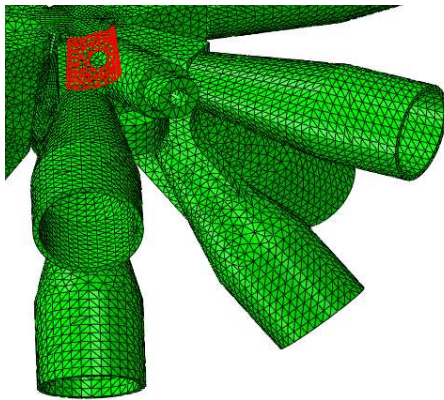


Multi-nut joint test section

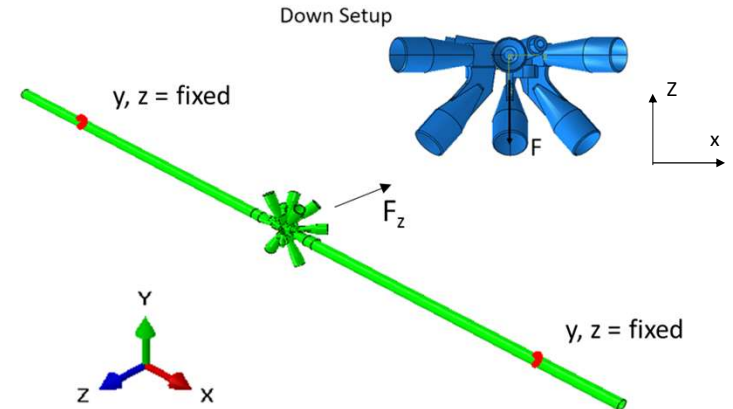
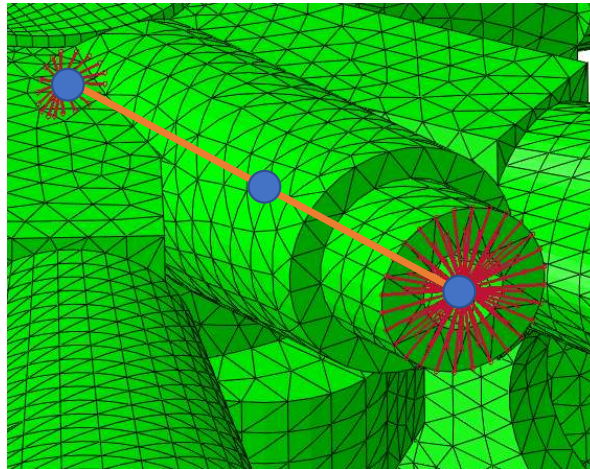


