

Cube Satellite Modal Survey



Presented by:
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Purpose of the Session

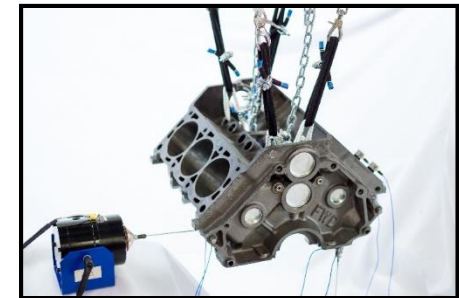
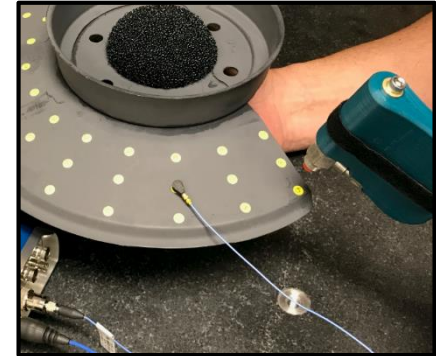
- Sensor Selection and Data Acquisition for Structural Measurements

Challenges Currently Faced

- Tools are job specific
- Multiple technics available
- Modeling is an approximation and isn't always achievable
- Measurement integrity

Structural Measurements

- Buildings
- Bridges
- Aircraft
- Satellites
- Automobile parts
- Specialty parts



Cube Satellite

- Landmapper BC
- Astrodigital
- Agricultural imaging
- 14 x 7 x 3 inches
- 26 lbs

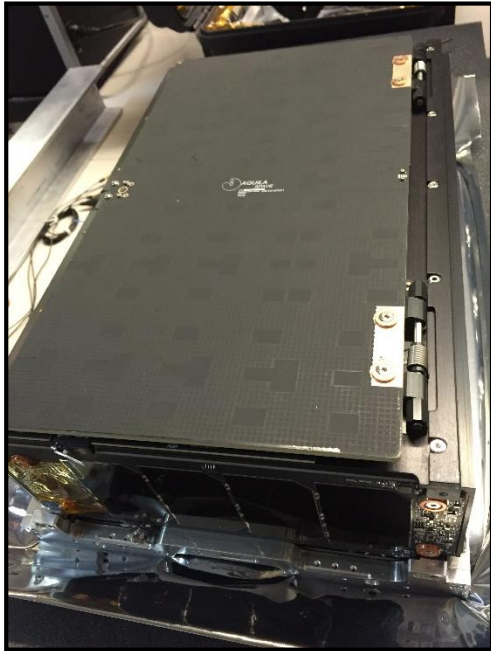


Solar Panels

- Deploy in orbit
- Material: FR4
 - Printed Circuit Board (PCB) material
 - Multi-layered: copper alloy/ fiberglass



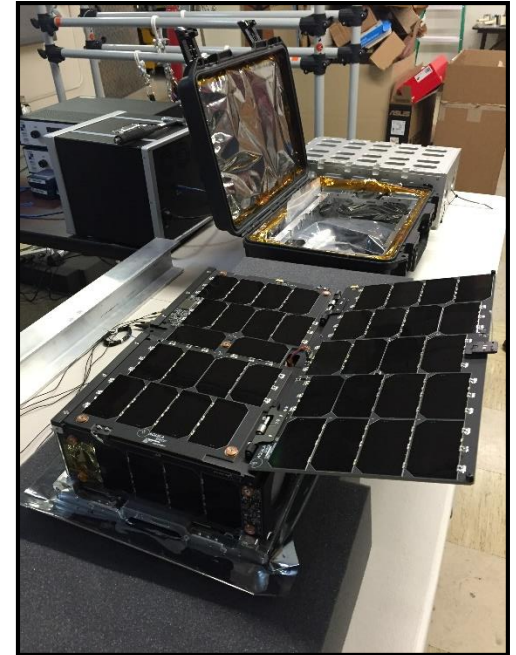
Solar Panel Deployed



1. Closed



2. Opening



3. Operational

Modal Testing Techniques

Hammer Impact

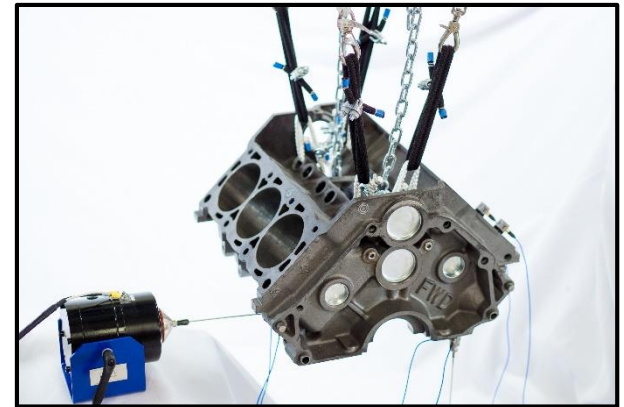
- Pros
 - Broad band frequency excitation
 - Quick, easy, inexpensive
- Cons
 - Varying impact from point to point
 - Double hit concerns
 - Tip performance over looked



Modal Testing Techniques

Shaker

- Pros
 - Increased repeatability
 - Many input waveforms available
 - MIMO analysis
- Cons
 - Longer test setup (stingers, modal shaker, etc.)
 - More equipment and input/output channels required
 - Requires additional experience



Modal Testing Techniques

Operational Modal Analysis

- Pros
 - No need for special boundary conditions
 - Uses natural excitation (response only meas.)
- Cons
 - Unscaled modal model
 - Assumption of Excitation covering frequency range of interest
 - Long time history data may be required
 - Computationally intensive

