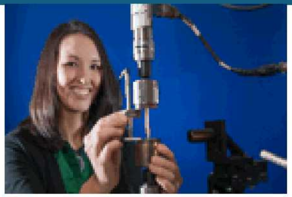
SAND2020-2192C

Technical Division Benchmark Structure for Dynamic Substructuring



PRESENTED BY

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IMAC 38, February 13, 2020

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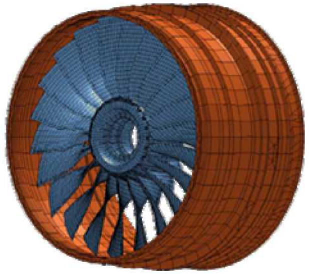
Motivation

- Often we are tasked with analyzing systems where one or more components are difficult to model analytically
  - Unknown material properties
  - Complicated geometry
  - Difficult to model
  - Produced and designed by an outside vendor
- The dynamics of these parts can have profound impact on the system level performance
- Experimental models are often the optimal choice for characterizing the impact of non-modeled hardware it's the system level response
- Experimental-analytical substructuring is a tool that can be used to combine the dynamics of an understood analytical system with the dynamics of a difficult to model experimental component

FEM Front Casing

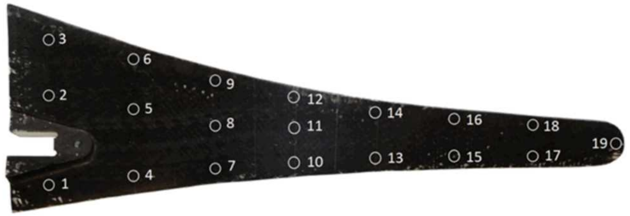


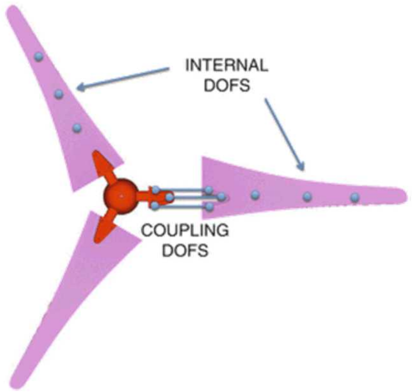
Experimental Model of Casing

Traditionally, these methods use linear models of each subcomponent. This work expands this using nonlinear models to describe subcomponent motion!

Background

- The substructuring community has a rich history which shares its roots with model reduction and structural modification
- Each year we see 4-5 sessions on substructuring at IMAC with various topics ranging including:
  - Component Mode Synthesis
  - Frequency Based Substructuring
  - Transfer Path Analysis
  - Model Reduction
  - Applications of Substructuring
  - Real-time Hybrid Substructuring and many more
- In 2012 the AmpAir 600 Wind Turbine was selected as a round-robin substructuring example that many universities and research groups have studied
- The Dynamic Substructuring focus group continued organizing IMAC sessions and in 2018 they officially became a technical division.





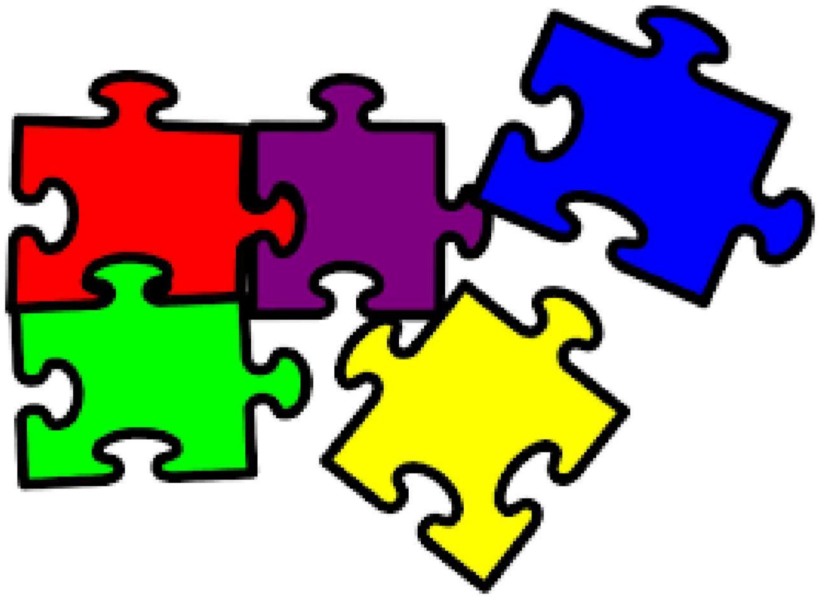
Round-Robin Challenge

- The Dynamic Substructuring – Technical Division has formed a team to begin creating a new round-robin challenge for researchers to utilize
- Sandia plans to manufacture the hardware and facilitate the delivery of hardware to interested universities/research groups. The goal is to have the hardware available for universities in the late-spring or early-summer of 2020
- Brainstorming the process and a challenge began in 2018 and continued in 2019
- The team refining the design and challenge includes:
  - Dan Roettgen – Sandia National Labs
  - Andrea Linderholt – Linnæus University
  - Pete Avitabile – University of Massachusetts Lowell
  - Julie Harvie – VIBES.technology
  - Steven Klassen - Technical University of Munich
  - Garret Lopp – Sandia National Labs
  - Jim DeClerck – Michigan Technical University

