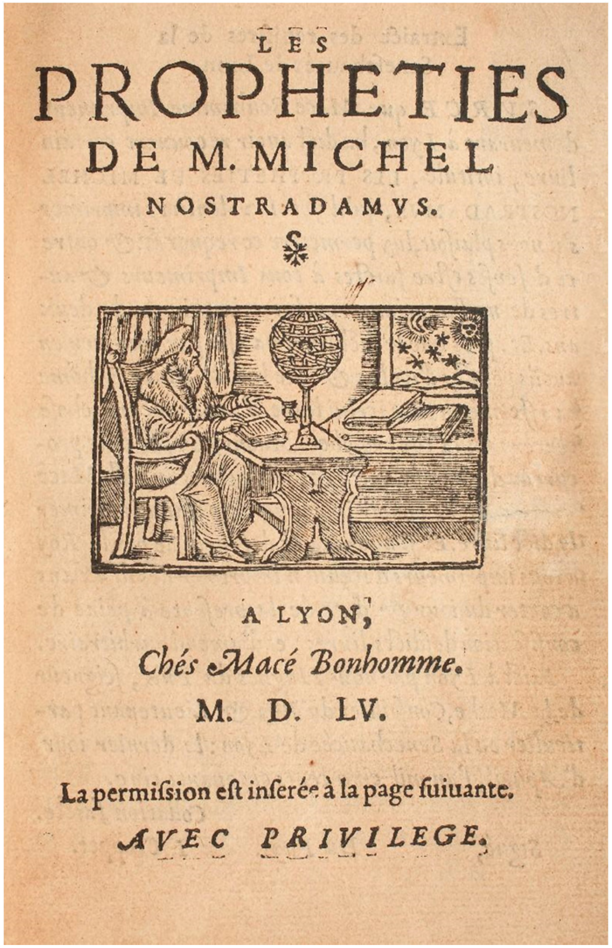
NOSTRODAMUS AND THE SYNCHROTRON ENGINEER:
Key Aspects of Predicting Accelerator Structural Response



CURT PREISSNER
Jeremy Nudell, Zunping Liu, Jeff Collins, and Herman Cease
Advanced Photon Source Upgrade Project

WEBA01-Wednsday, September 14th

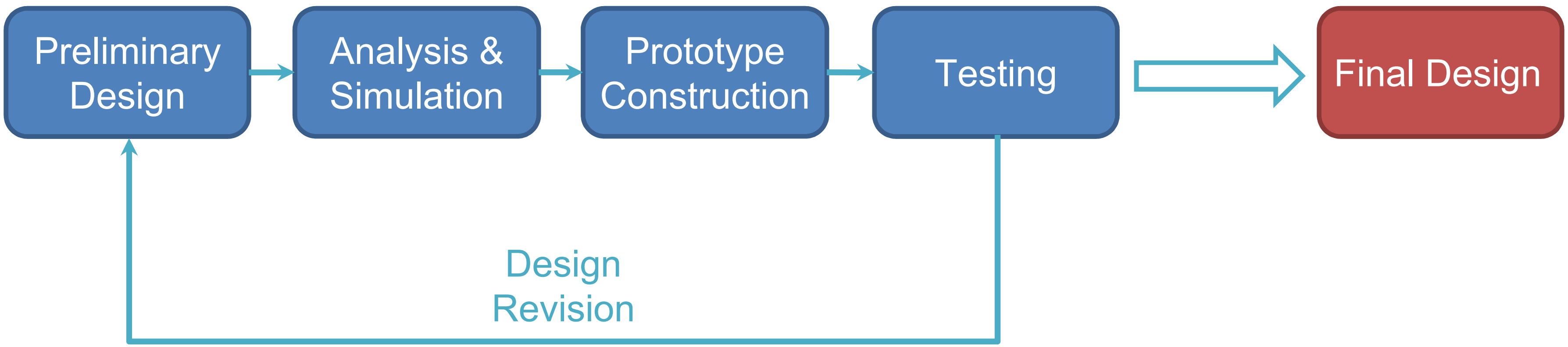
WHAT DOES ANY ENGINEERING TEAM WANT?

Final Design

Q: WHAT DOES ANY ENGINEERING TEAM WANT?

A: An efficient and reliable process that produces a design that meets specifications

WHAT DOES ANY ENGINEERING TEAM WANT?



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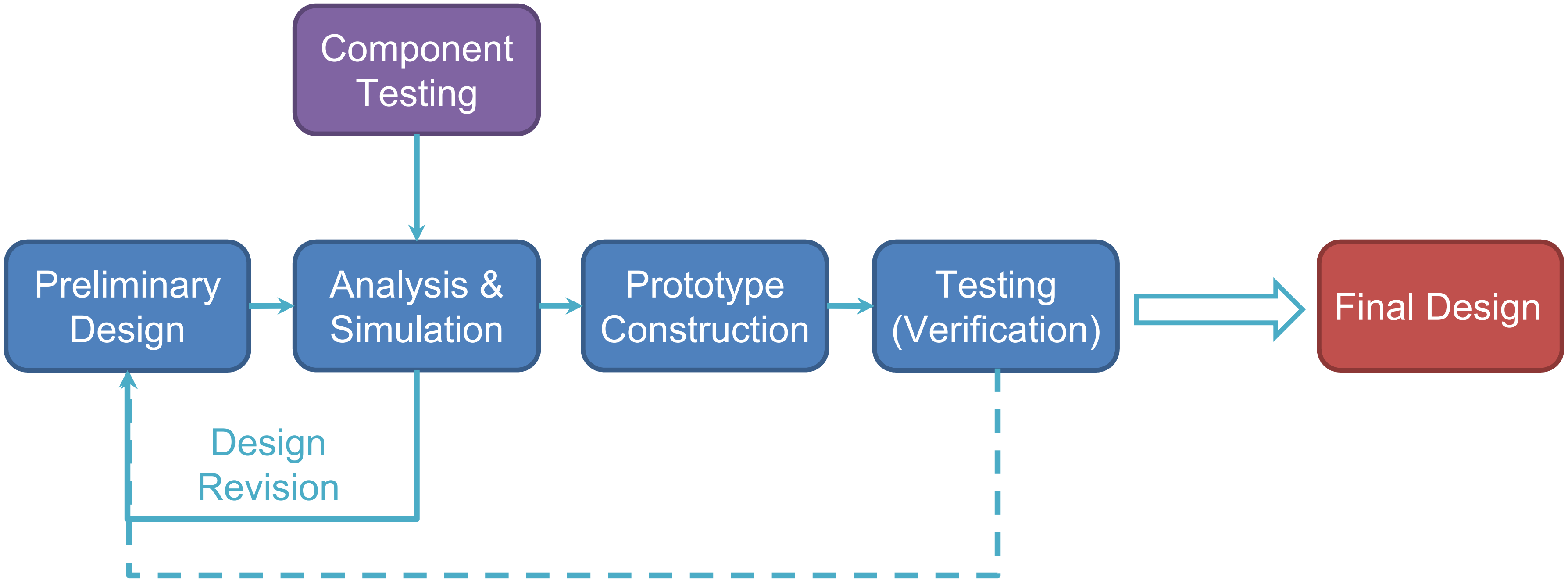