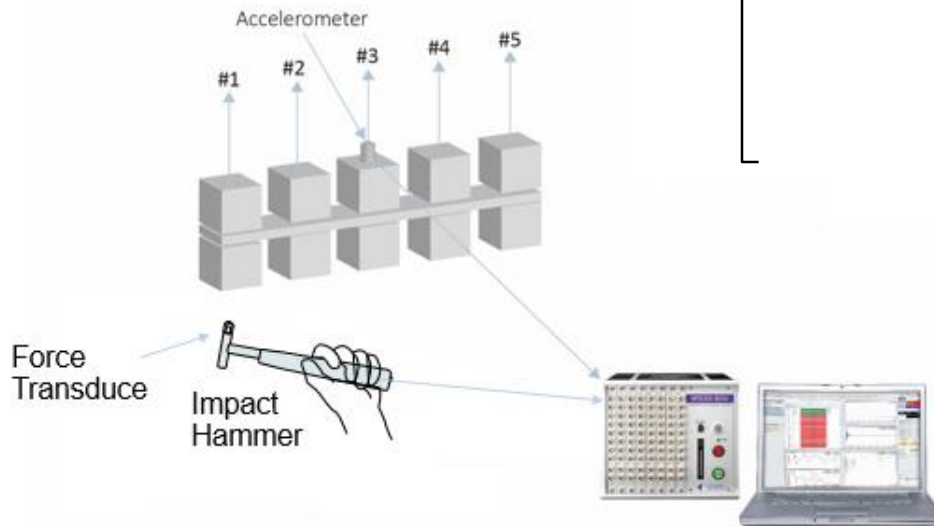
Multiple Hammers

Description	Application
Mini Hammer	Printed Circuit Board, Hard Drive
General Purpose	Parts, Components
Large Size	Heavy large sized structures
Sledge Hammer	Buildings, Bridges, etc.

Impact Hammer Excitation

Measuring one *row* of the FRF matrix by roving impact position

$$\begin{bmatrix} H_{11}(\omega) & H_{12}(\omega) & \cdots & H_{15}(\omega) \\ \cdots & \cdots & \cdots & \cdots \\ \cdots & \cdots & \cdots & \cdots \\ \cdots & \cdots & \cdots & \cdots \\ \cdots & \cdots & \cdots & \cdots \end{bmatrix}$$

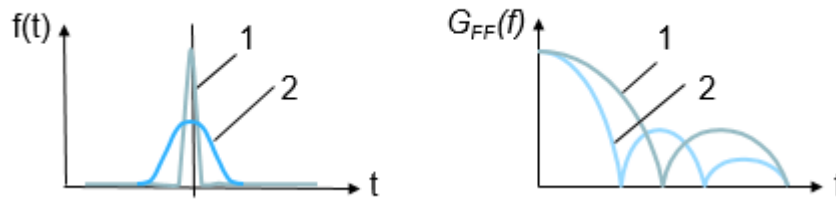


Impact Excitation

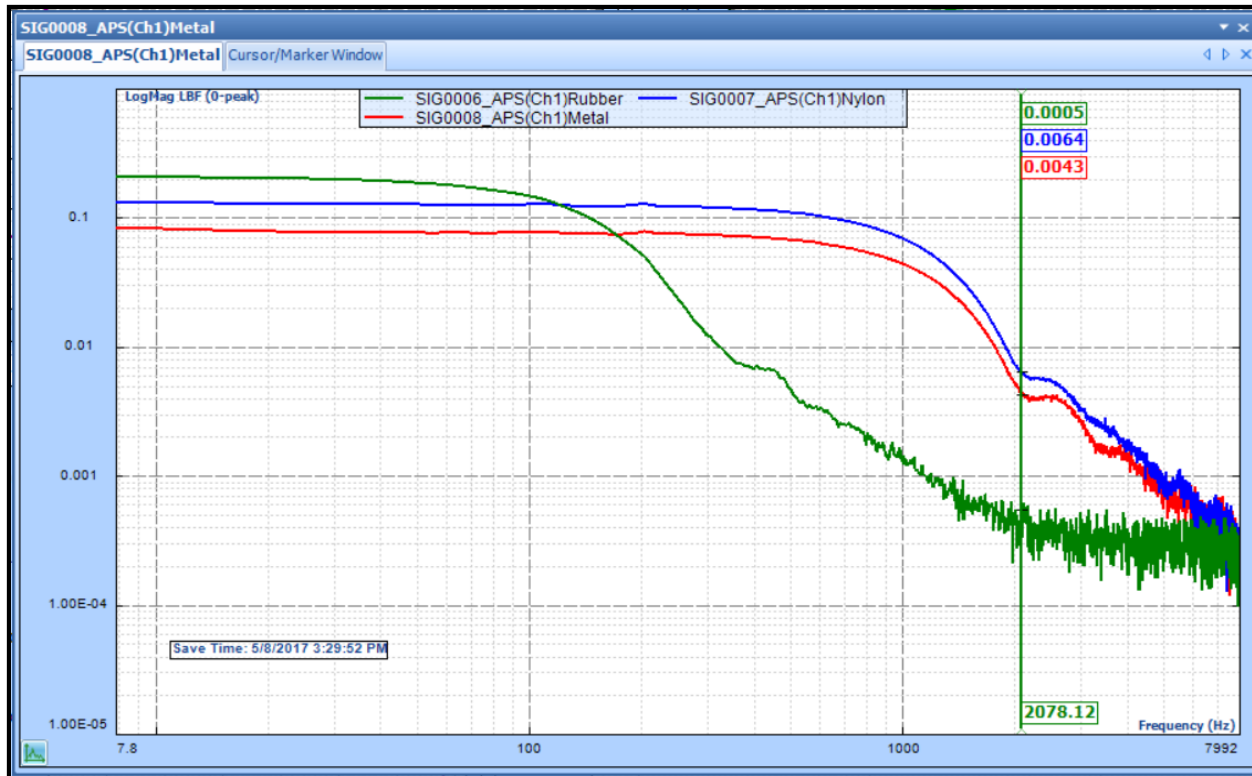
Impact force magnitude and duration depends on

