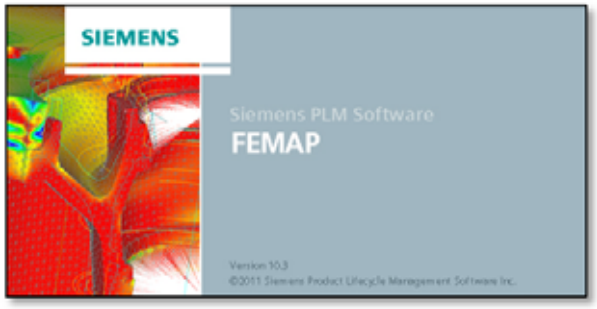
Seminar Outline

- Normal Modes Analysis: Basics
- Why is it Useful
- How it Works
  - Principle of Orthogonality
  - Strain Energy
  - Mass Participation
- Available Resources
- Next Training Opportunity on October 15-19, 2012



Normal Modes Analysis

Linear Dynamics: E.O.M. $m\frac{\partial^2 u}{\partial t^2}+c\frac{\partial u}{\partial t}+ku=r(t)$

Eigenvalue problem: undamped free vibration: $m\frac{\partial^2 u}{\partial t^2}+ku=0$

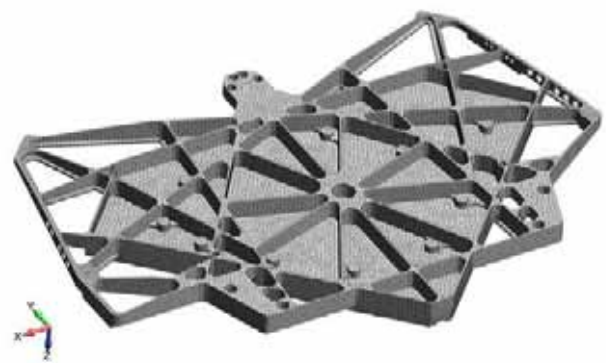
Assuming a solution of the form: $u=u_o \sin\omega t$

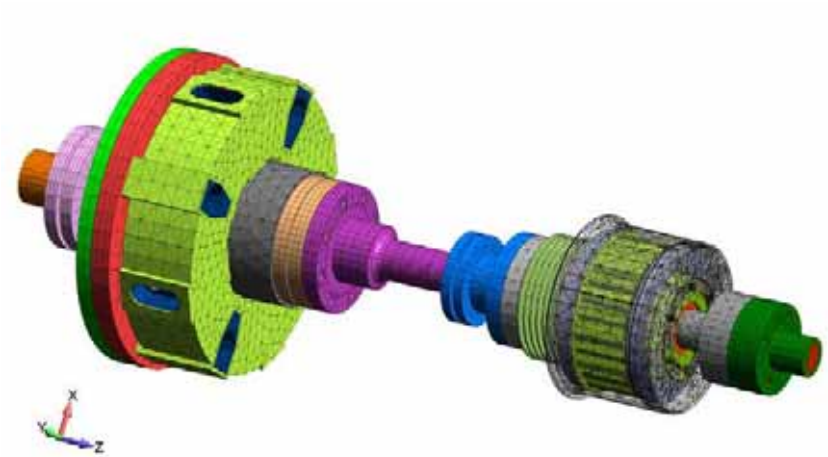
Then: $\left[k-\omega^2 m\right]\{u_o\}=0$

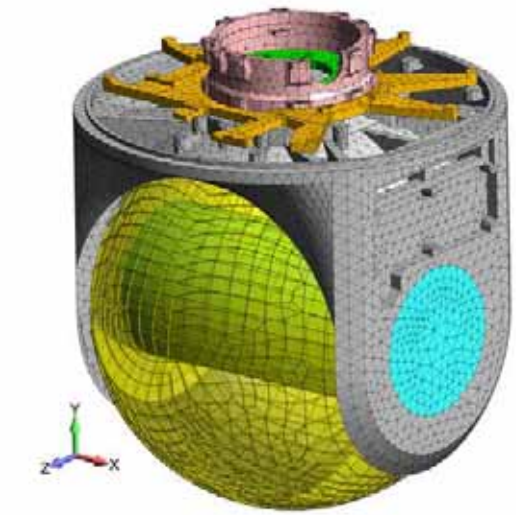
For non-trivial solutions (i.e., solutions that are more than just zeros):