Updated Schedule	
Down Select Design	2019
Manufacture Hardware	November 2019 - March 2020
Webinar of SNL Testing Results on Round-Robin Challenge	April 13th 2020
Hardware Available for Checkout	May 1st 2020

Desired Structure Qualities

- To develop a structure that suits everyone's needs the team assembled a list of desired qualities that the round-robin challenge structure should have:
  - Interfaces challenging and suited for both FBS and CMS techniques
  - Simpler system than the Ampair with more similar dynamics between substructures
  - Potential for future circular transfer paths
  - Repeatability designed into the interfaces
  - Nonlinear dynamics due to joints in the structure should be minimized
  - Something that is easy to manufacture and transport
  - Structure that is simple to test

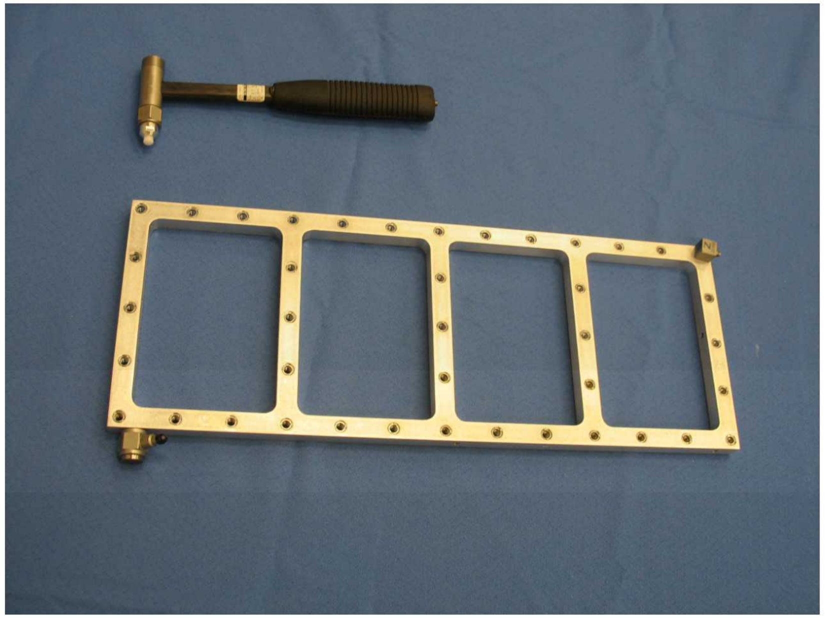


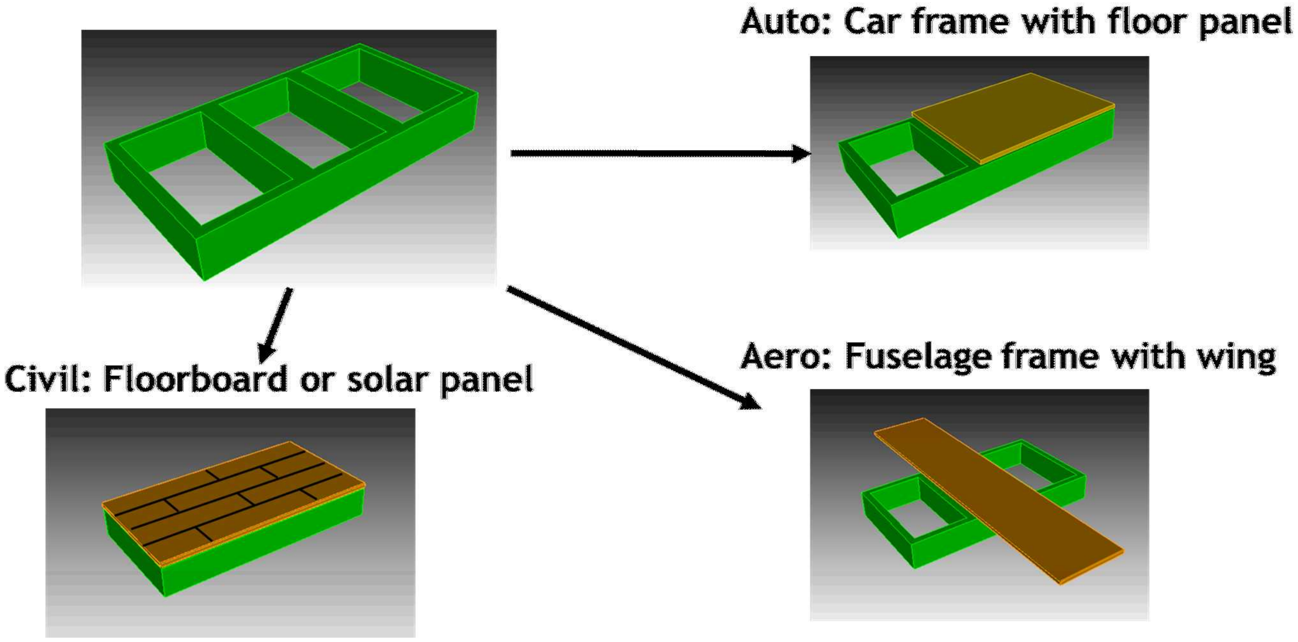
Experimental Substructure (Four-unit frame)