- Hammer weight
- Hammer tip (steel, plastic or rubber)
- Dynamic characteristics of surface
- Velocity at impact

Impact force spectrum bandwidth inversely proportional to pulse duration



Impact Excitation (In Practice)



Response

- Accelerometer
- Size
- Frequency Range
- G level
- Type
 - IEPE, charge, voltage



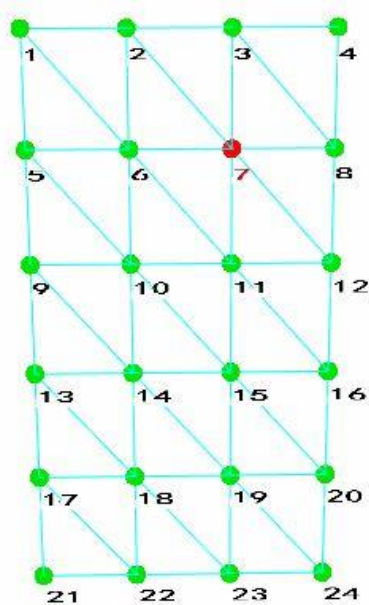
Sensor Placement

- Adherence
 - Wax, tape, epoxy, stud, magnet
- Location
 - Avoid nodes

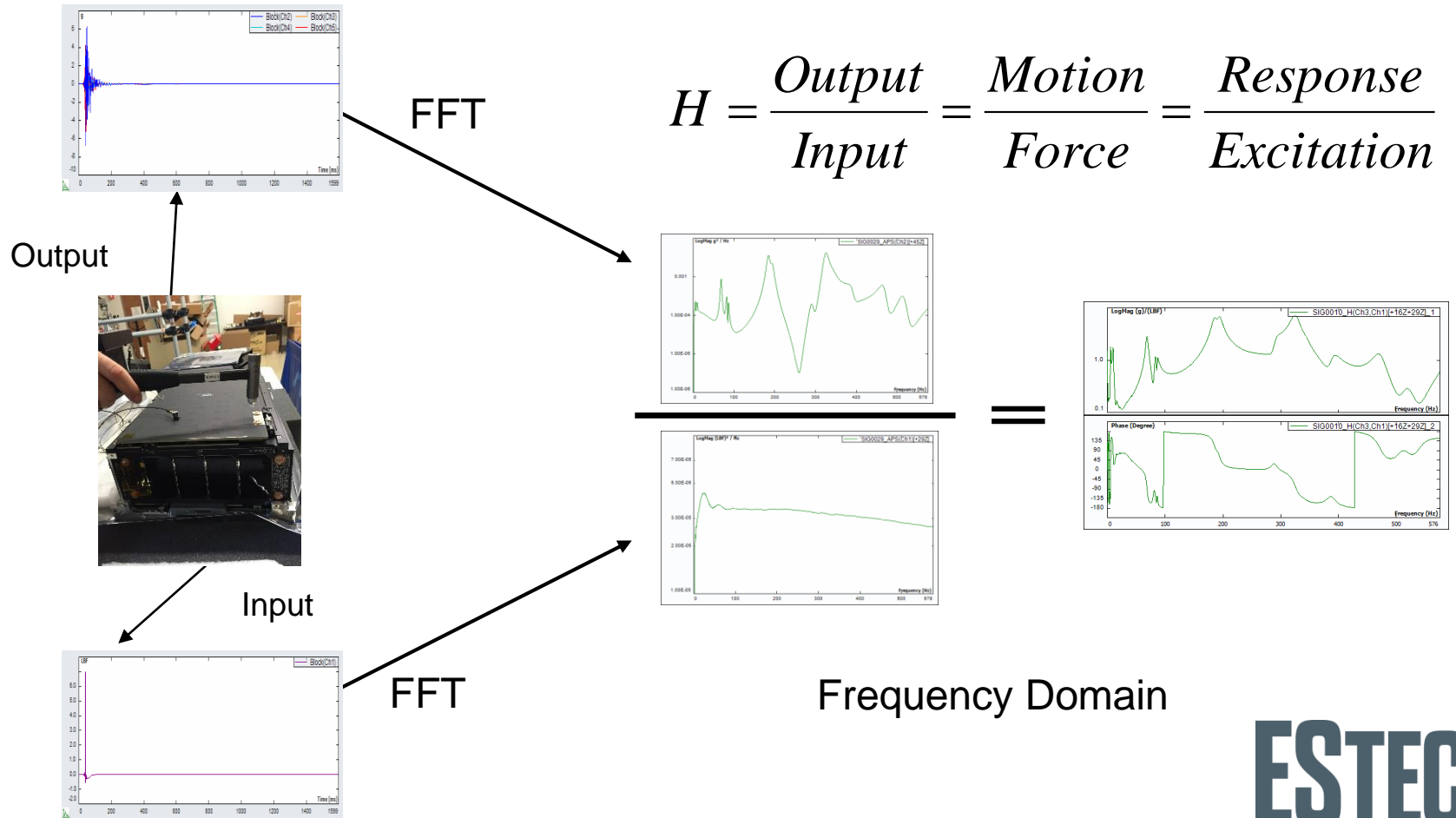


Test Setup

- Test stand
 - Isolation
- Roving hammer



Data Collection



Data Collection

Single Input Single Output