$\left[k-\omega^2 m\right]=0$ Giving us the well know frequency relationship: $\omega=\sqrt{\frac{k}{m}}$

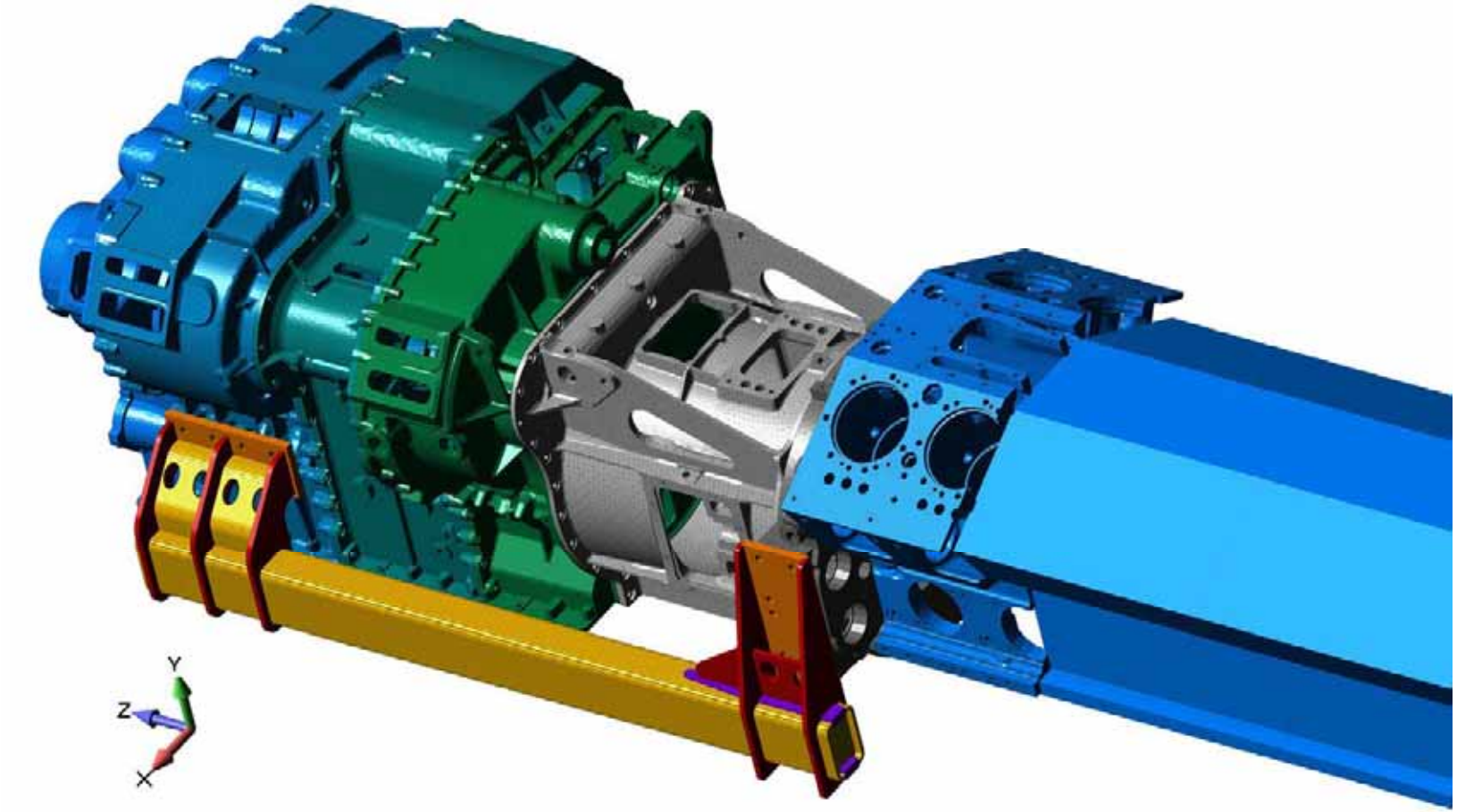
Why it is Useful: Just Basic Goodness of Normal Modes