Finite Element Model of Bending Test Specimen

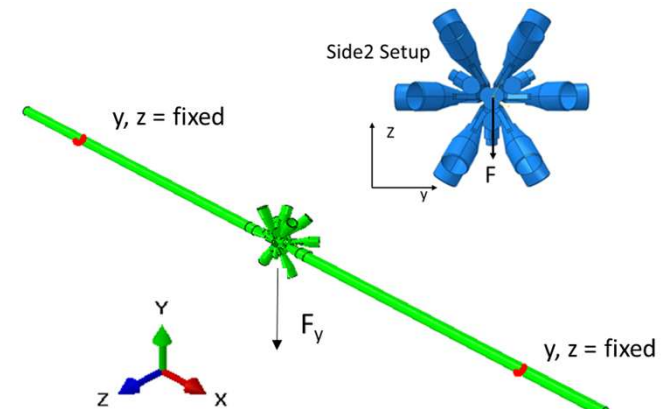
Contact between node and multi-nut



Beam element and kinematic coupling to model fastener



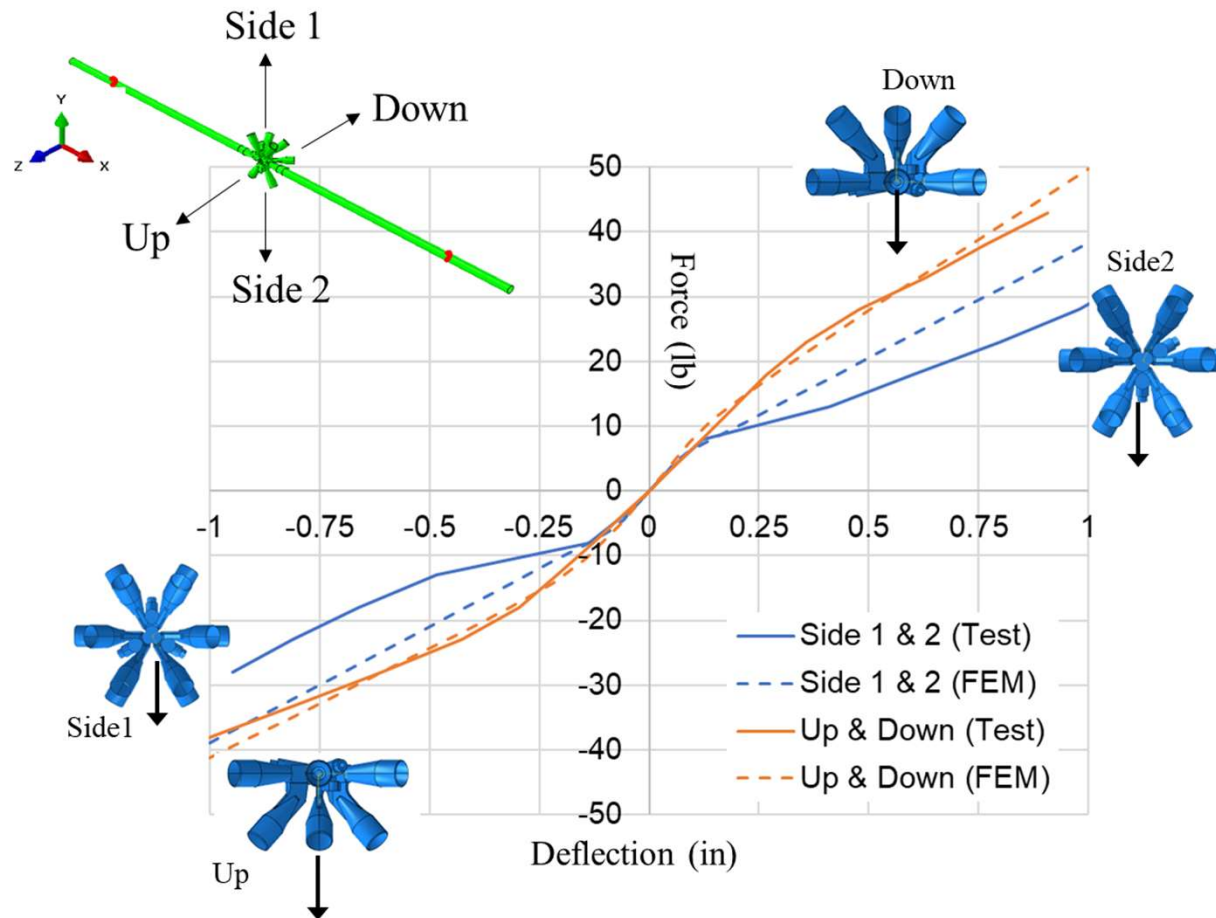
Downward condition (-Z)



Side 2 condition (-Y)



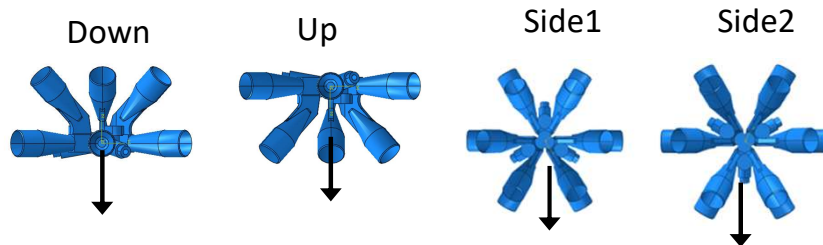
Test Results and Predicted Load-Deflection



Precision Assembled Space Structure (PASS)



Minimum Equivalent Bending Stiffness



$$EI_J = \left(\frac{L^3}{48} - \frac{a^3}{6} \right) \div \left(\frac{y}{P} - \frac{a^3}{6EI_s} \right)$$