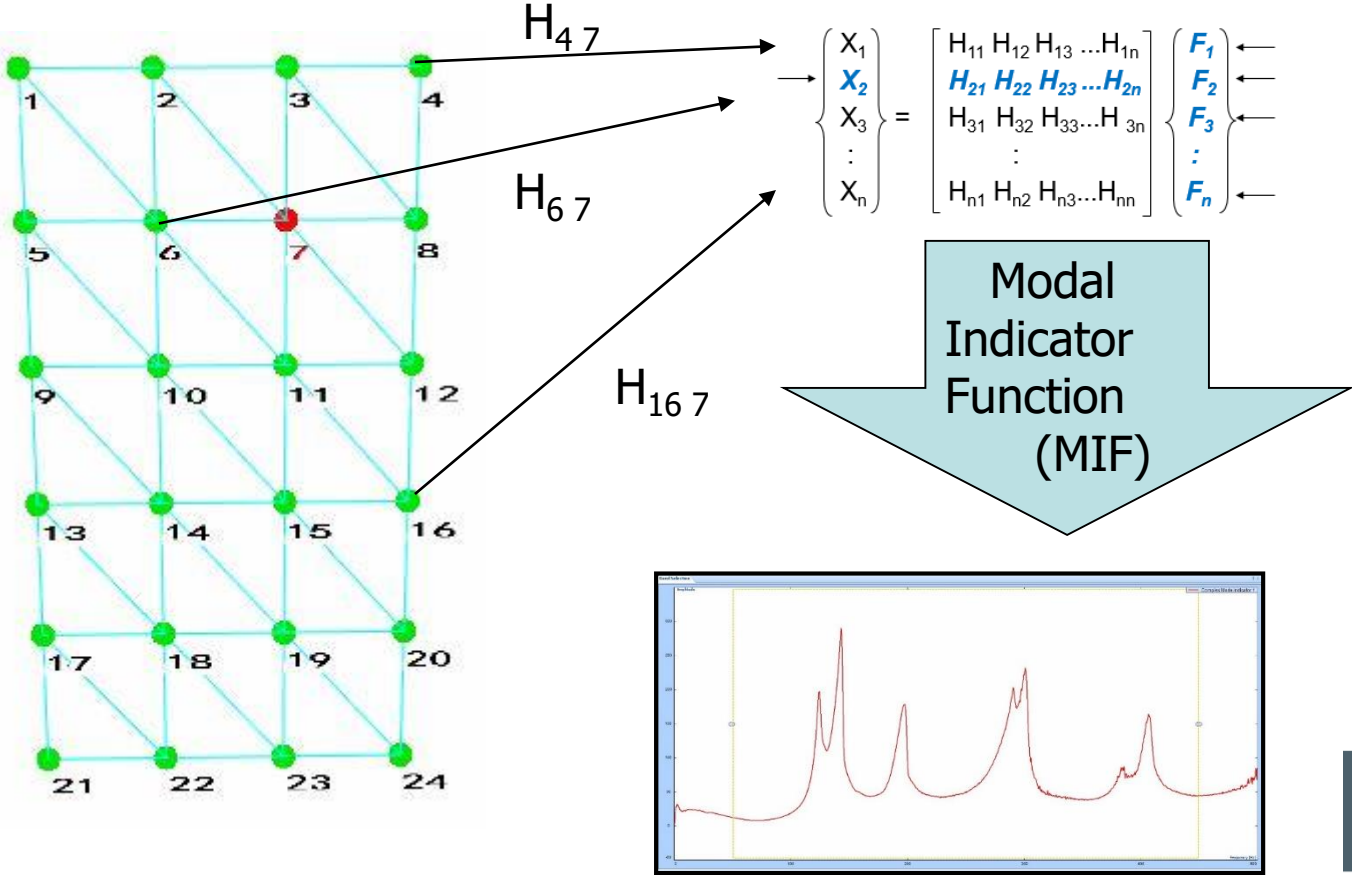
One Roving Excitation

One Fixed Response

Measures one row of FRF Matrix

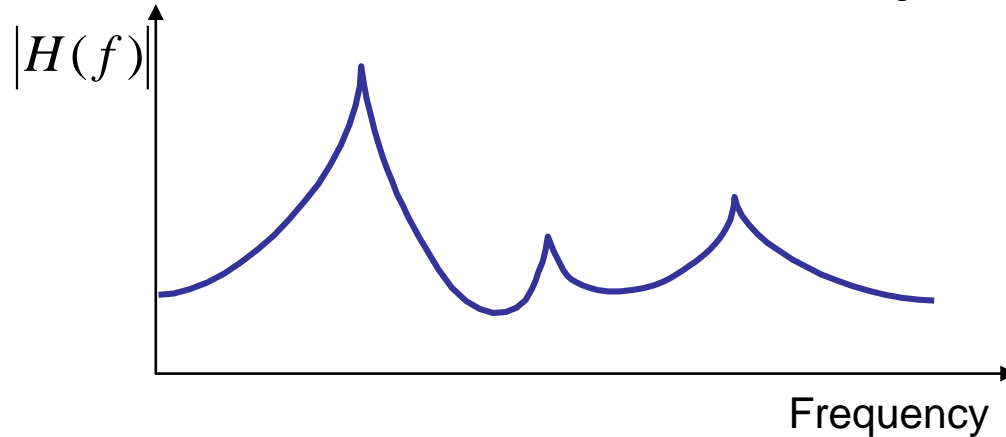
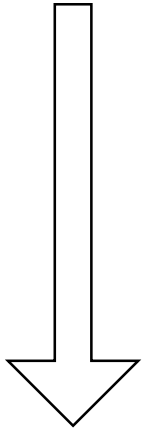
$$\rightarrow \begin{Bmatrix} X_1 \\ X_2 \\ X_3 \\ \vdots \\ X_n \end{Bmatrix} = \begin{bmatrix} H_{11} & H_{12} & H_{13} & \dots & H_{1n} \\ H_{21} & H_{22} & H_{23} & \dots & H_{2n} \\ H_{31} & H_{32} & H_{33} & \dots & H_{3n} \\ \vdots & \vdots & \vdots & \dots & \vdots \\ H_{n1} & H_{n2} & H_{n3} & \dots & H_{nn} \end{bmatrix} \begin{Bmatrix} F_1 \\ F_2 \\ F_3 \\ \vdots \\ F_n \end{Bmatrix} \leftarrow$$