We'd be happy with a process:

- That enables us to efficiently explore design space,
- In which we are confident in results (can be compared to specifications),
- that preferably has physical meaning and is not post-hoc.

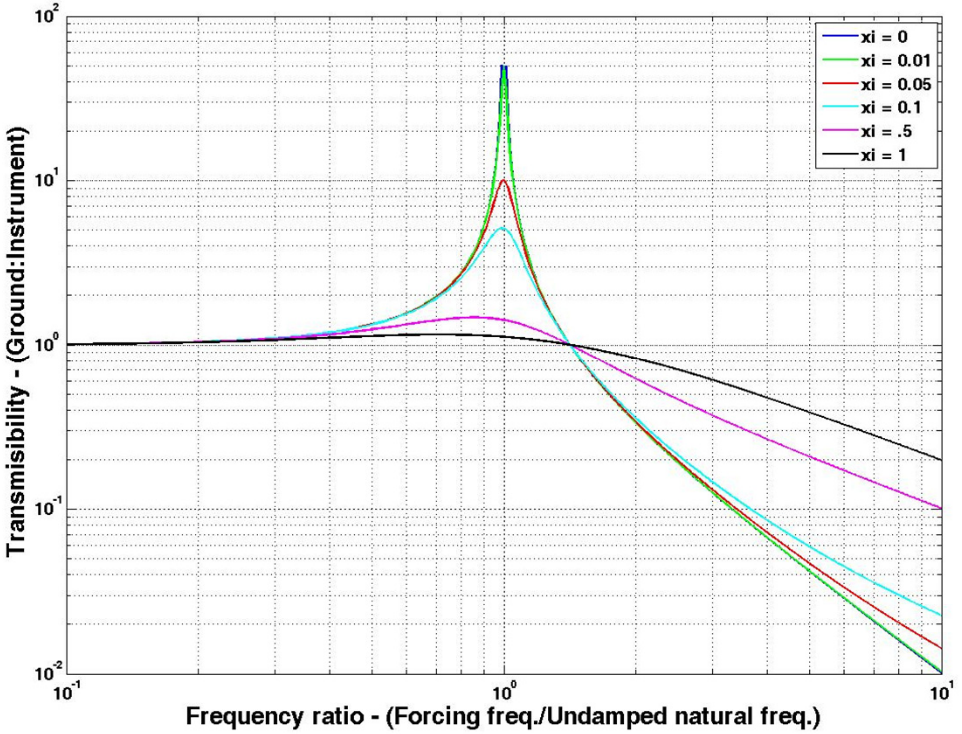
THIS CAN BE DIFFICULT TO DO

Consider context of synchrotron magnet support design…

- We'd like to evaluate conceptual designs against requirements
- Behavior may be dependent upon characteristics that are not easily determined
- Magnet support deflection requirement is:
  - Dependent mostly upon material properties and geometry,
  - Both of which can be well characterized.
  - Analysis can be good predictor of performance.
- Magnet support first natural frequency requirement is:
  - Dependent upon material properties and geometry, but
  - Also dependent upon sub-structure behavior.
  - These can be hard to characterize.
  - Analysis can be an inconsistent and/or unreliable predictor of performance