- Team developed design for a “four-unit” frame

Key features

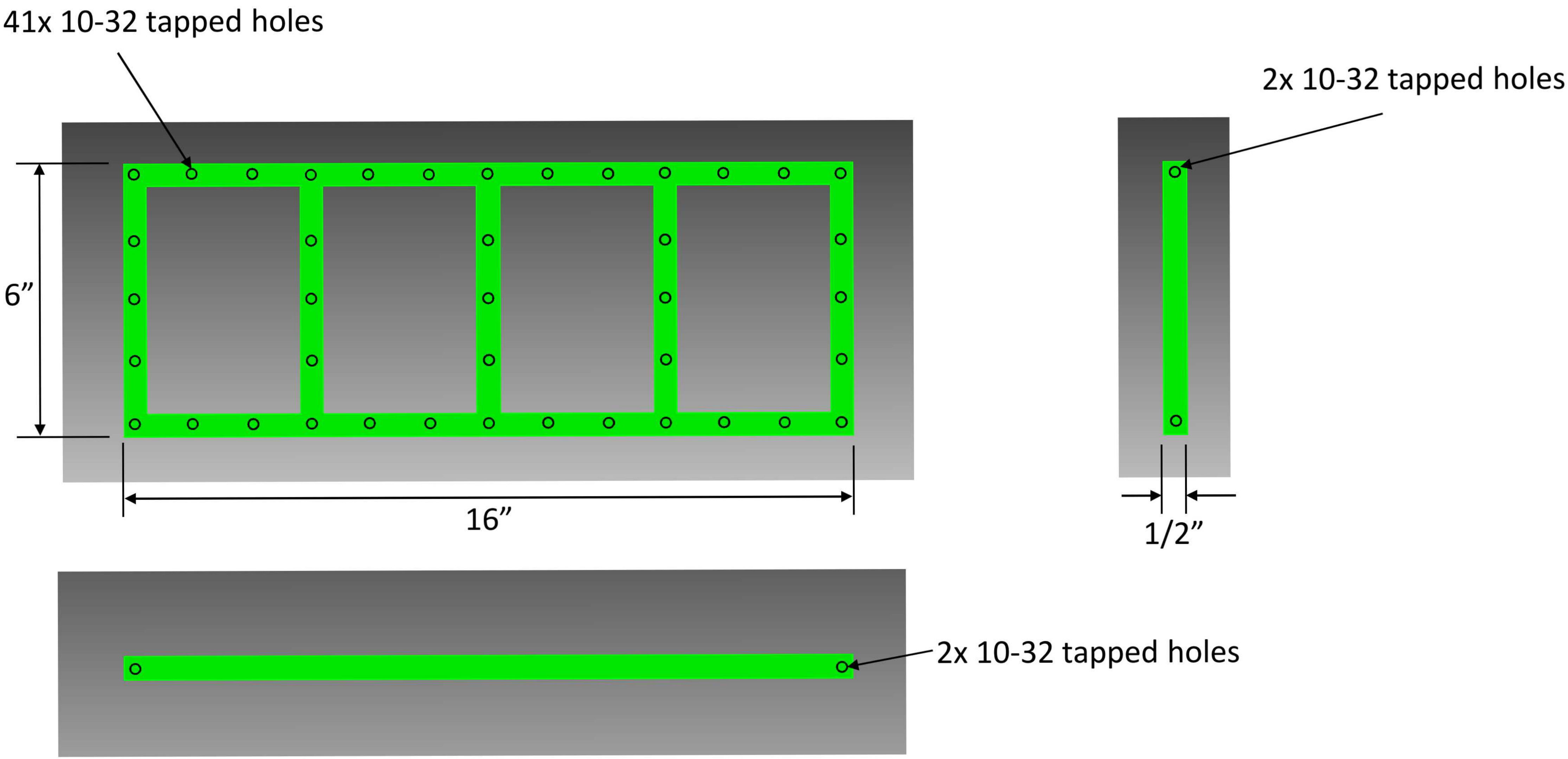
- Manufactured from one piece of metal of stock
- Subcomponent and shaker attachment points machined into frame
- Adaptable to many types of studies
- Possible circular/recursive transfer path
- Large enough to minimize error due to mass loading



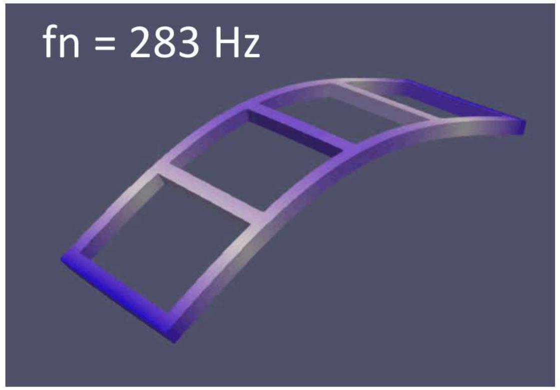


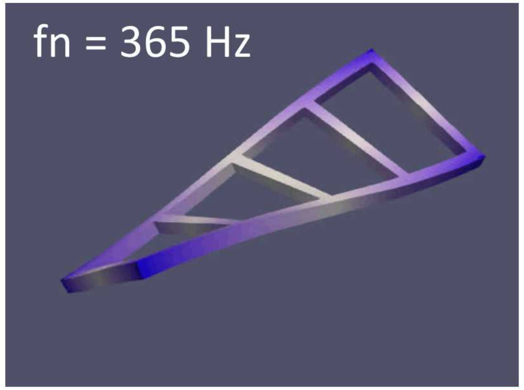
Shown is 3-unit frame (final design has 4 units)