Multiple FRF's

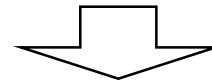


Measured Data to Analysis

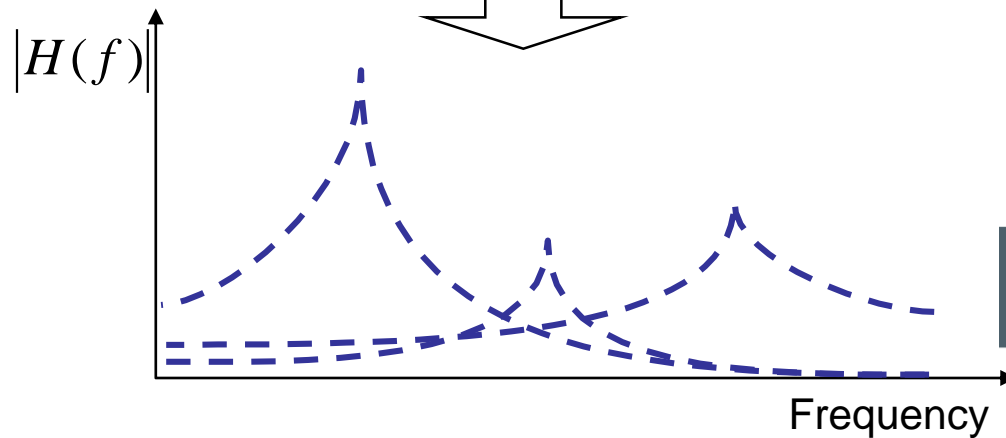
Measured
FRF



Curve Fitting
(Parameter Identification)

