Walk-in Slide: AU 2014 Social Media Feed

1. Click on the link below, this will open your web browser

http://aucache.autodesk.com/social/visualization.html

2. Use “Extended Display” to project the website on screen if you plan to work on your computer. Use “Duplicate” to display same image on screen and computer.

Beyond Inventor Sim: Taking Simulation to the Next Level with Autodesk Nastran In-CAD

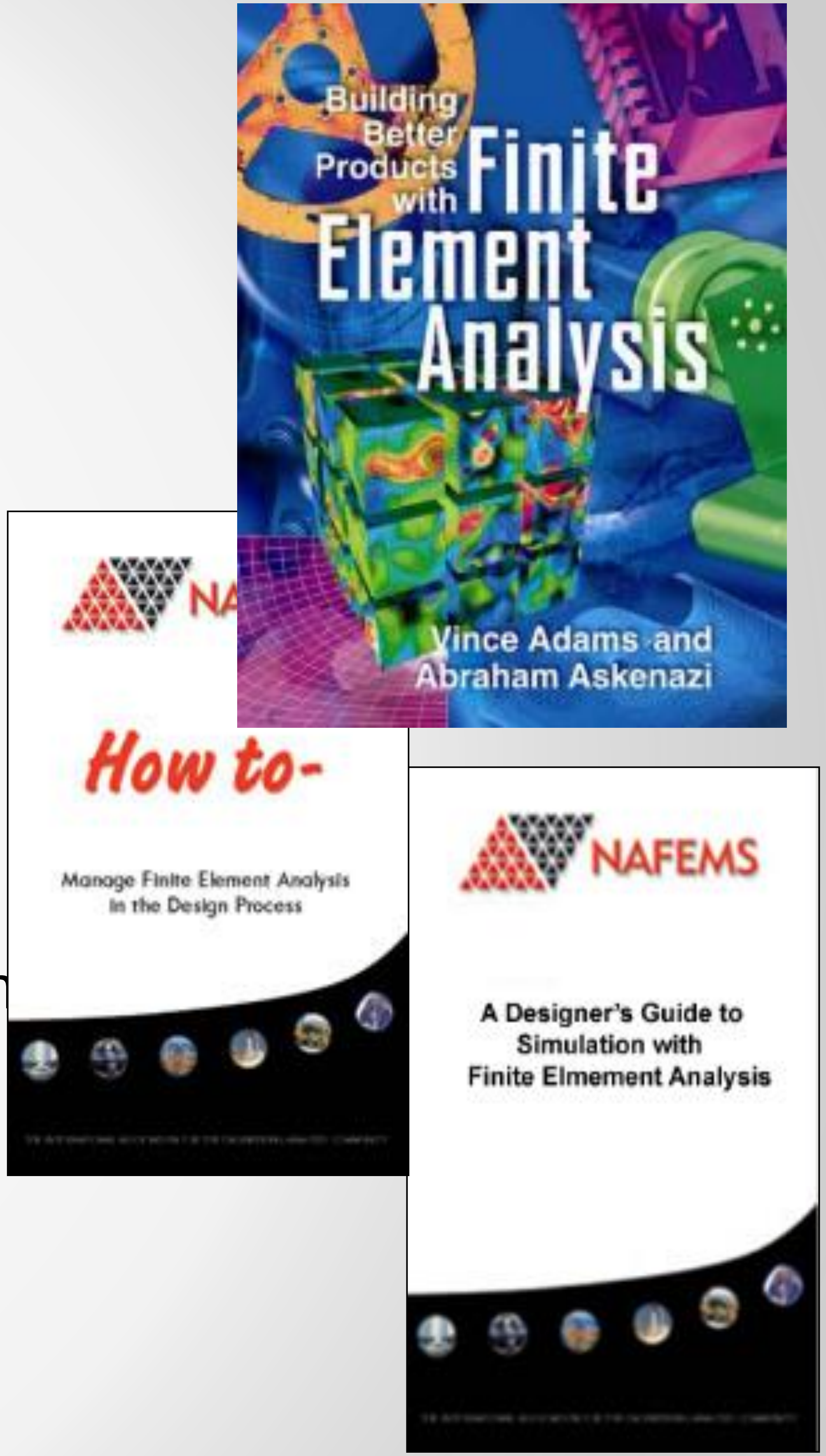
Vince Adams

Autodesk Simulation Business Development

Vince.Adams@Autodesk.com

Background on Vince Adams

- Career started in product design & engineering management
- Focused on Use, Training, and Support of Finite Element Analysis for 20 Years
- Active in Leadership of FEA User's Groups
- Inaugural Chairman; NAFEMS North America
- Co-Authored "Building Better Products with Finite Element Analysis" & authored 2 NAFEMS Books on FEA in Design
- International Speaker/Lecturer on FE Concepts
- Regular contributor on FEA related topics to Desktop Engineerin Magazine, Design News & Ansys Solns
- Recently selected as a Founding Member to the NAFEMS PSE (Professional Simulation Engineer) Certification Program