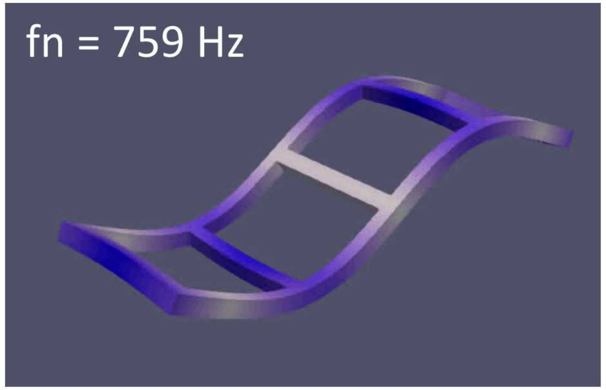
Frame Design (Four-unit frame)

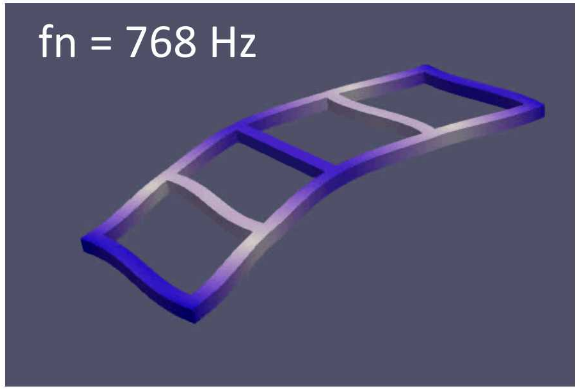


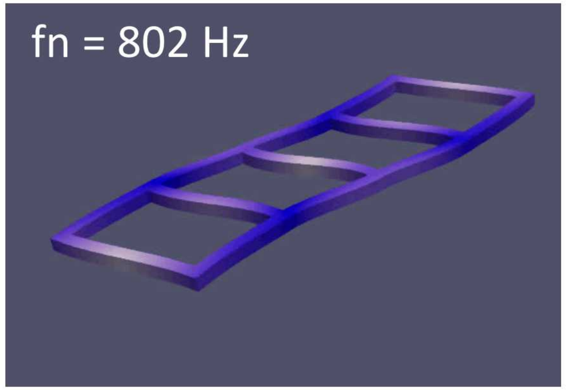
Four-Unit Frame dimensions:
L x W x H = 16 in x 6 in x 0.5 in with 0.5 in wall thickness