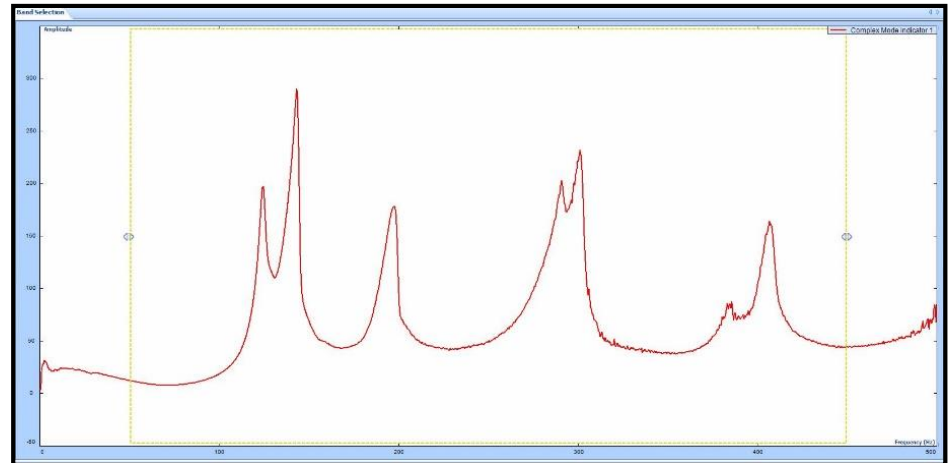


Modal Analysis

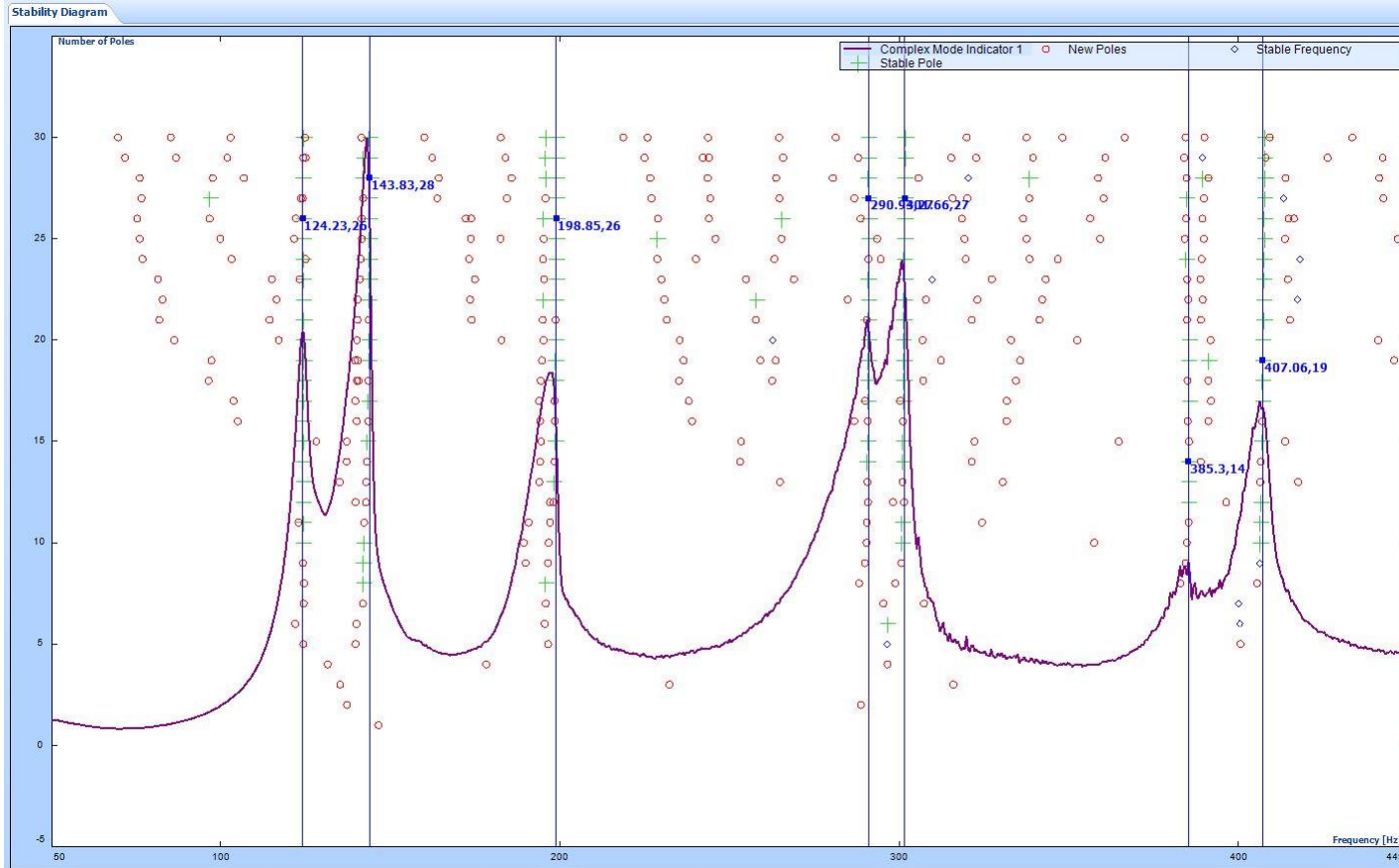


Modal Indicator Function (MIF)

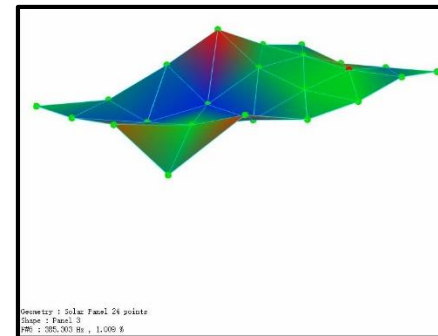
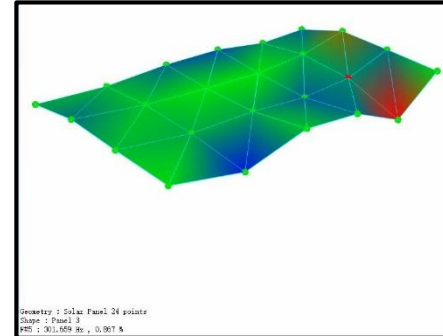
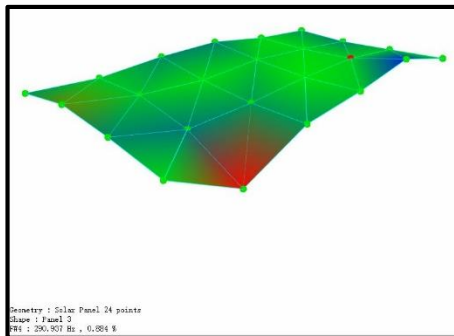
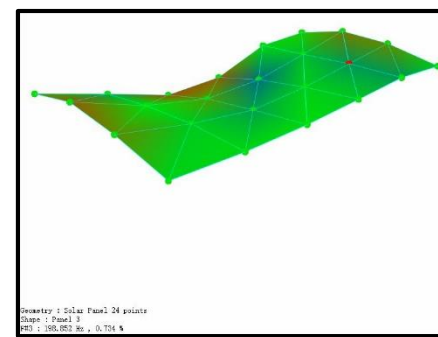
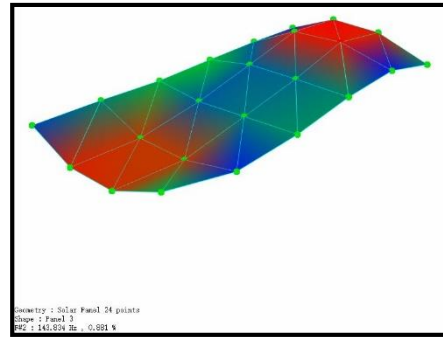
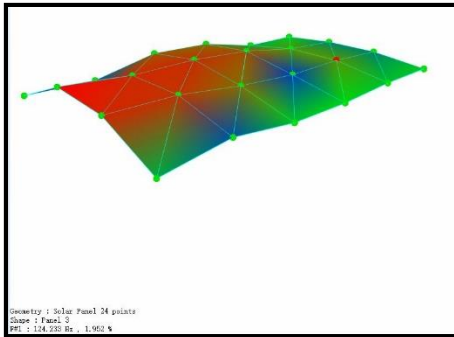
- Complex MIF
- Multi-Variate MIF
- Real MIF
- Imaginary MIF