Class summary

90% of Finite Element Analysis performed today is Linear Static. **However, real life is rarely linear or static.**

Advanced analysis techniques are now accessible with Autodesk Nastran In-CAD so 21st century engineers can:

- Test more products digitally
- Test more product behaviors and failure modes digitally
- Innovate with new materials & in new markets with confidence historically requiring years of product history

Key learning objectives

At the end of this class, you will be able to:

- Recognize the need for and apply advanced Boundary Conditions
- Use digital prototyping to assess the danger of buckling
- Model multiple types of vibration and interpret results for better decisions
- Identify the 3 common types of nonlinearity and capture them in a model

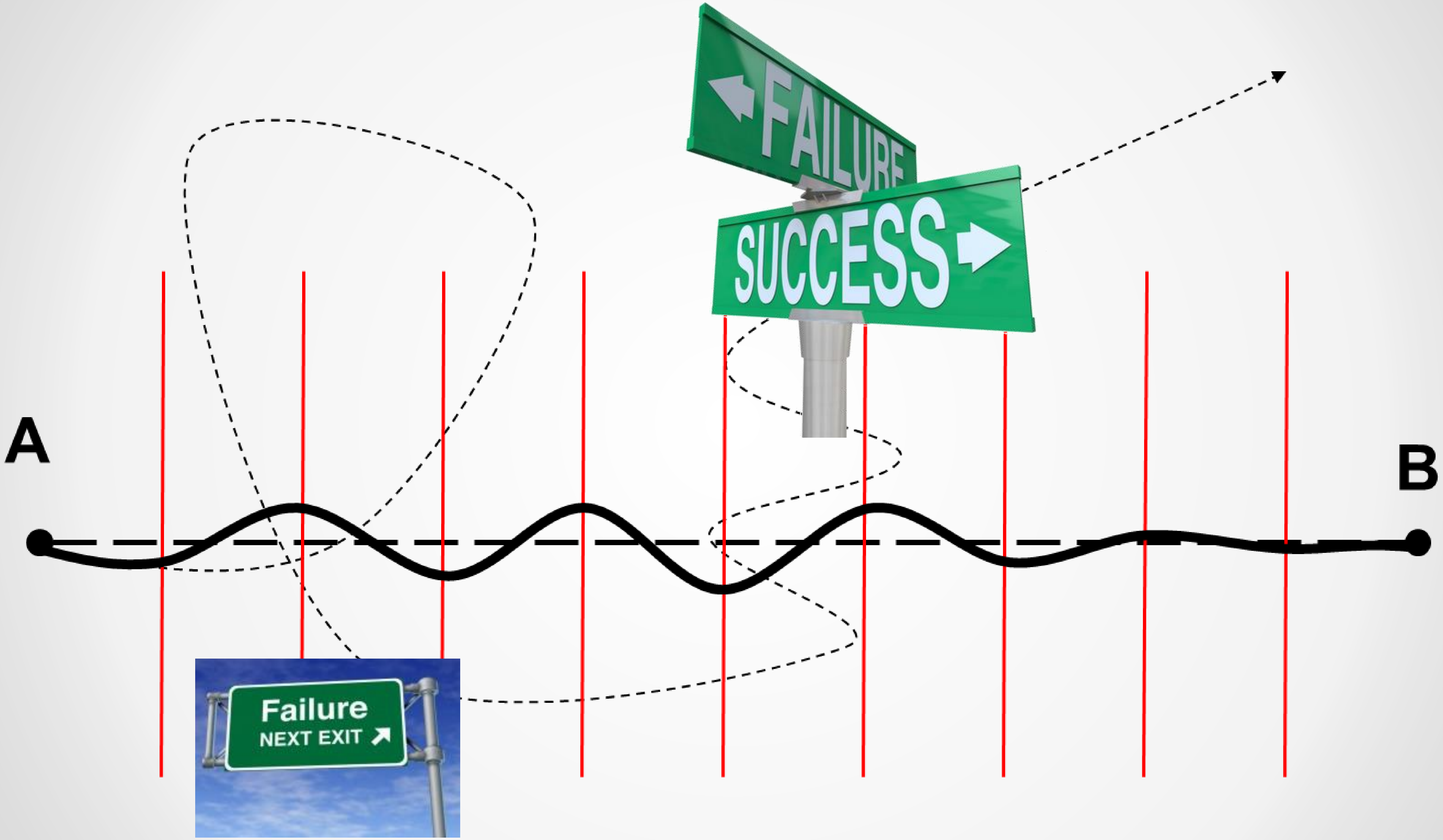
Key Concepts in Finite Element Analysis

The Role of Analysis in Innovation…

What are the benefits of using analysis to innovate?