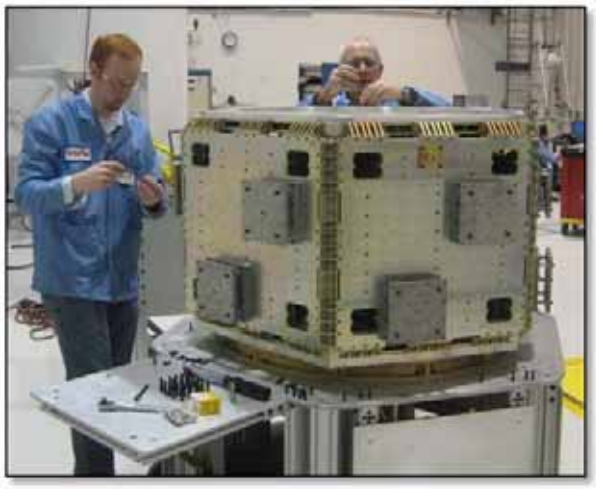




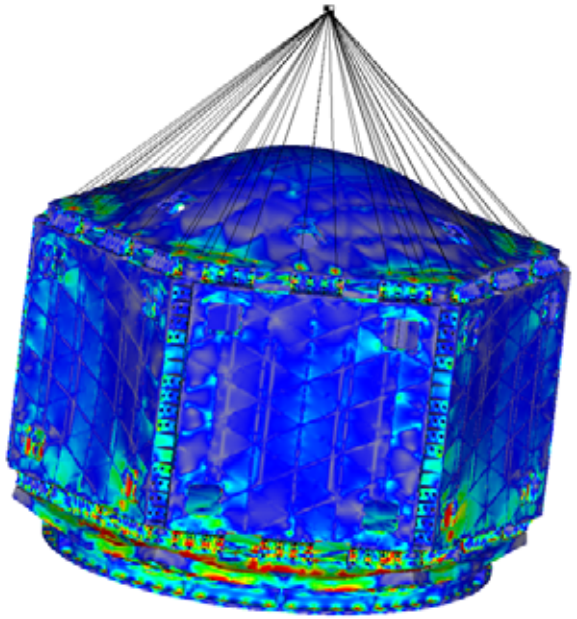
Why it is Useful: Just Basic Goodness of Normal Modes



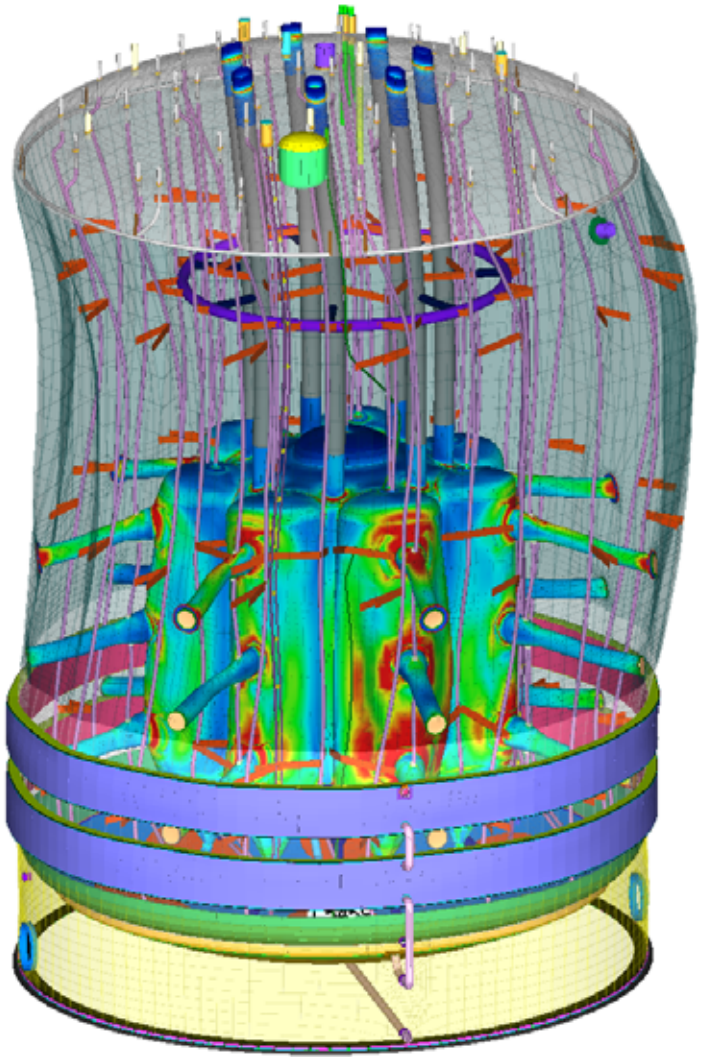
Why it is Useful: PSD Analysis (*Frequency Domain Analysis*)