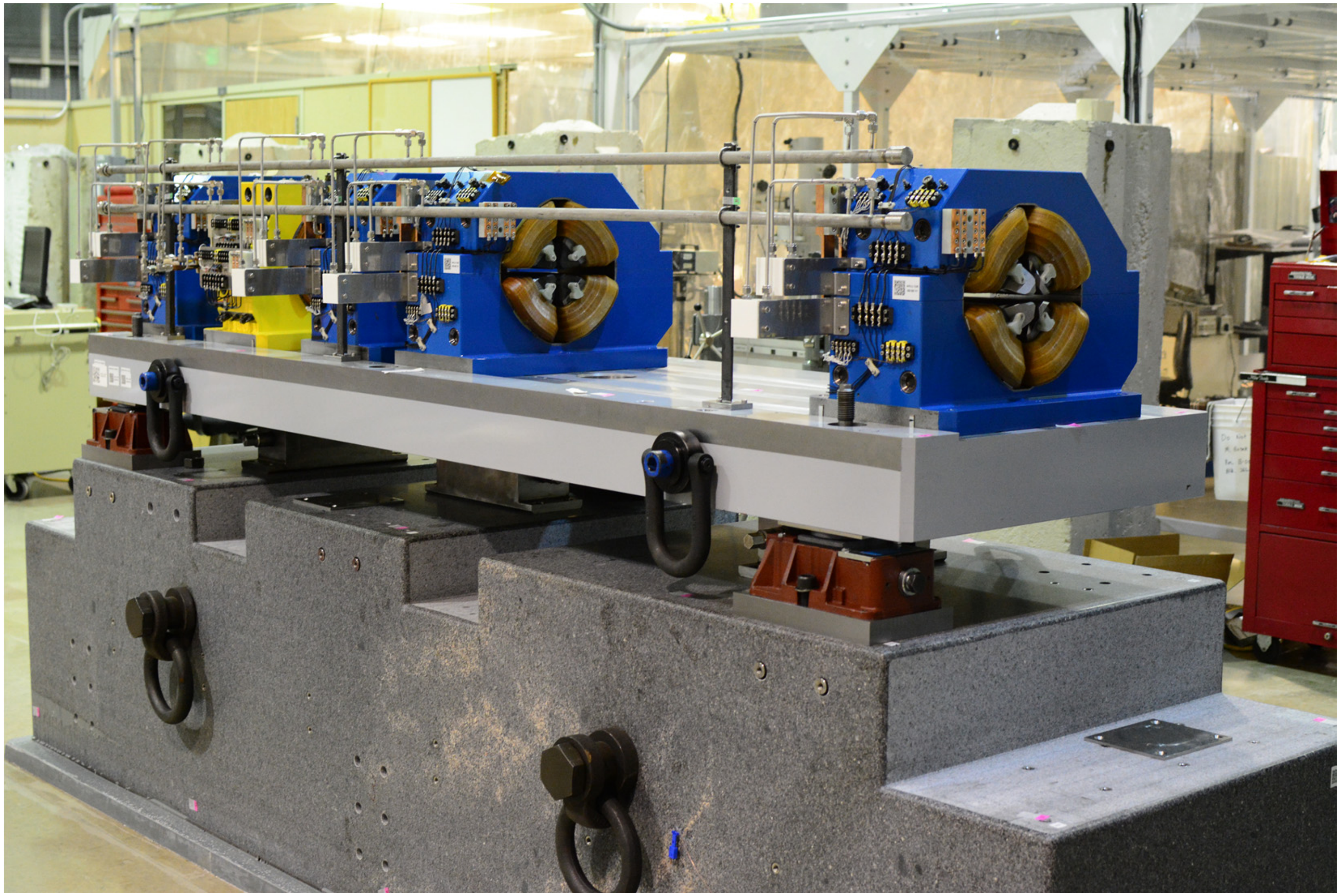
SUBSTRUCTURE BEHAVIOR

A brief word about damping…



In the context of analysis, damping is a knob that can be turned…

CONSIDER THE MAGNET SUPPORT SYSTEM CASE



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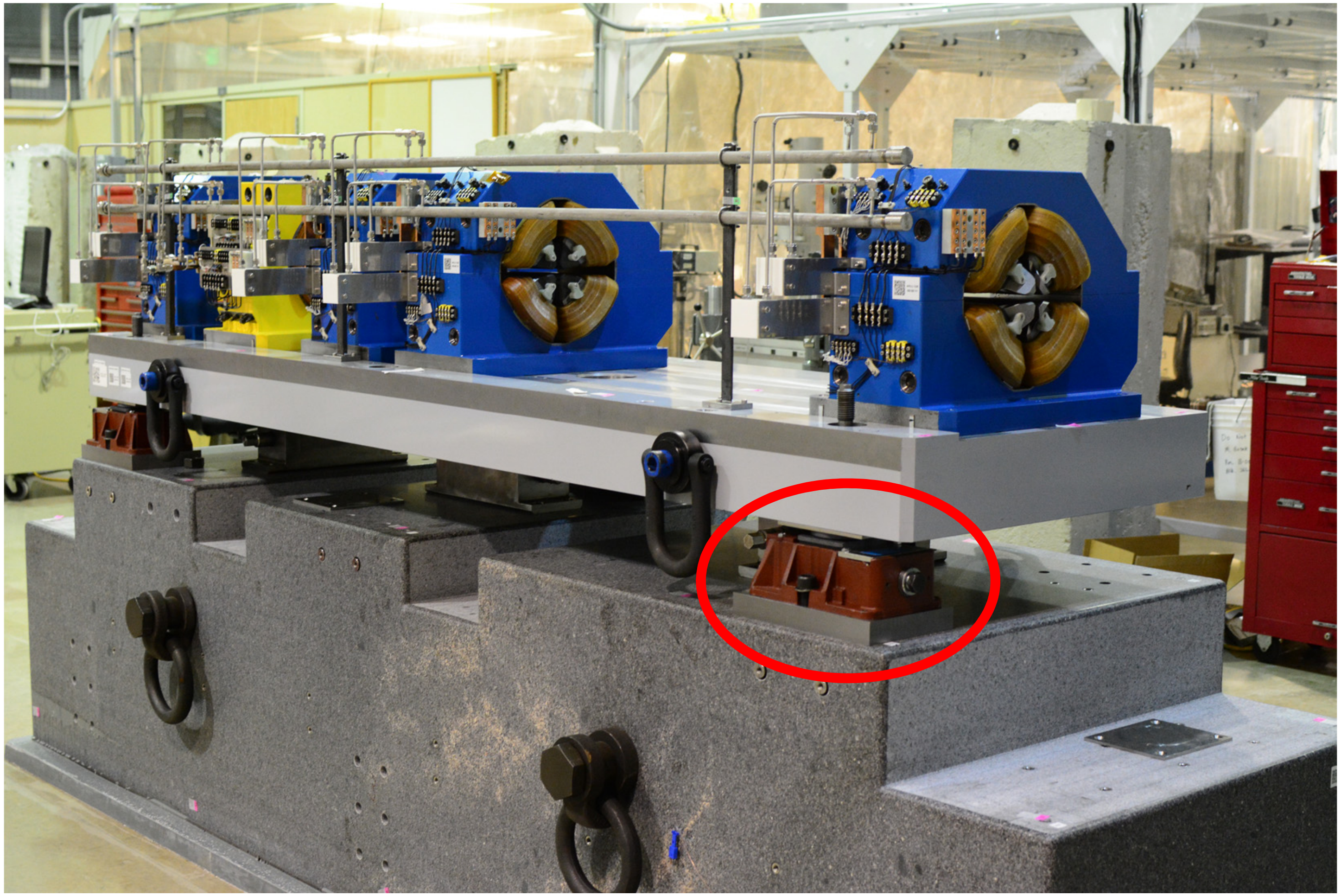