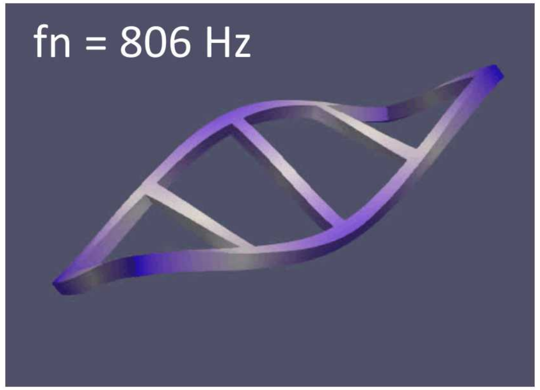


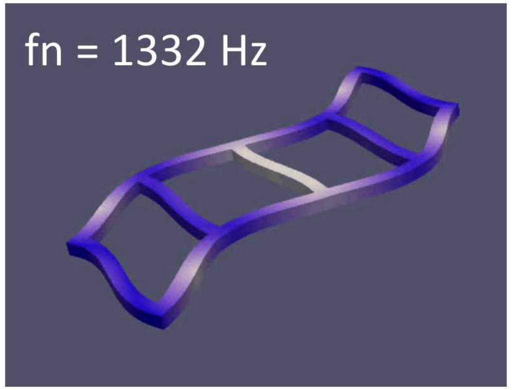


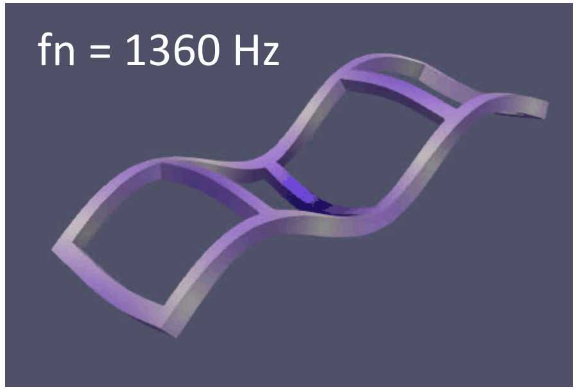




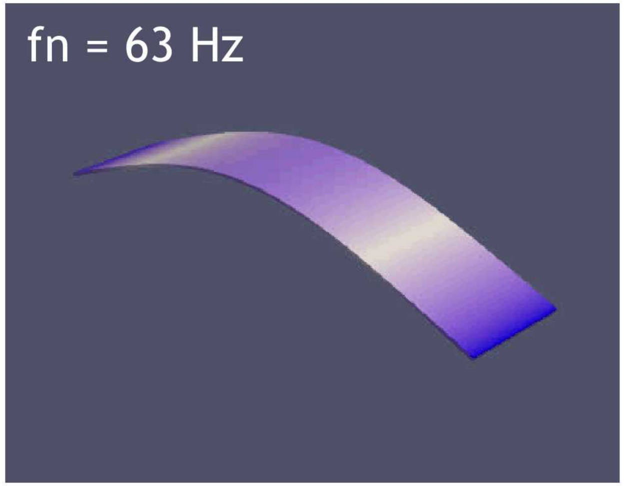


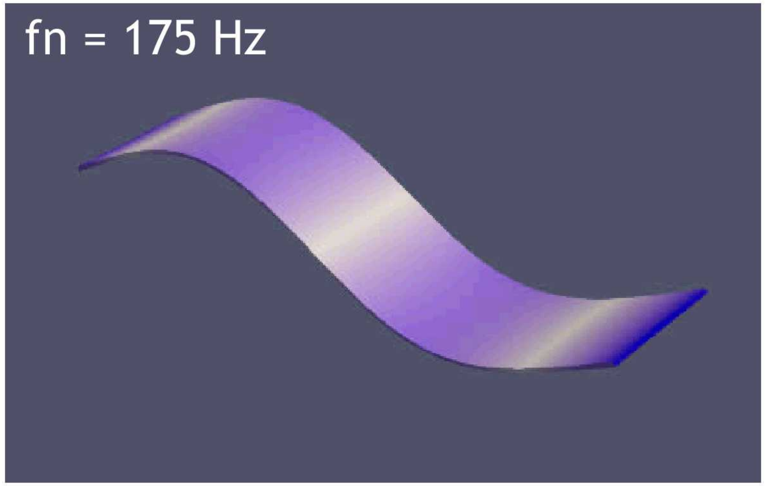


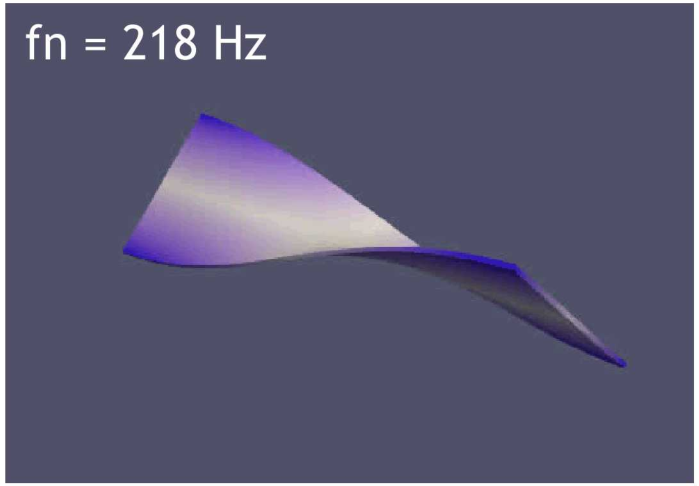


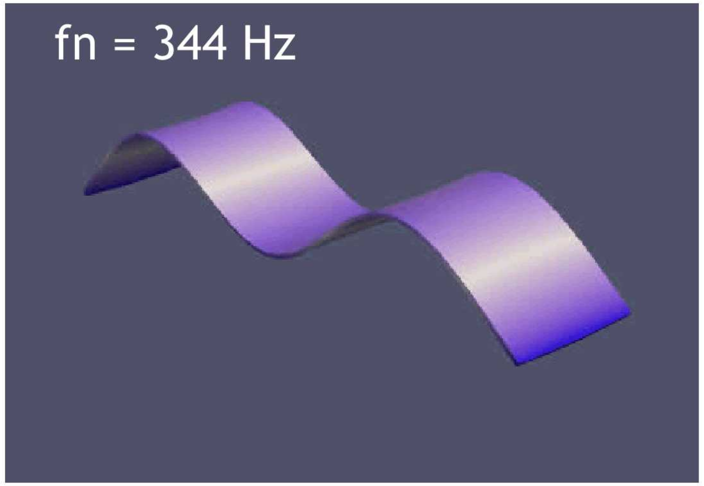


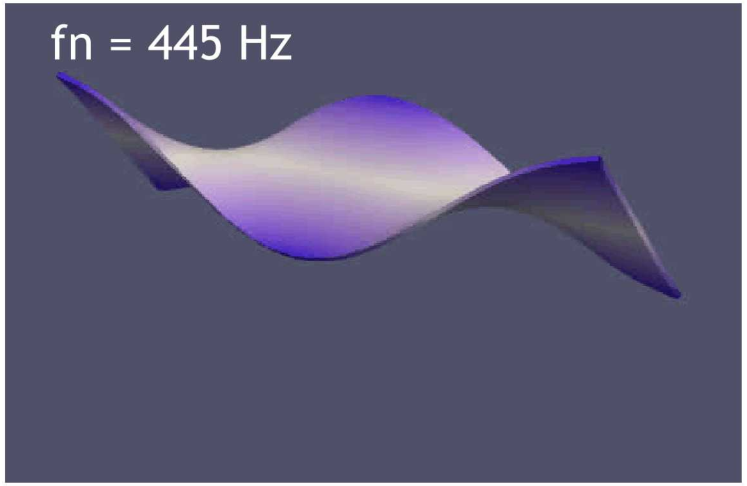
Plank/Wing dimensions:
L x W x H = 22 in x 4.375 in x 0.125 in