Stability Diagram

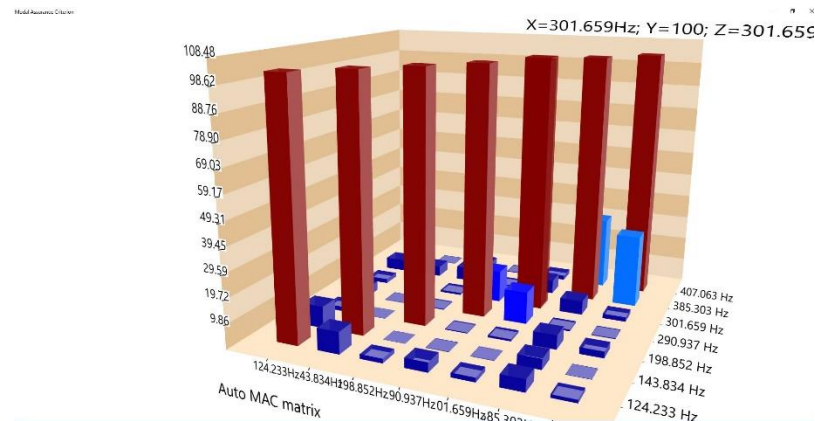


Mode Visualization



Modal Assurance Criteria (MAC)

- Cross eigenvalue (singular value) effect
- Reverse data calculation
- Believability of the data

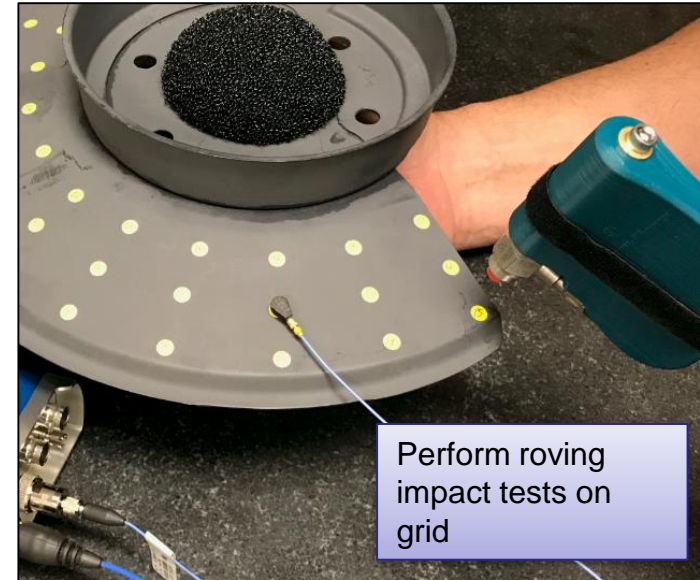
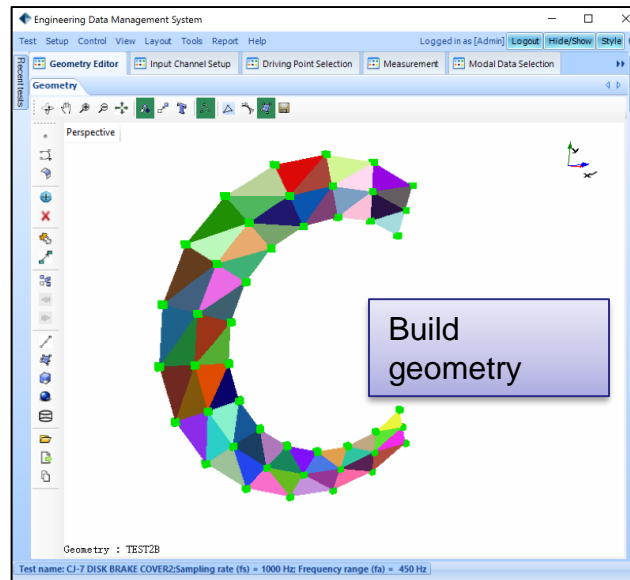
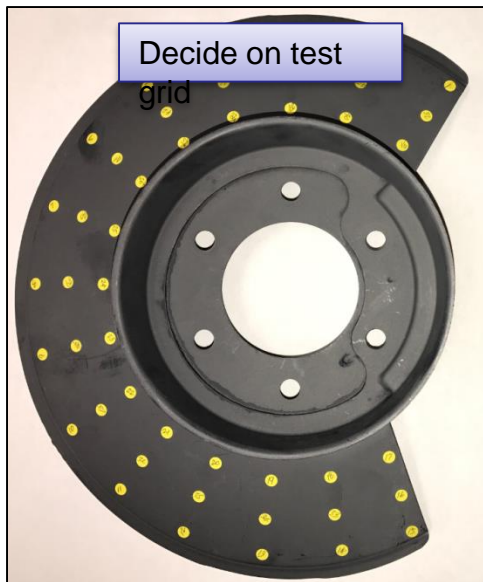


Modeling vs Measurement

- Unknown composite material
- Complex non-linear layering
- Boundary conditions for in situ piece
- Manufacturing tolerances (non-uniform geometry)
- Expensive (3-D laser scanner)

Modeling vs Measurement

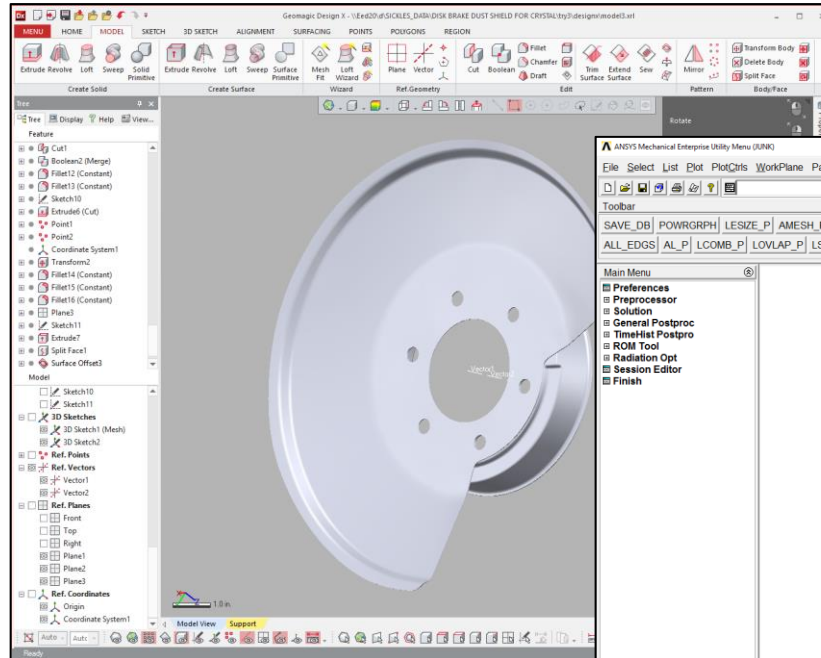
- Known linear material
- Simple geometry, removable