SUPPORT MECHANISM PROPERTY IDENTIFICATION

Possible methods…

- “Constitutive” FEA modeling
- Static testing
- Dynamic testing

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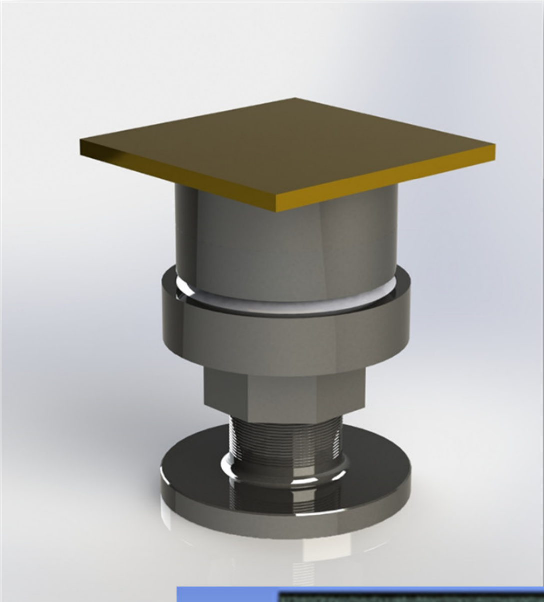
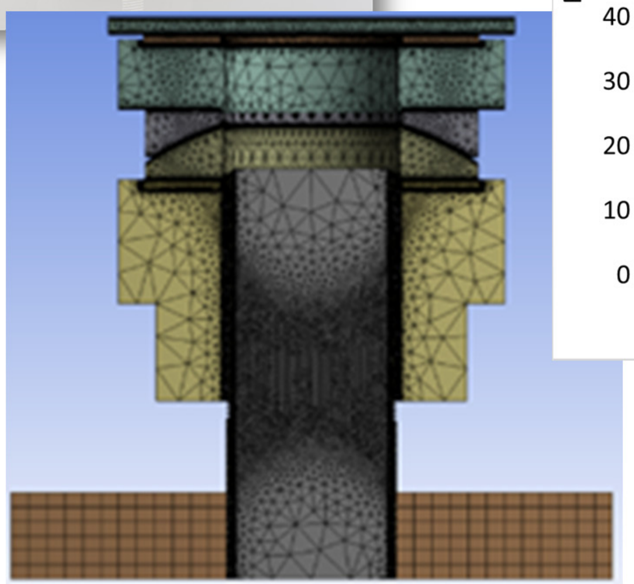
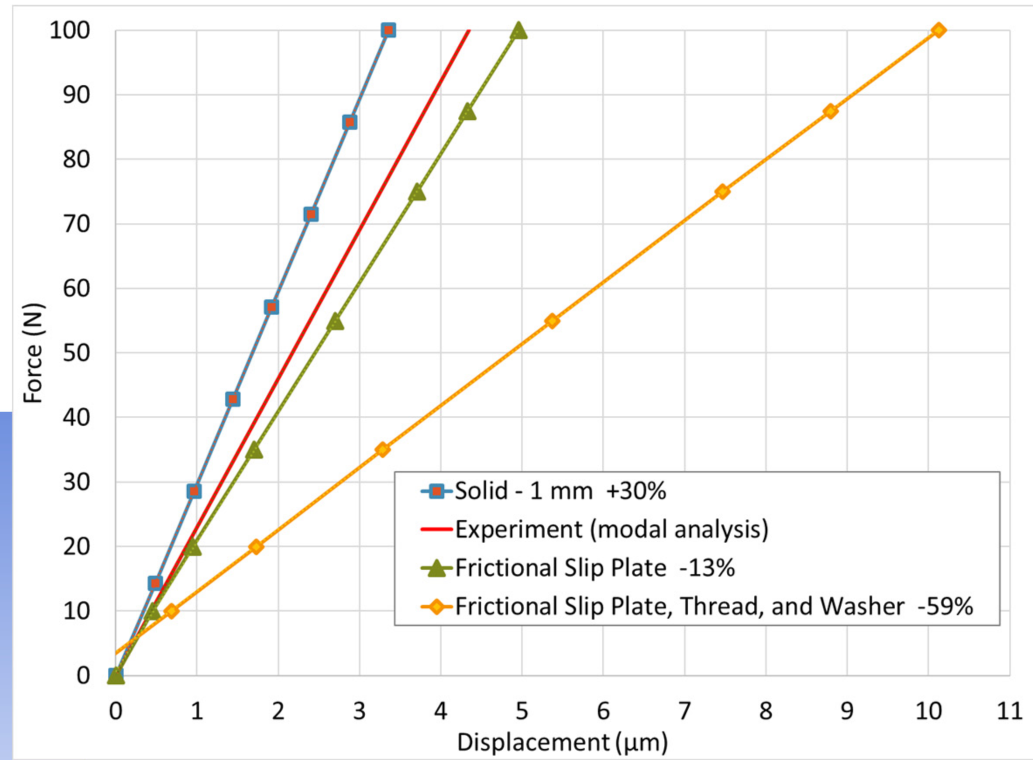
- Dynamic testing
  - Pro: provides stiffness *and* damping data, fully populated stiffness matrix if desired (with only one test)
  - Con: need vibration test equipment, some fixturing (easiest with free B.C.s)