- A process to achieve Inspired Improvements
- More prototypes in less time…maybe even **The Big Idea!**
- "Fast Failure"
- Shorter & less costly product development cycles
- Opportunity to optimize increases exponentially

Innovation is not a Linear Process…



… and all behavior should be on the table.

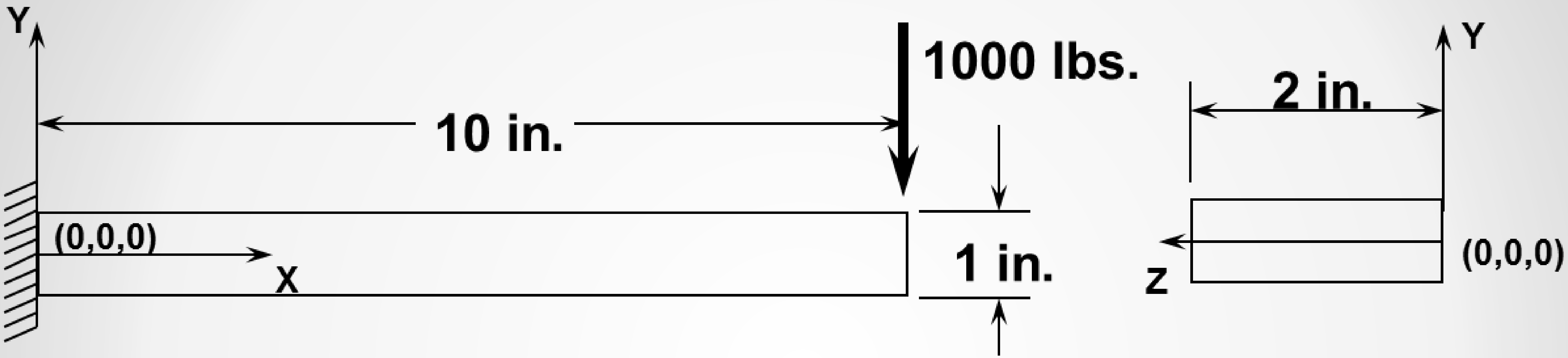
- **Static:** Slowly applied, continuous load
  - Includes contact, contact with friction, large displacement/stress stiffening
- **Frequency:** Distinct natural frequencies to understand vibration response
- **Dynamic:** Actual response to time or frequency-based inputs
- **Buckling:** Stiffness-related instability resulting from compression
- **Thermal:** Temperature variation or flux
- **Drop Test:** Impact of part or assembly with ground
- **Fatigue:** Response to cyclic load; estimate life/durability
- **Nonlinear:** Nonlinear stress-strain or path dependent behavior

What is Finite Element Analysis?

In the simplest terms, FEA answers complex questions about structural behavior...

Based on a Given Set of Assumptions!

What is Finite Element Analysis?

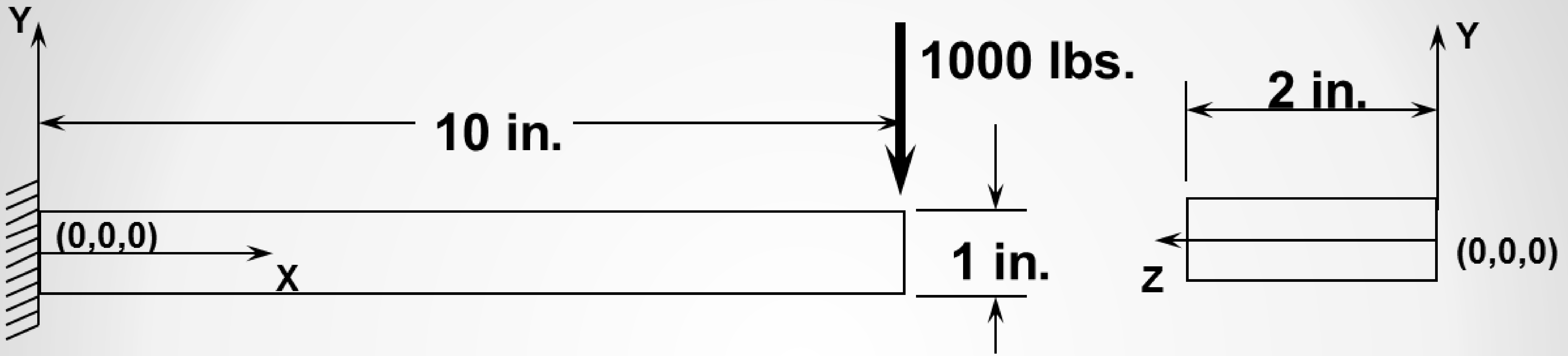


To calculate response by hand, use this information:

- Thickness
- Length
- Width
- Force
- End Condition
- Material Modulus

What else?