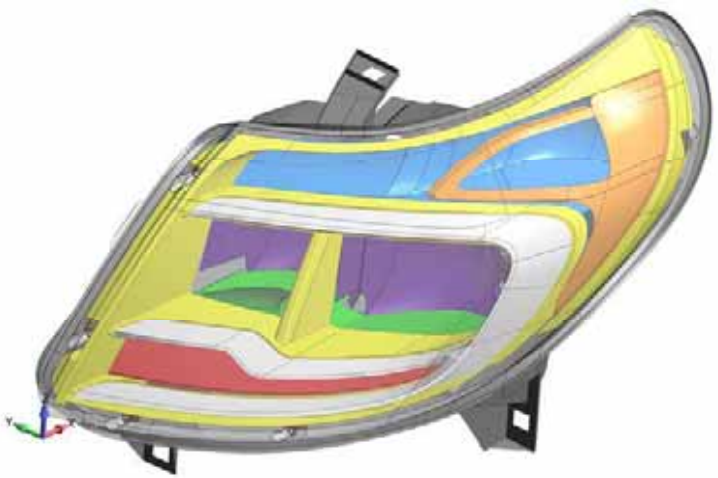
- ✓ Fatigue
- ✓ Wind Turbine
- ✓ Air flow over a wing
- ✓ Acoustic Input from Jet Engine Exhaust
- ✓ Earthquake Ground Motion
- ✓ Wheels running over a Rough Road
- ✓ Ocean Wave Loads on Offshore Platforms