“CONSTITUTIVE” FEA MODELING

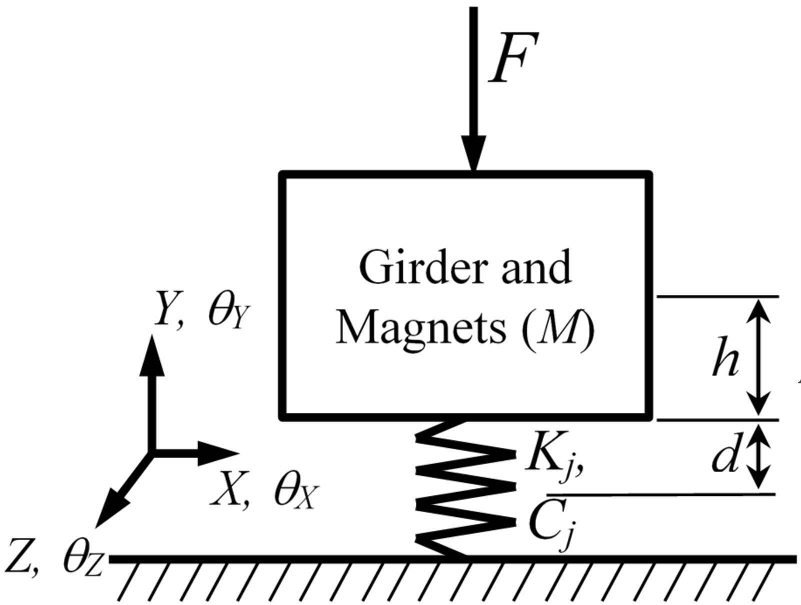






STATIC TESTING

DYNAMIC STIFFNESS TESTING



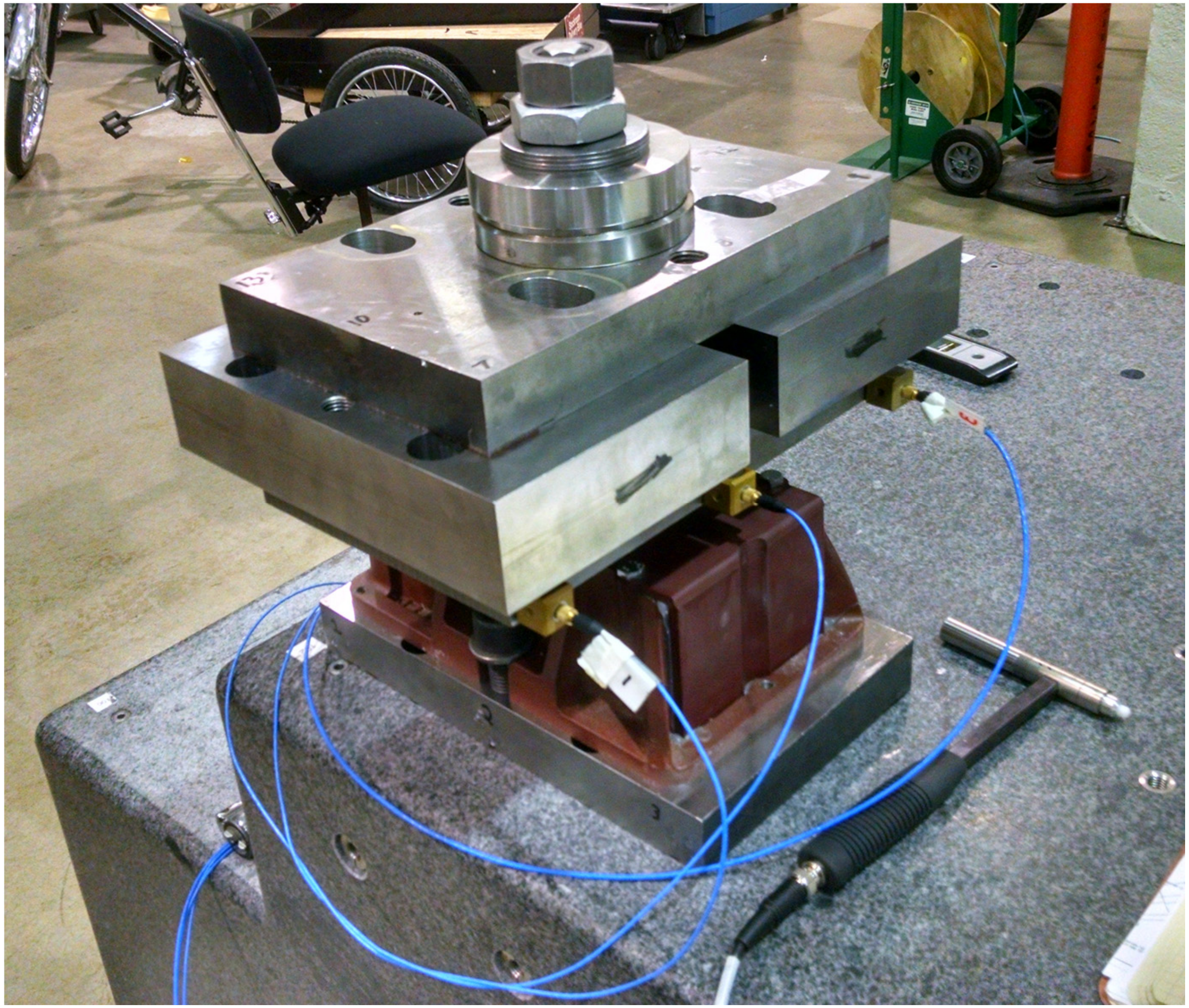
$$F = \mathrm{M}\ddot{\mathrm{x}} + \mathrm{C}\dot{\mathrm{x}} + \mathrm{Kx}$$

$$K_J = \begin{bmatrix} K_{XX} & K_{XY} & K_{XZ} & K_{X\theta x} & K_{X\theta y} & K_{X\theta z} \\ & K_{YY} & K_{YX} & K_{Y\theta x} & K_{Y\theta y} & K_{Y\theta z} \\ \vdots & & K_{ZZ} & K_{Z\theta x} & K_{Z\theta y} & K_{Z\theta z} \\ & & & K_{\theta X} & K_{\theta x\theta y} & K_{\theta x\theta z} \\ \vdots & \iddots & & & K_{\theta y} & K_{\theta y\theta z} \\ & \cdots & & \cdots & & K_{\theta Z} \end{bmatrix}_{sym}$$

$$K = \begin{bmatrix} K_{XX} & 0 & 0 & 0 & 0 & (h+d)K_{XX} \\ 0 & K_{YY} & 0 & 0 & 0 & 0 \\ 0 & 0 & K_{ZZ} & -(h+d)K_{ZZ} & 0 & 0 \\ 0 & 0 & -(h+d)K_{ZZ} & K_{\theta X} + (h+d)^2 K_{ZZ} & 0 & 0 \\ 0 & 0 & 0 & 0 & K_{\theta y} & 0 \\ (h+d)K_{XX} & 0 & 0 & 0 & 0 & K_{\theta Z} + (h+d)^2 \end{bmatrix}$$