L = 60 inch (Distance between support)

a = 26 inch (Distance from the support to the joint-node interface)

y = Center deflection

EI_s = Equivalent bending stiffness of the composite strut

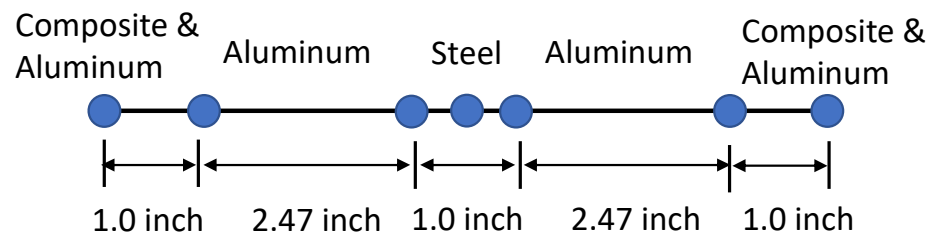
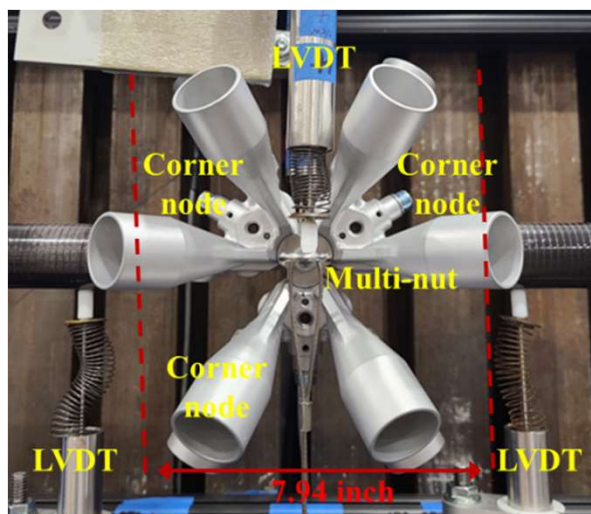
Minimum equivalent bending stiffness of multi-nut joint in different bending orientation based on test results.

Orientation	Bending Stiffness (lb-in ²)
Downward	7.303 x 10 ⁴
Upward	1.059 x 10 ⁴
Side 1	6.237 x 10 ⁴
Side 2	5.845 x 10 ⁴

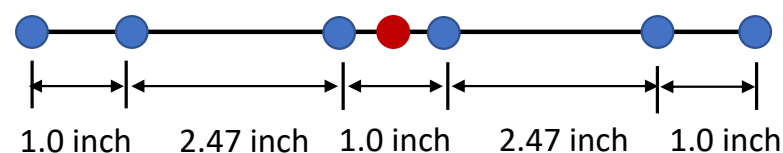
* Wu, K.C., "Characterization of the Bending Stiffness of Large Space Structure Joints," NASA TM-101565, May 1989.



General Beam Modeling Approach

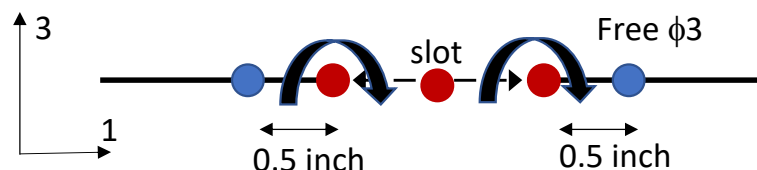


Type A. Circular beam definition with steel property



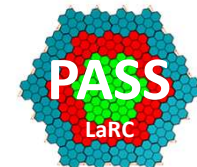
Type B. General beam definition with equivalent E, I, G and A