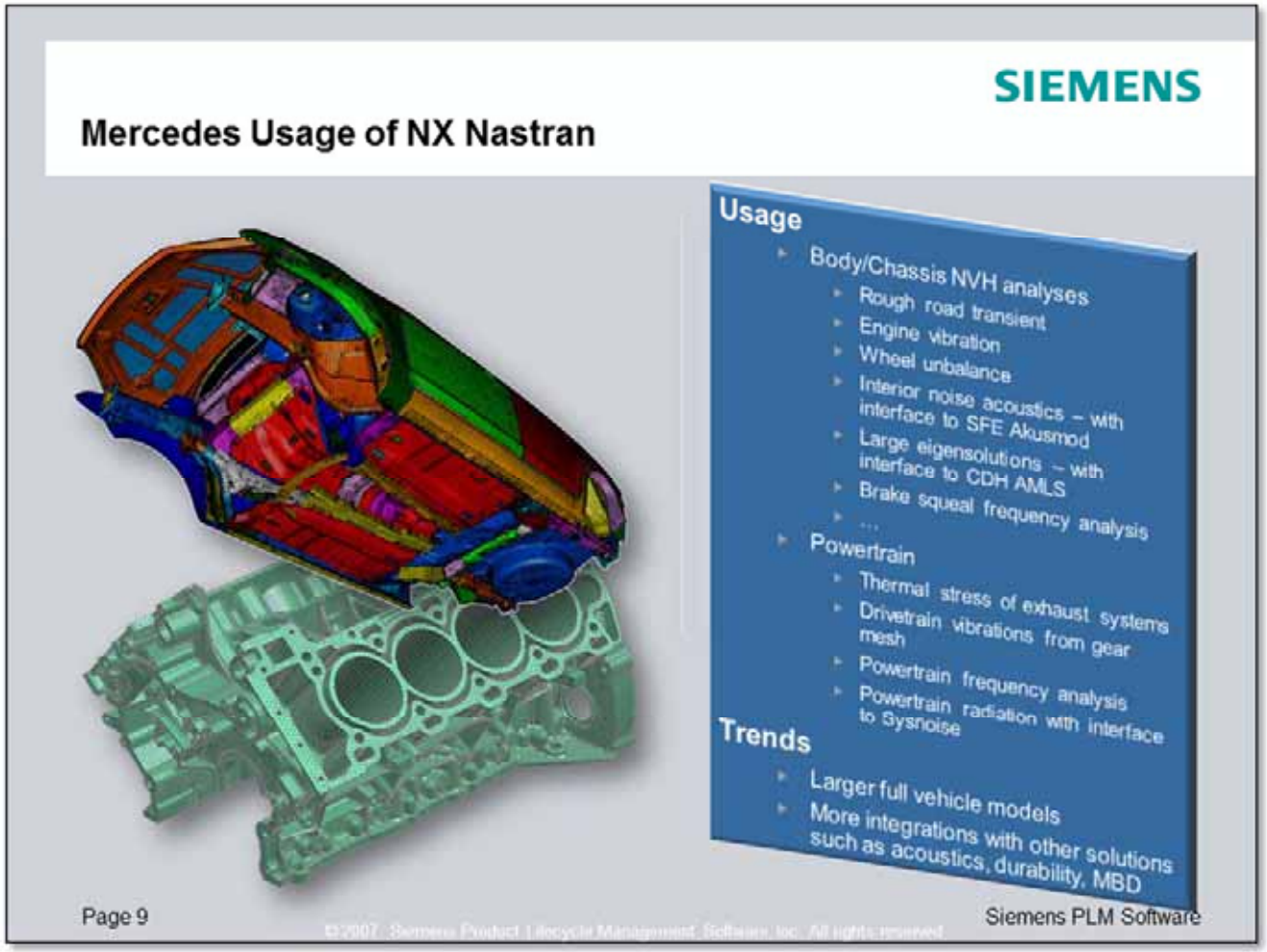
Why it is Useful: Earthquake Analysis



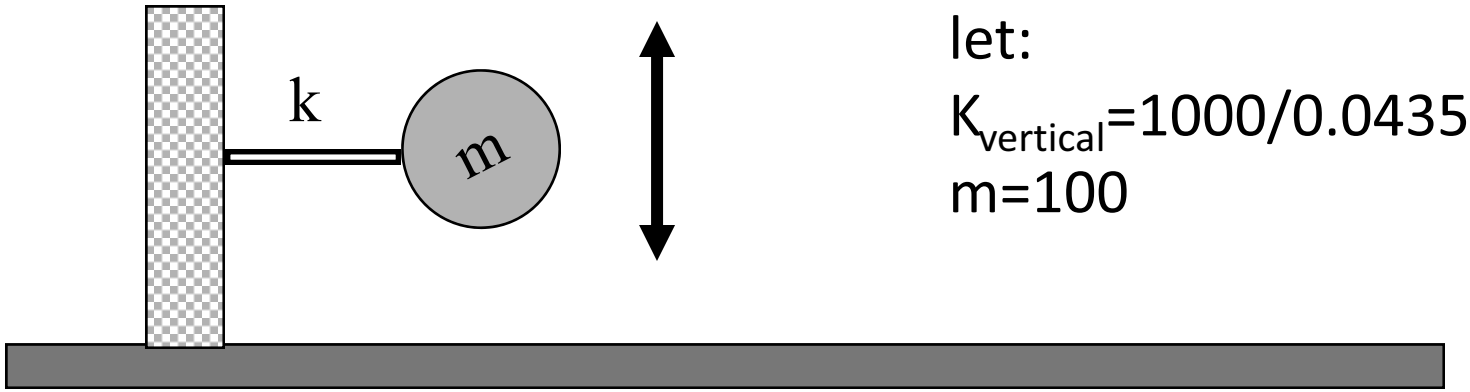
Why it is Useful: Modal Frequency Sweep



Why it is Useful: NVH



Normal Modes / Eigenvalue problem: undamped free vibration



let:

$K_{vertical}$=1000/0.0435

m=100

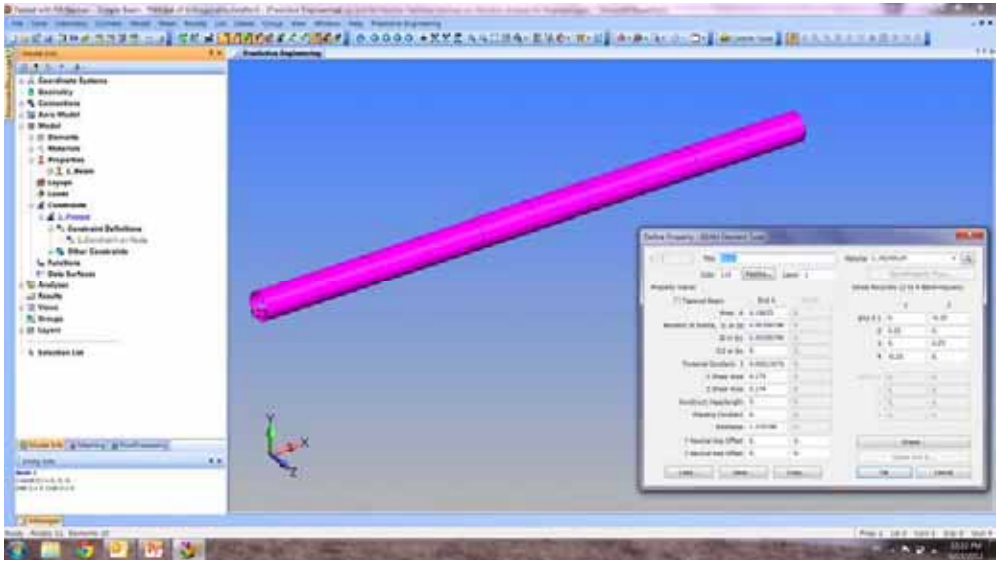
$$\omega = \sqrt{\frac{k}{m}} = \sqrt{\frac{23{,}000}{100}} = 15.16\,^{rad}/_{sec}$$

NX Nastran reports frequencies in cycles per second. Hence, 15.16 radians/sec is equal to 2.41 cycles/sec.

Example Model: Normal Modes Validation Start.modfem
Simple CBUSH with Mass Element
Focus: Units | Theory | Why Only Three Modes?

Normal Modes / Eigenvalue problem: Principal of Orthogonality

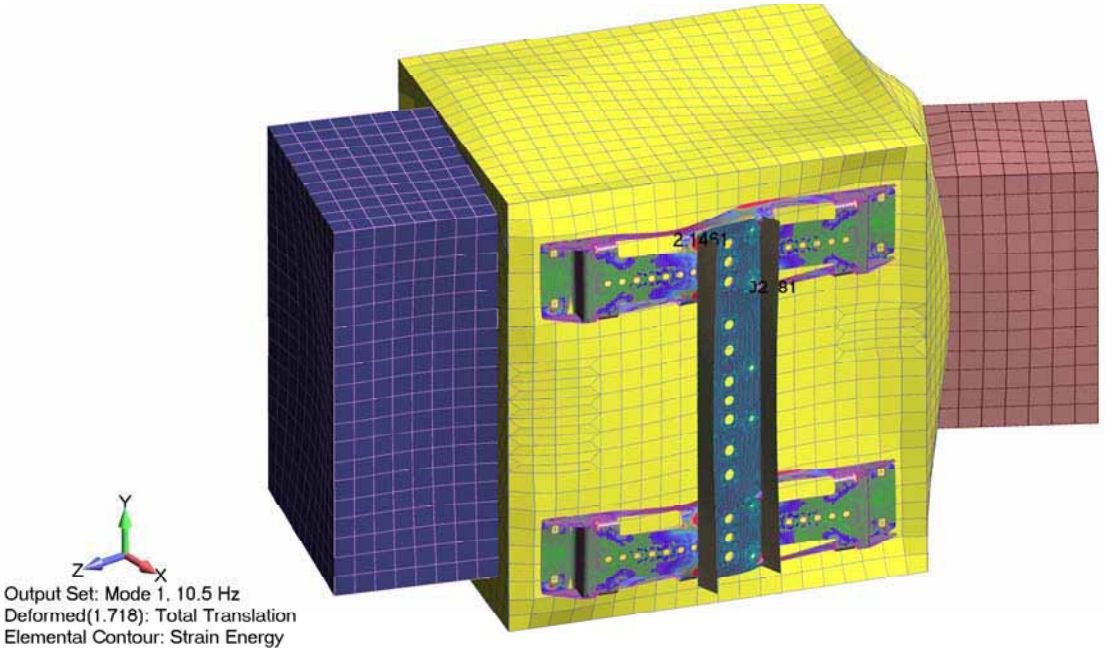
- Even basic normal modes analysis can be confusing
- Basic beam model with a pinned support is interrogated
- Is it logical?
- Why are there double modes?