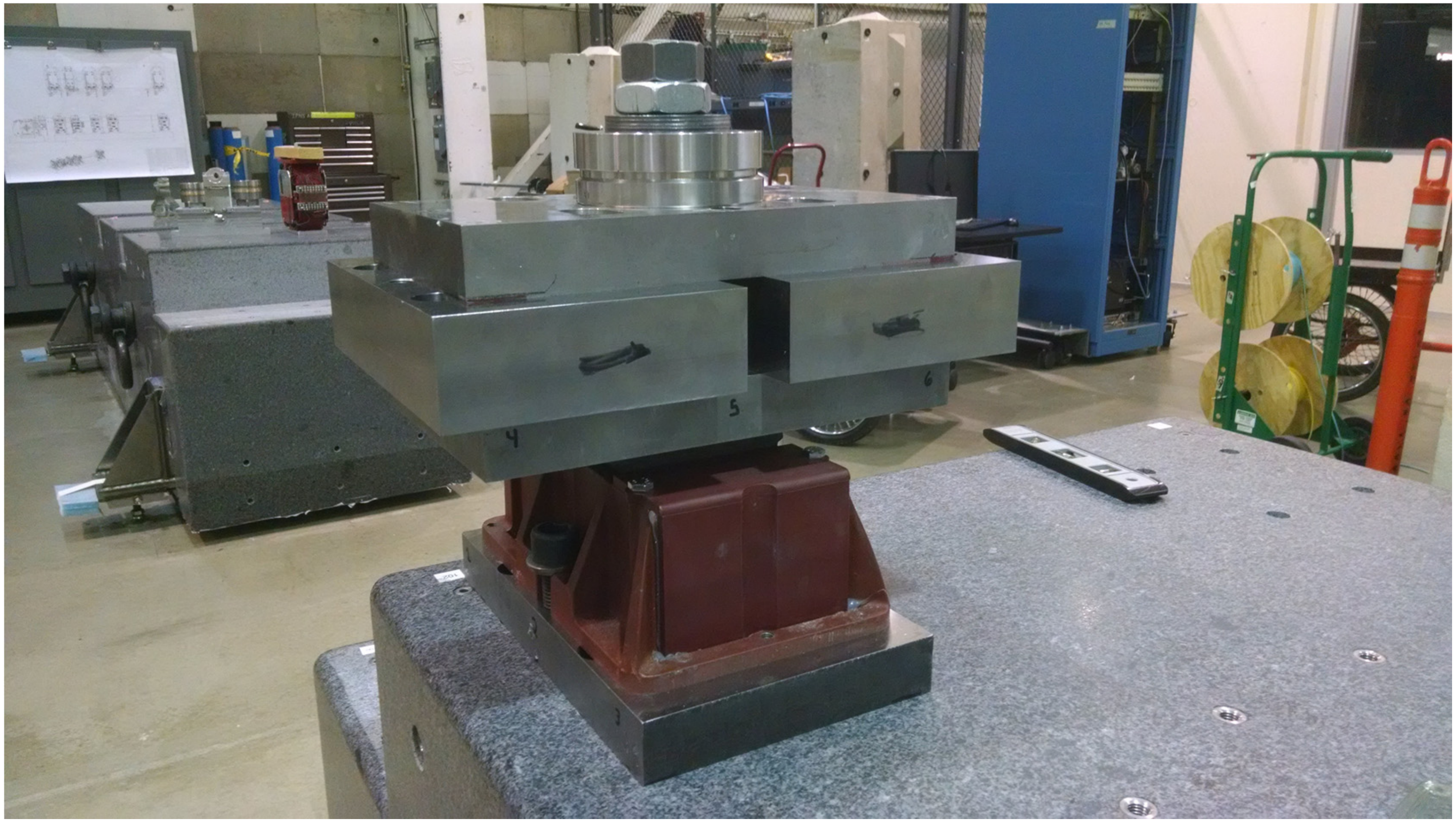
RK-IV STIFFNESS TEST

“Table-top” test

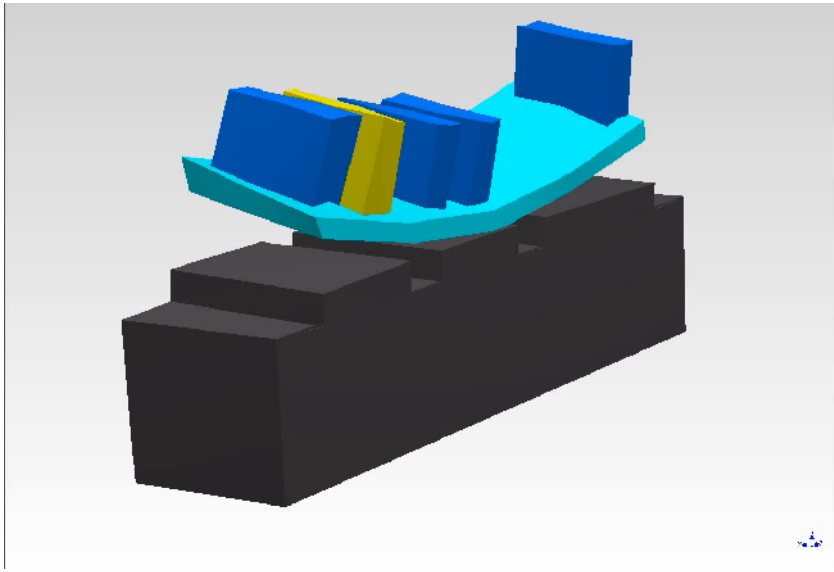


RK-IV STIFFNESS TEST

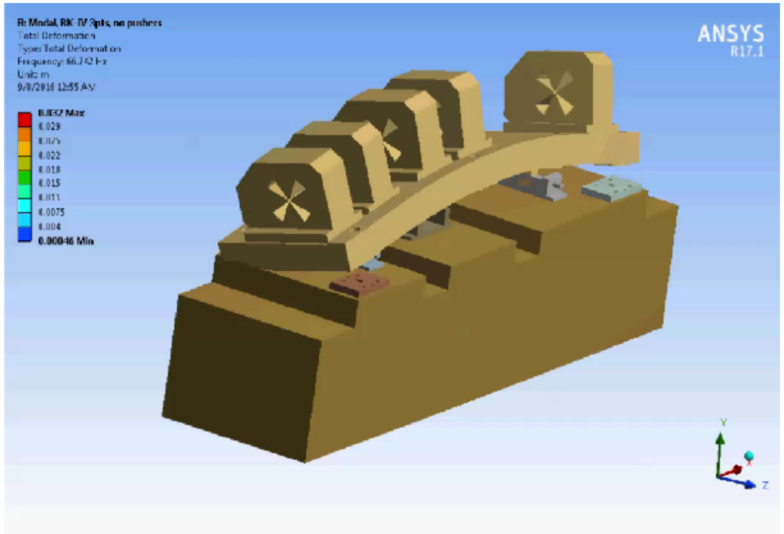
“Table top” test



MODAL ANALYSIS COMPARISON