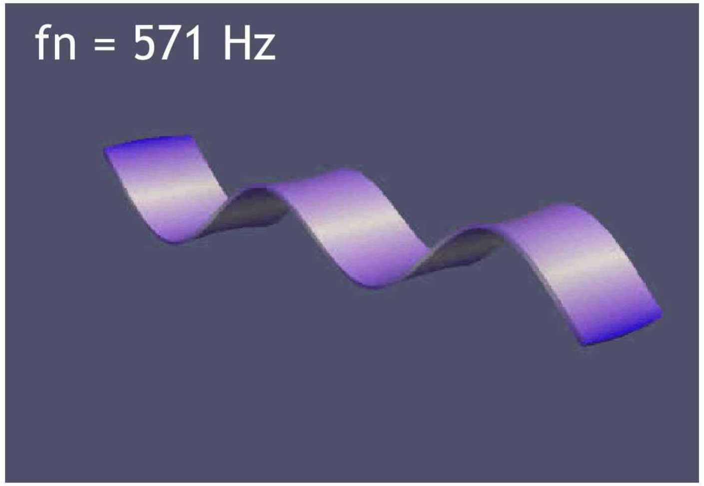




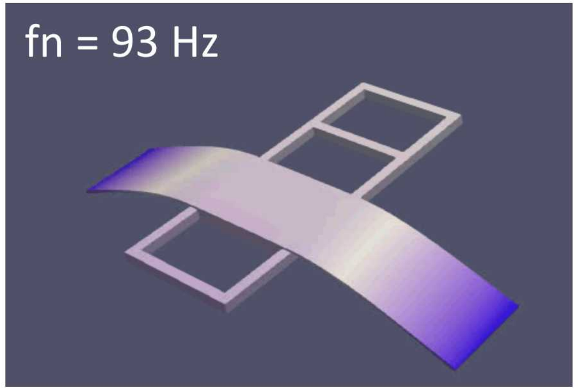


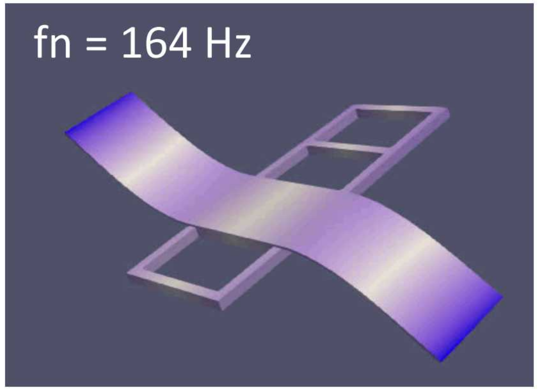


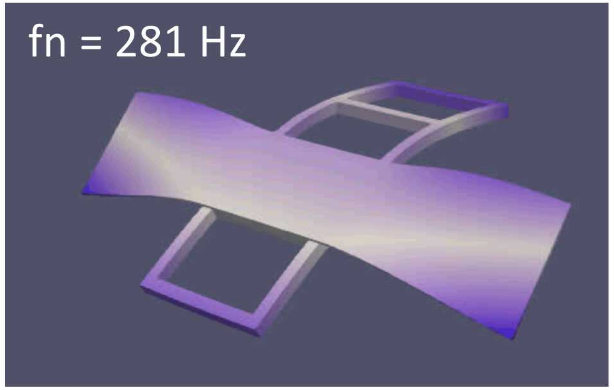


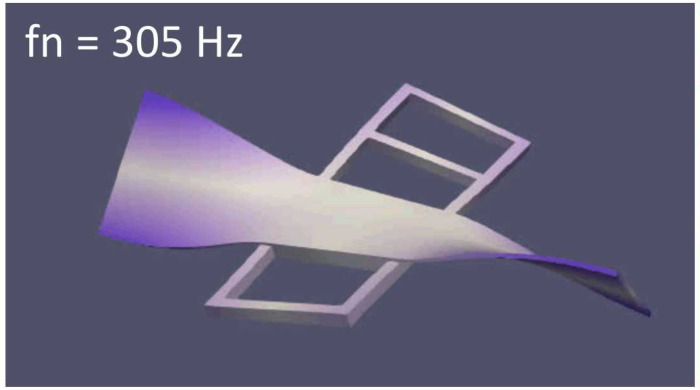


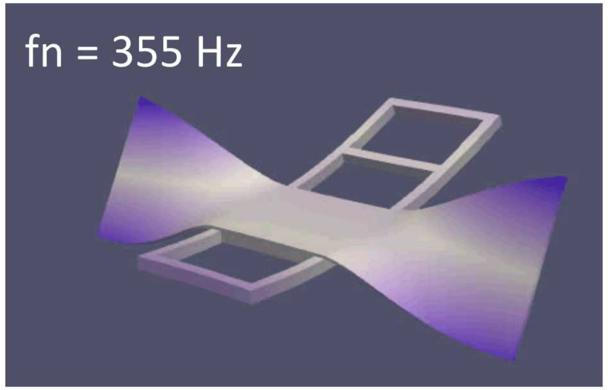
Assembly Modes

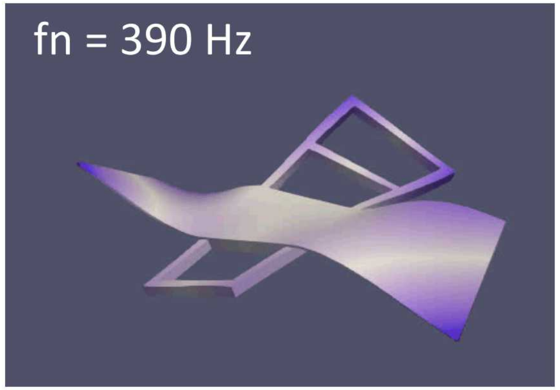


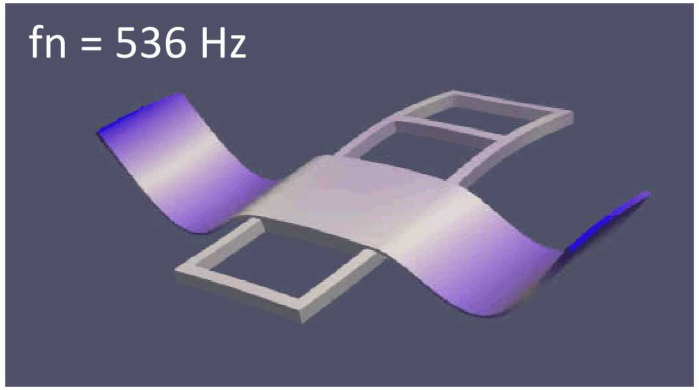


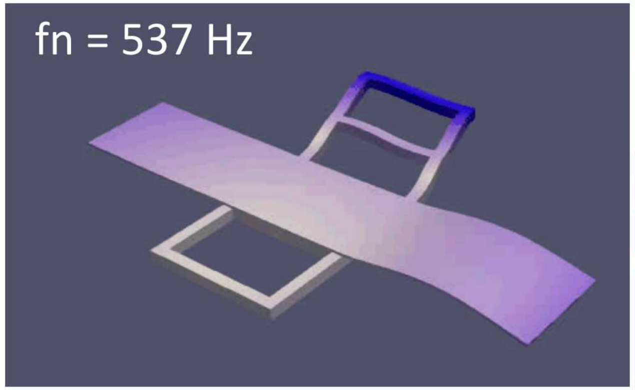






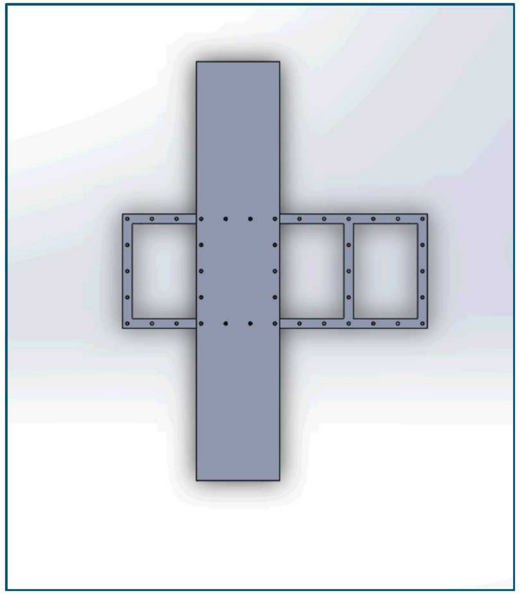




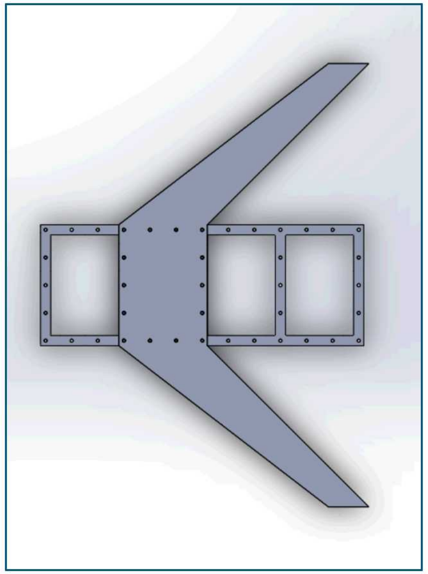


Substructuring Round-Robin Procedure

- Participants will be provided:
  - Hardware of the frame, rectangular wing, and necessary fasteners
  - Assembly Procedure
  - FEM Models of the Rectangular Wing and Swept Wing
- Researchers can demonstrate their substructuring techniques using the rectangular wing hardware then use the FEM model of the Swept Wing to estimate the system response of the modified system
- System can be tested with connection at just corner holes, or all 14 holes



(1) Original Design (Frame and Rectangular Wing)



(2) Modified Design (Frame and Swept Wing)