Example Model: Simple Beam - Principal of Orthogonality.modfem
Analyze | Change B.C.'s | Double Modes

Normal Modes / Eigenvalue problem: Strain Energy Density

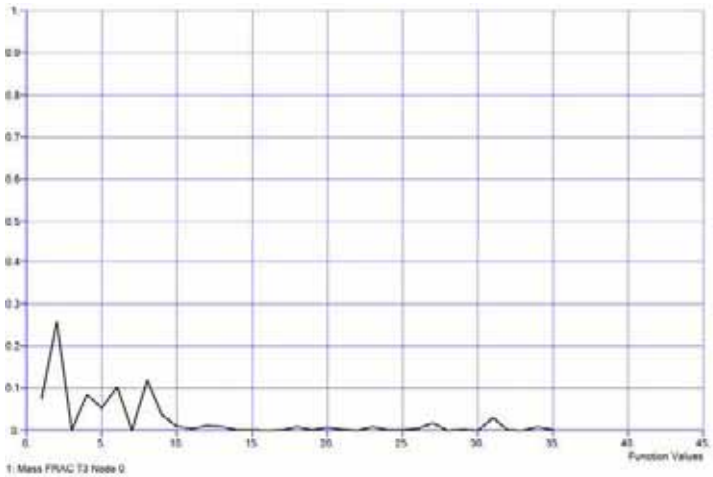
- To improve the dynamic performance it is often as simple as moving the first mode to a higher frequency
- Normal modes is all about stiffness and mass
- Strain energy tells you where to add stiffness

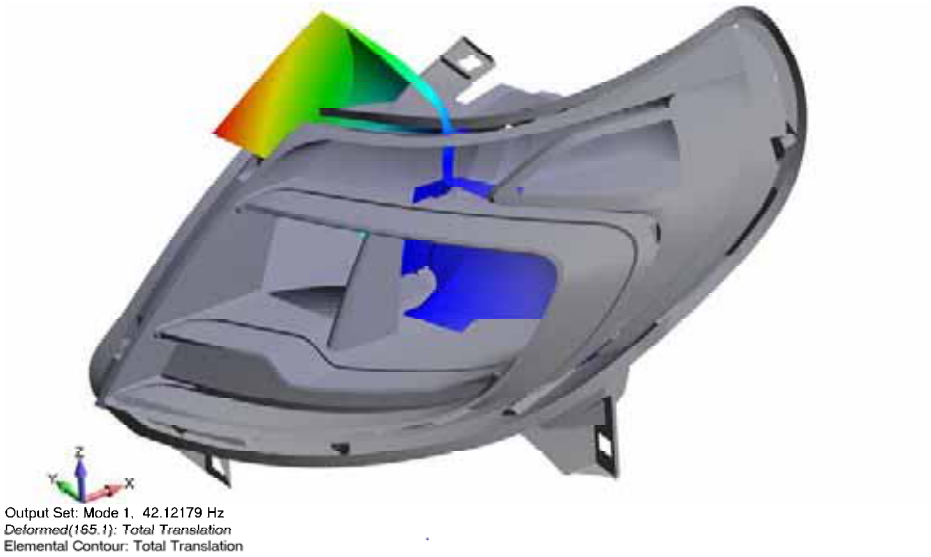


Example Model:Radioframe Networks GR-63-Core Seismic Analysis.MODFEM
Show Strain Energy | Discuss How Improvements Were Made | CORE-GR-63 Zone 4 Seismic

Normal Modes / Eigenvalue problem: Mass Participation and Frequency Sweep Analysis

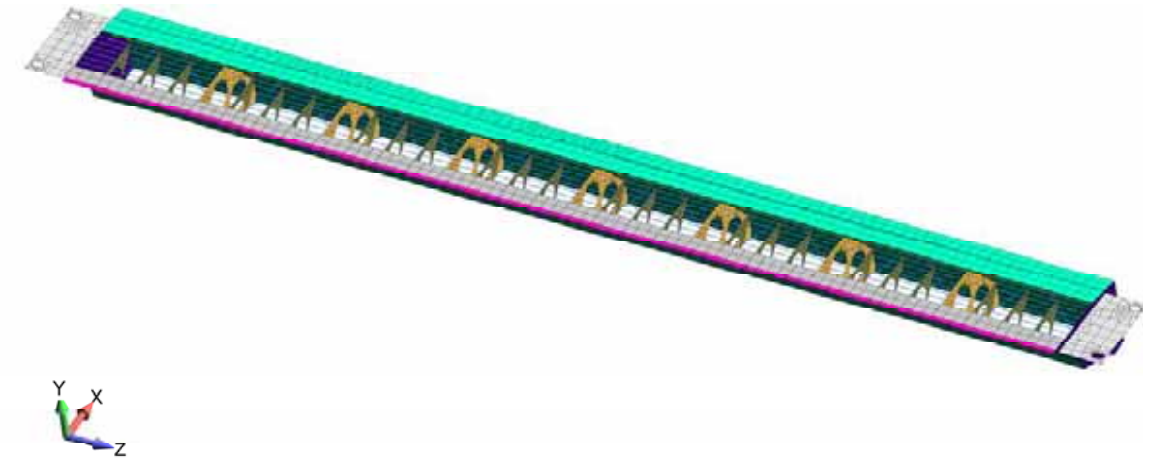
- Mass Participation Tells you what is important
- Expand around significant modes