EMA Mode 1 64 Hz



FEA Mode 1 67 Hz
5% difference

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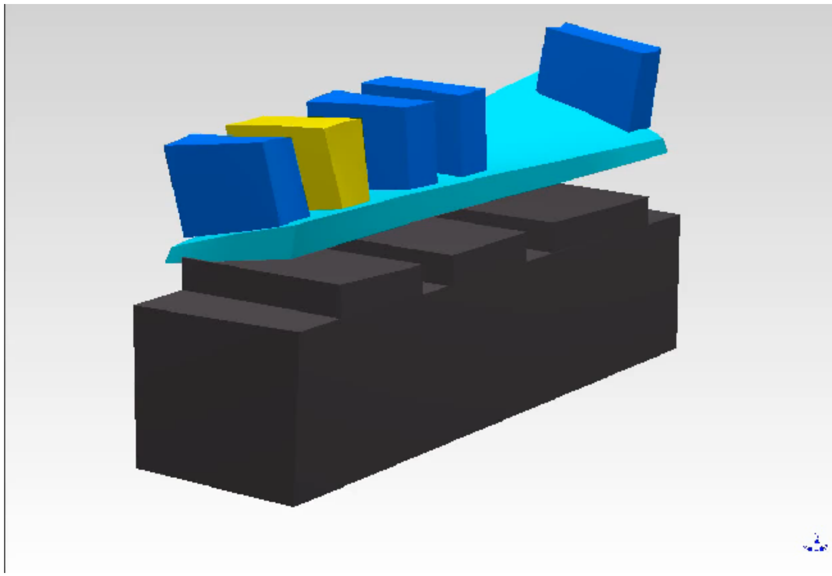
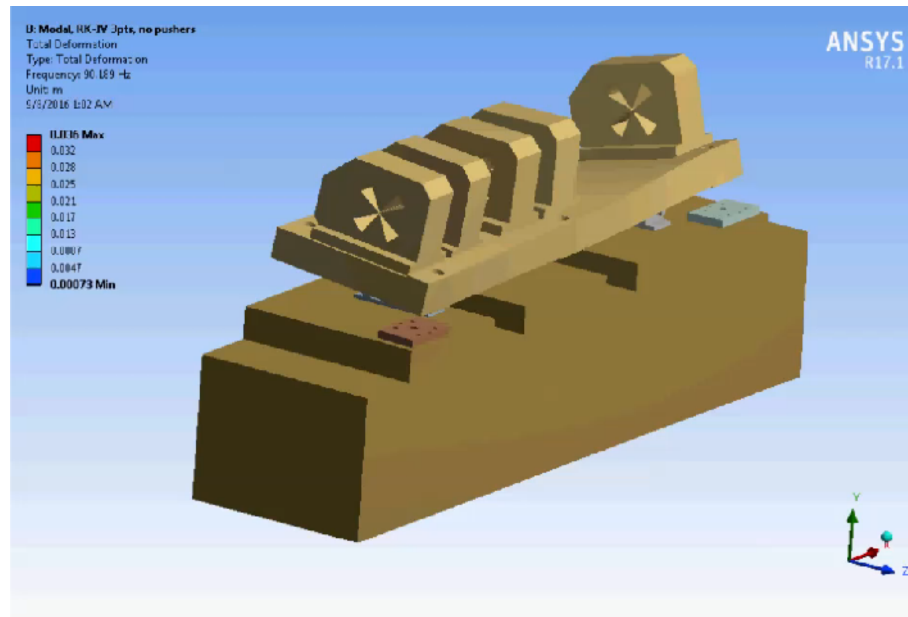
MODAL ANALYSIS COMPARISON