● Beam element node

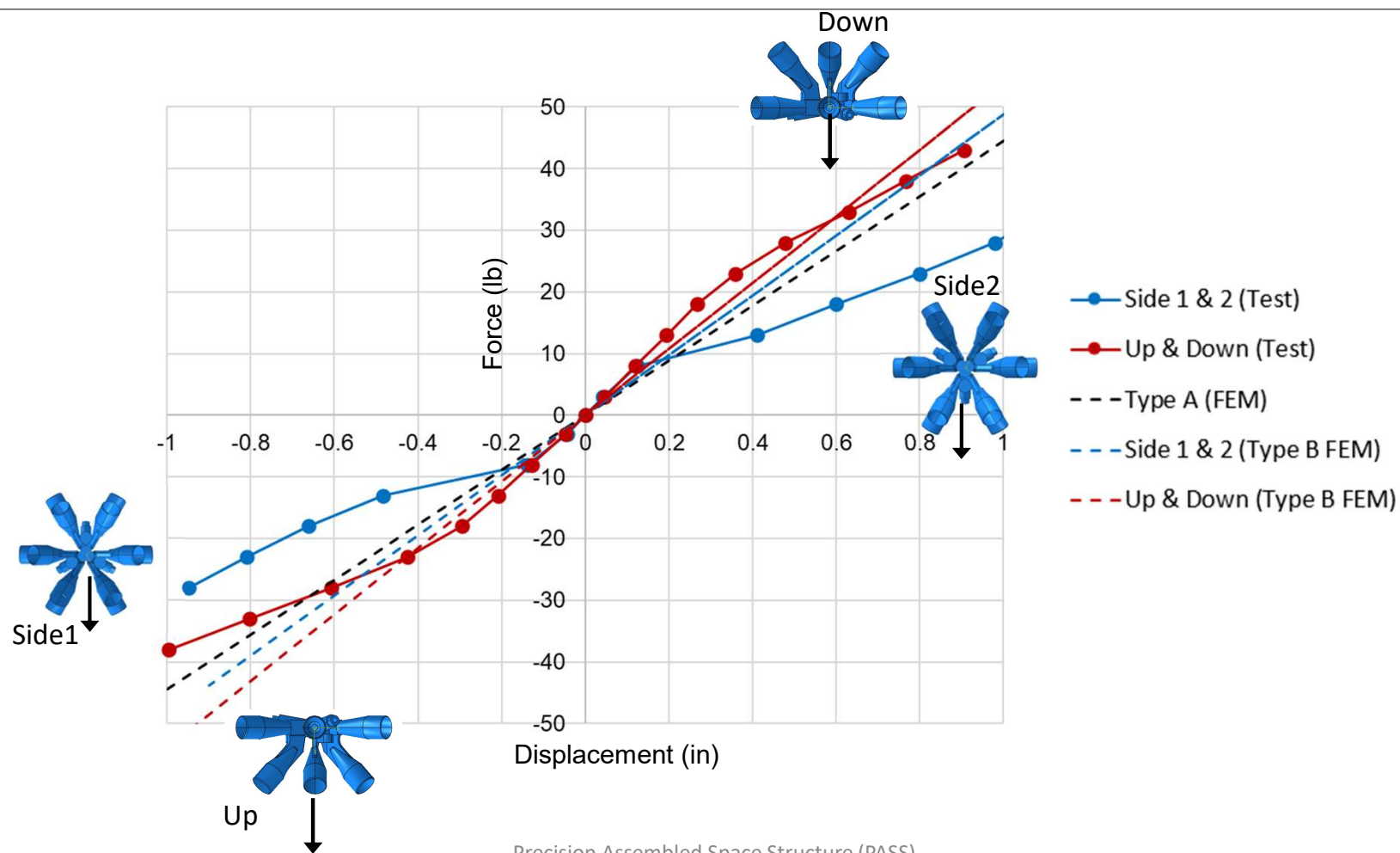


● 0.0001-inch-long connector element node

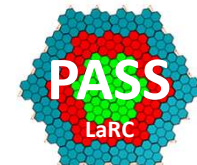
Type C. General beam with connector elements