Normal Modes / Eigenvalue problem: Mass Participation and Optimization

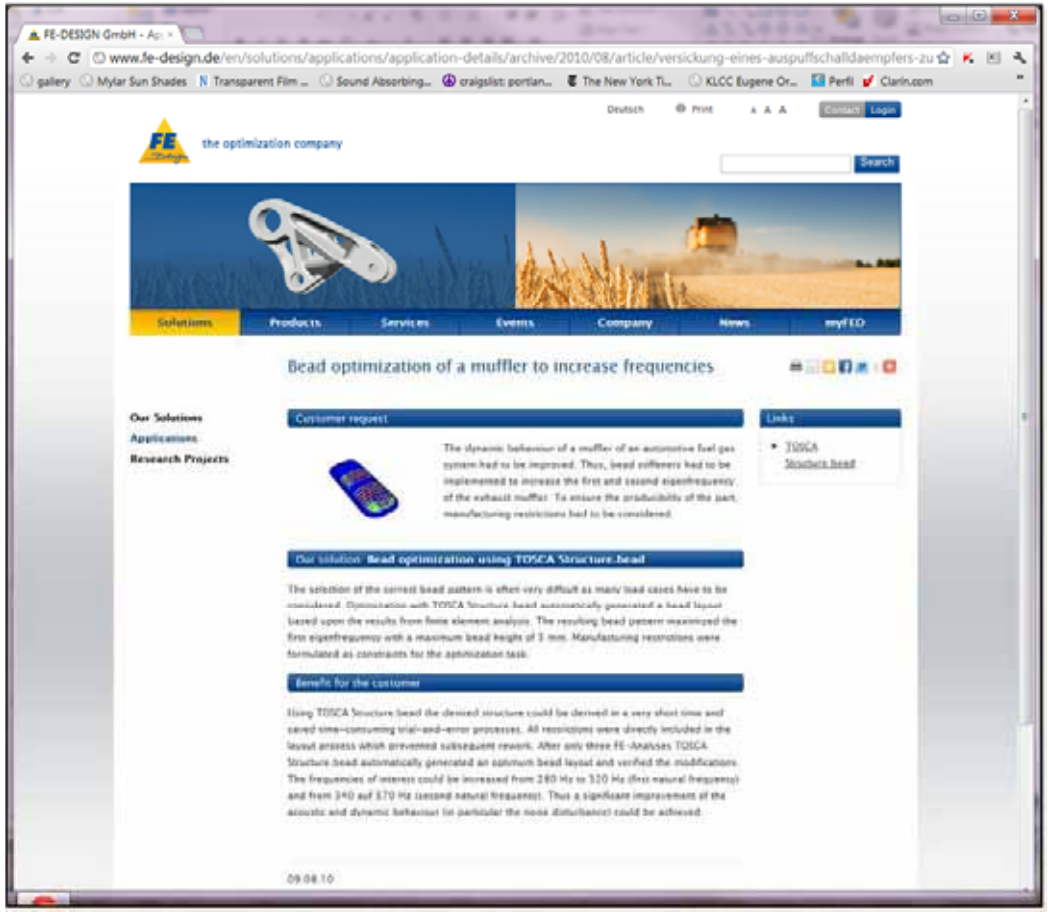
- Mass Participation Tells You Heaps
- Optimization is often best done by intelligent inspection
- Don't expect miracles from computer programs



Example Model: Coors Tek Paper Mill Forming Board - Original Design - Start.modfem

Normal Modes / Eigenvalue problem: TOSCA Optimization

- Femap Optimization for Vibration



Normal Modes / Eigenvalue problem: Resources

- NX Nastran Documentation
- Predictive Engineering Website
- Be Inquisitive – we have lots of expertize to leverage