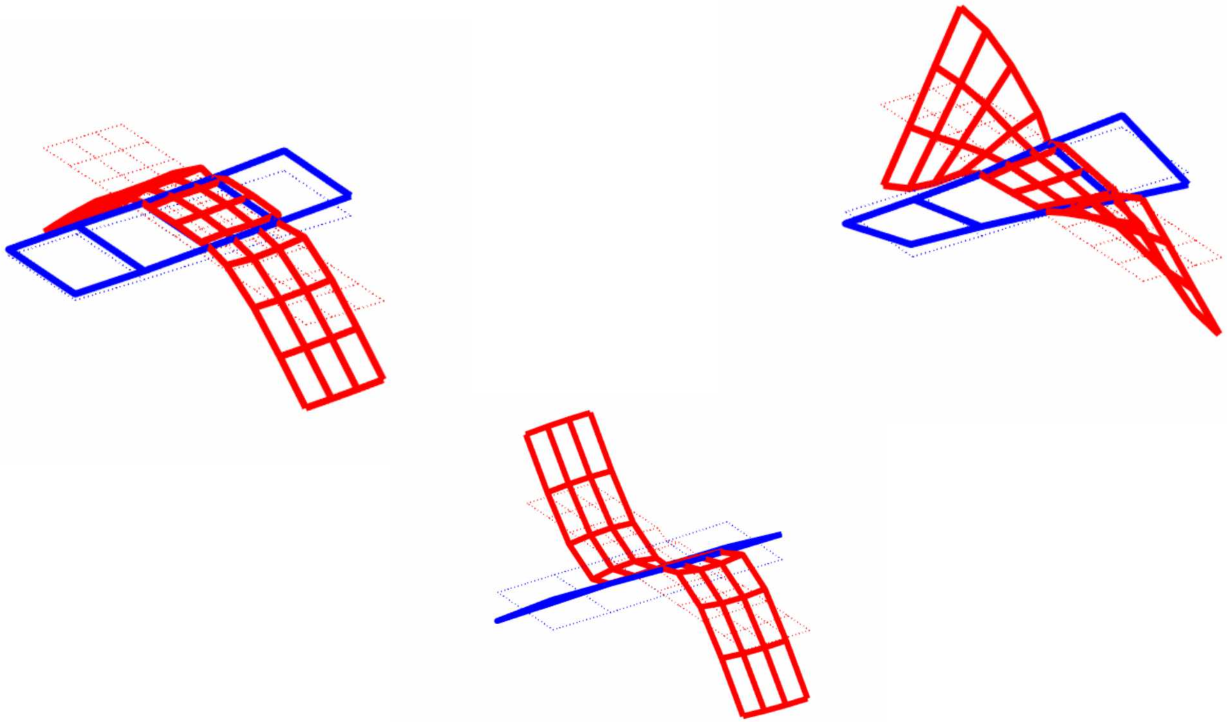
What is the "truth" answer?

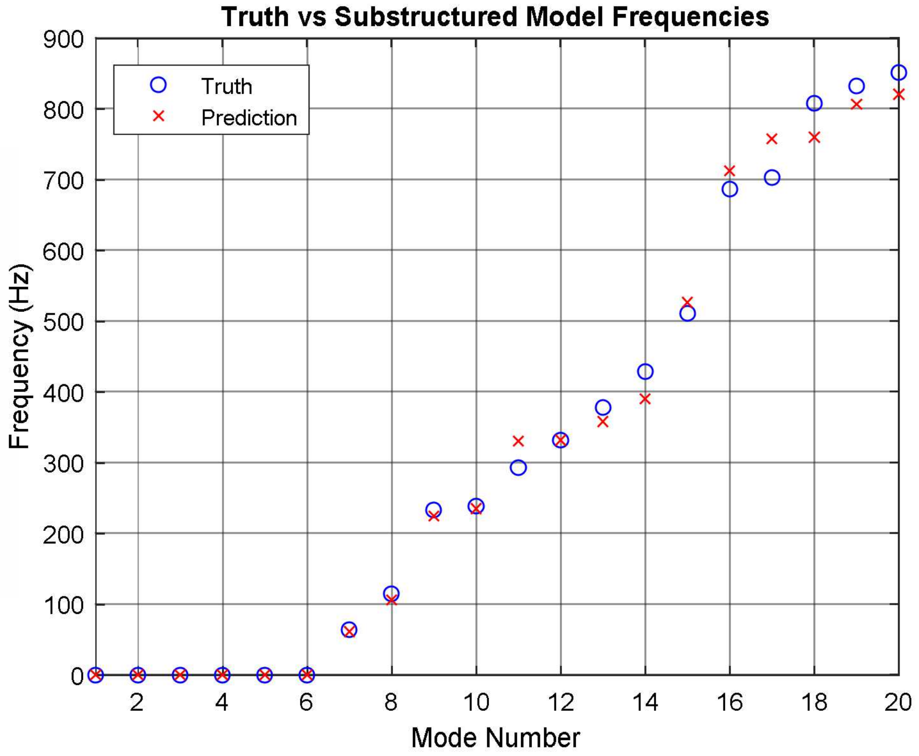
- Truth depends on a lot of factors:
  - Assembly procedure
  - Frequency range of interest
  - Linearity of joints
  - And other factors…
- The goal of this round-robin isn't to see which method is the closest to truth
- Instead… Round-Robin goals include:
  - Fostering collaboration between universities and industrial researchers
  - Helping researchers focus on how to best approach a substructuring problem when truth is unknown
  - Discuss different approaches taken and why some methods are more suited for specific connection interfaces
  - See range of blind predictions to understand the range of answer found using substructuring practices

It depends… but we can learn a lot by comparing and collaborating on methods

Example Substructuring Results

- While waiting for hardware we did a cursory look at substructuring models of the frame and rectangular wing together
- **Method used:** Component Mode Synthesis
- **Connections used:** 4 corner bolt holes
- **Modes retained in the "experimental" frame model:** 12
- **Modes retained in the numerical wing model:** 100





Closing Remarks

- The Dynamic Substructuring – Technical Division round robin challenge is rapidly approaching!
- Talk to your graduate colleagues and students now to see if they are interesting in participating
- Talk to me after the session to be added to the Dynamic Substructuring e-mail list and to receive the WebEx invite for the Webinar on April 13th
- We can't wait to see some amazing results on this new benchmark structure in the future!

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- Contact drroett@sandia.gov to be included in future e-mails about this opportunity!