Modeling vs Measurement

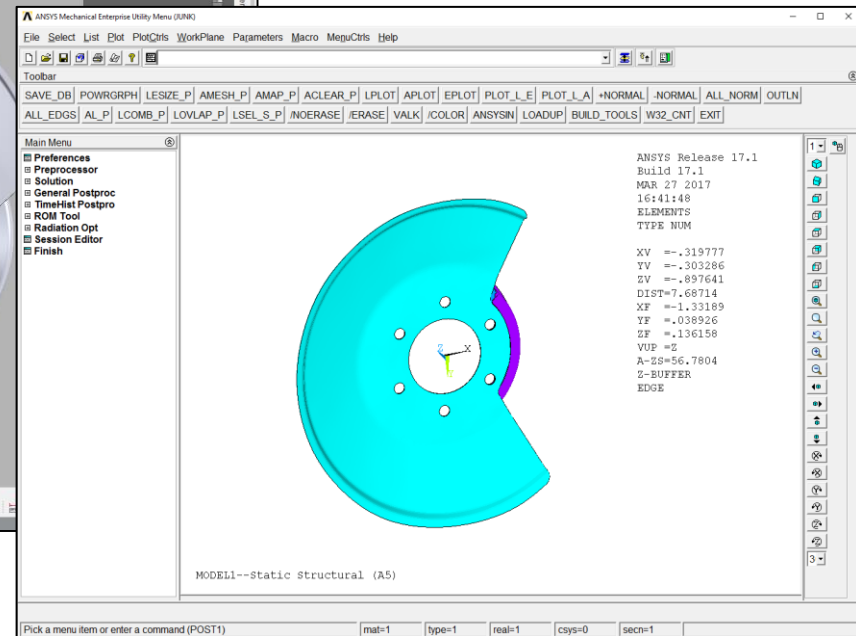


Laser Scans



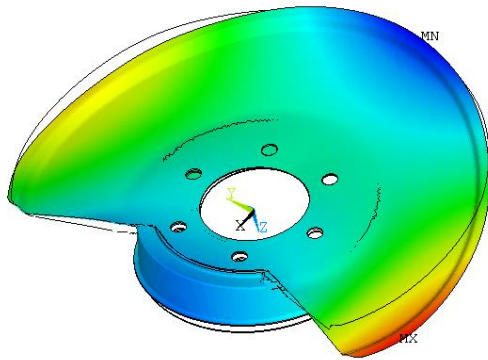
Model from Scans

Finite Element Model

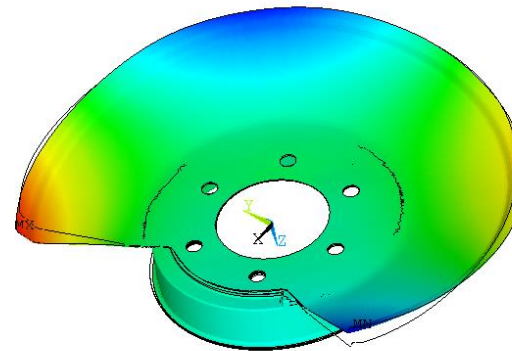


Modeling vs Measurement

FEM

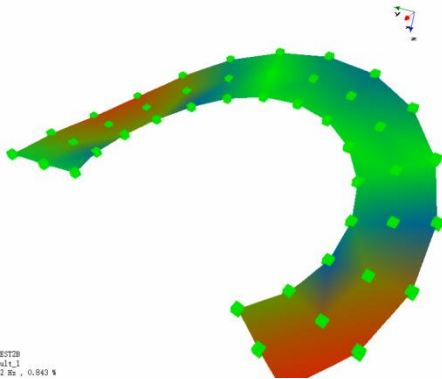


107.7 Hz

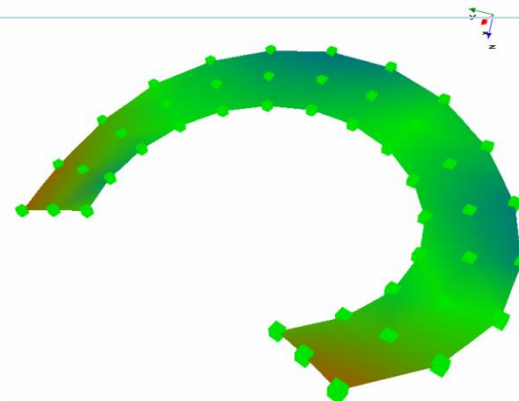


111.7 Hz

EDM
MODAL



106.8 Hz



109.8 Hz

* With permission from Stream Lion Design LLC, Paul Sickles

Conclusion

- There are simple methods for obtaining measurements and analyzing modes
- The tools required are within reach
- Modeling may not be available
- Planning and proper setup before test \ saves time and effort ensuring accuracy while minimizing erroneous results
- Animation /MAC etc. to check and validate modal analysis results

Questions and Answers

- ?

Thank you (final) page

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