Test Results and Predicted Load-Deflection

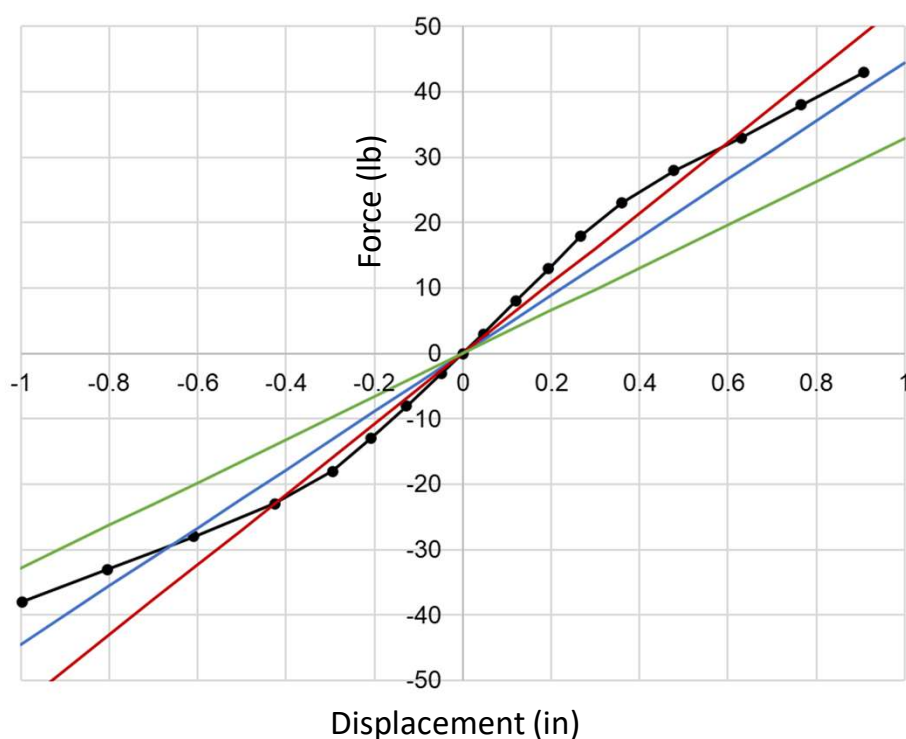


Precision Assembled Space Structure (PASS)

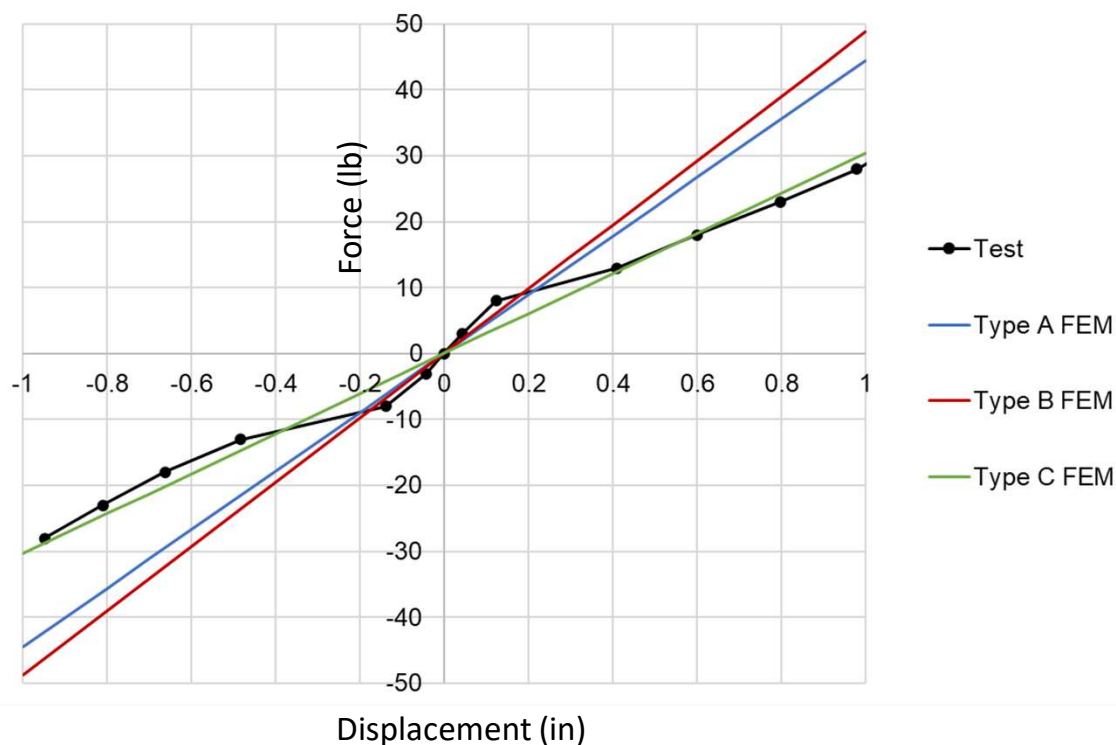


Test Results and Predicted Load-Deflection

Up and down orientations



Side 1 and 2 orientations



- Details of the tests and analyses for the multi-nut axial and bending tests are presented
- The axial tests provide insights into the preloaded torque values required for fastener installation
- Based on the test and analysis results, the joint's equivalent axial stiffness (EA) and the joint's equivalent bending stiffness (EI) were calculated
- FEMs, incorporating both general beam and connector elements, successfully predicted the load-deflection responses of the bending test specimens