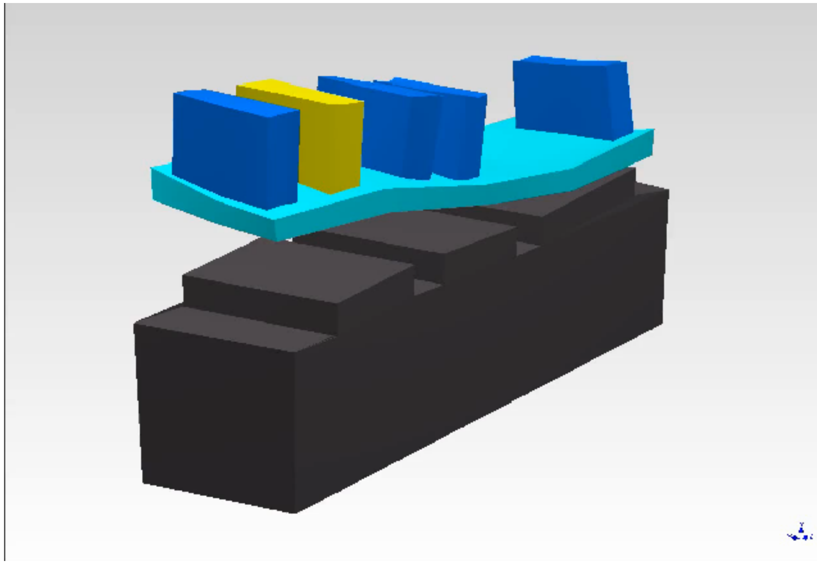


EMA Mode 2 91 Hz

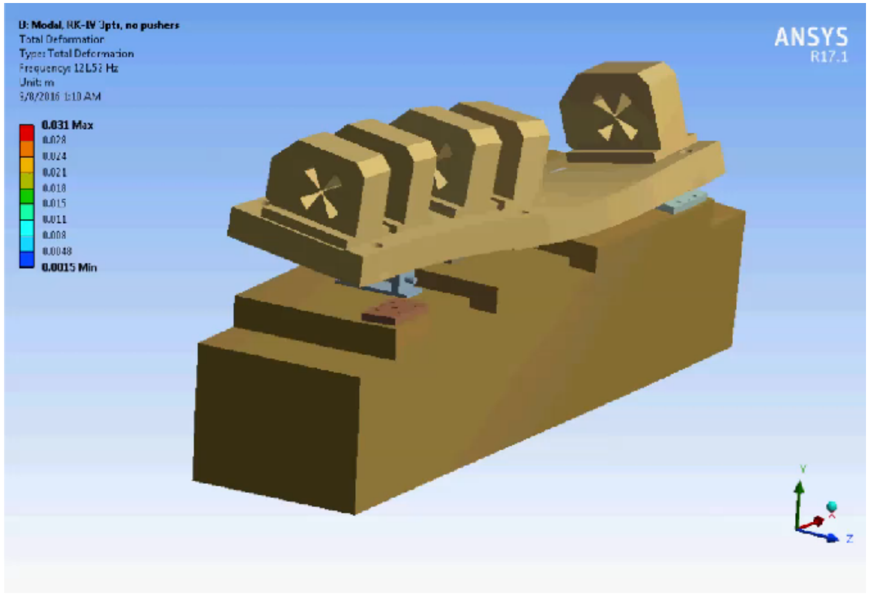


FEA Mode 2 90 Hz
1% difference

MODAL ANALYSIS COMPARISON

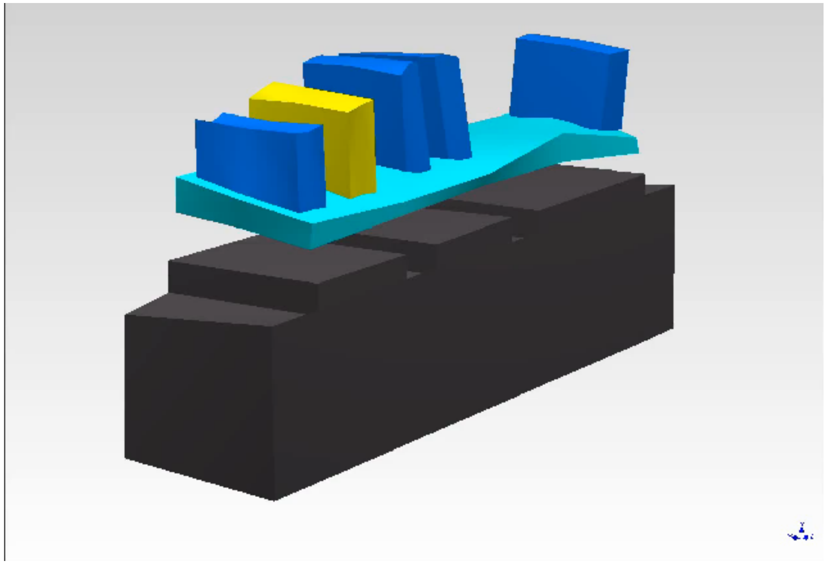


EMA Mode 3 130 Hz

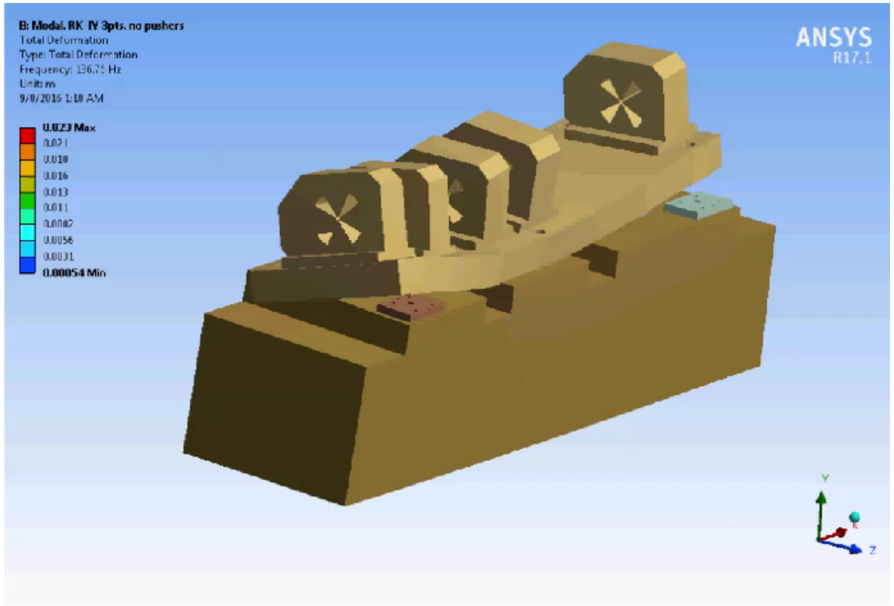


FEA Mode 4 (3) 122 Hz
6% difference

MODAL ANALYSIS COMPARISON



EMA Mode 4 137 Hz



FEA Mode 5 (4) 137 Hz
0% difference

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MOLTES GRÀCIES!

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