What is Finite Element Analysis?



To calculate response by hand, use this information:

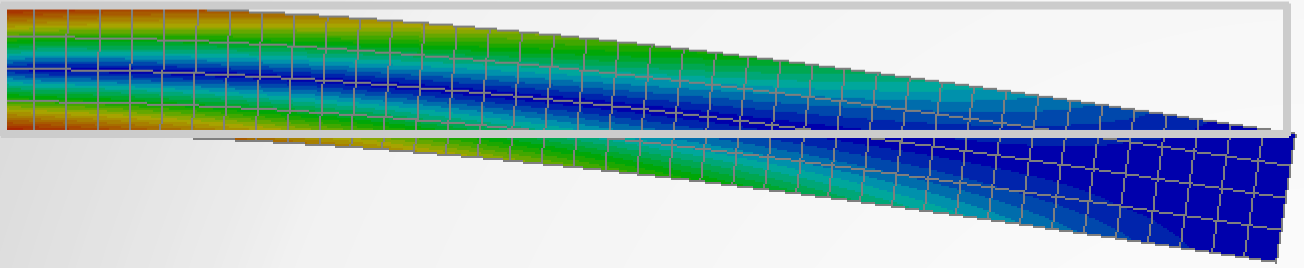
- Thickness
- Length
- Width
- Force
- End Condition
- Material Modulus

What else?

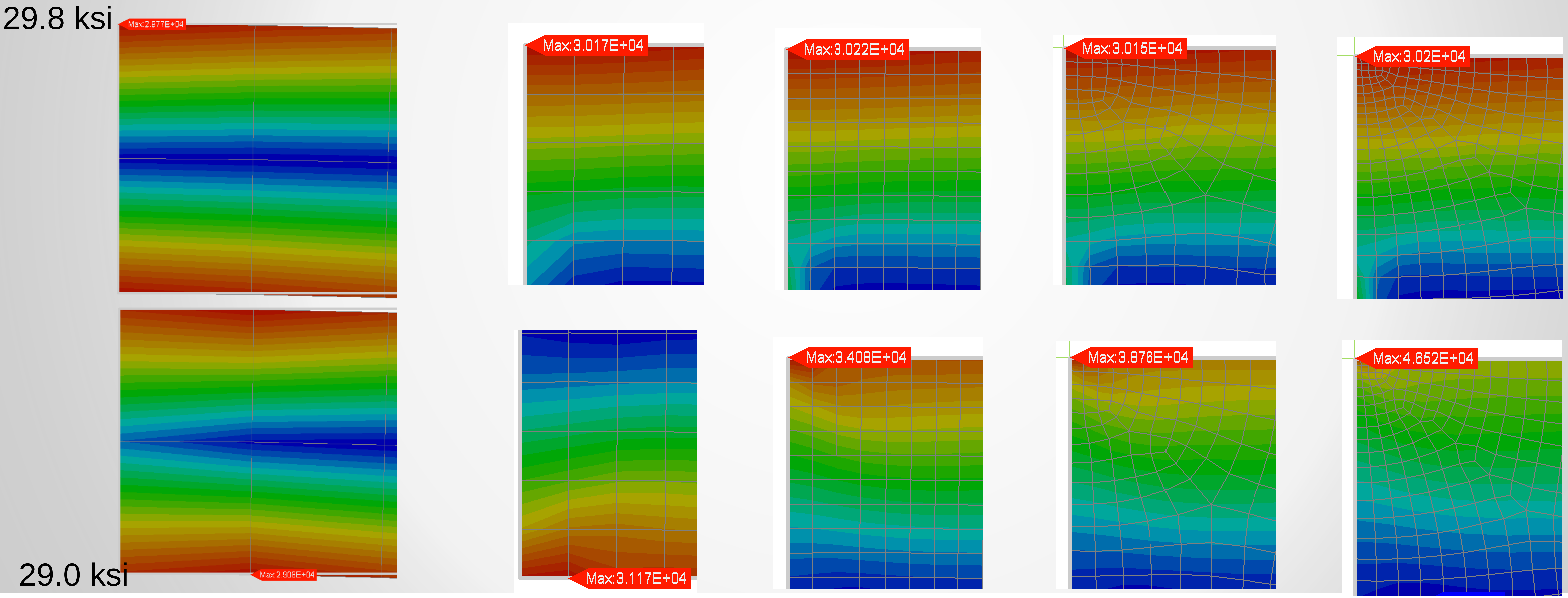
- Gravity Negligible
- Displacement Small
- Stress-Strain Linear
- Force Doesn't Change Magnitude, Orientation, Distribution or Time Dependence

Advanced Boundary Conditions

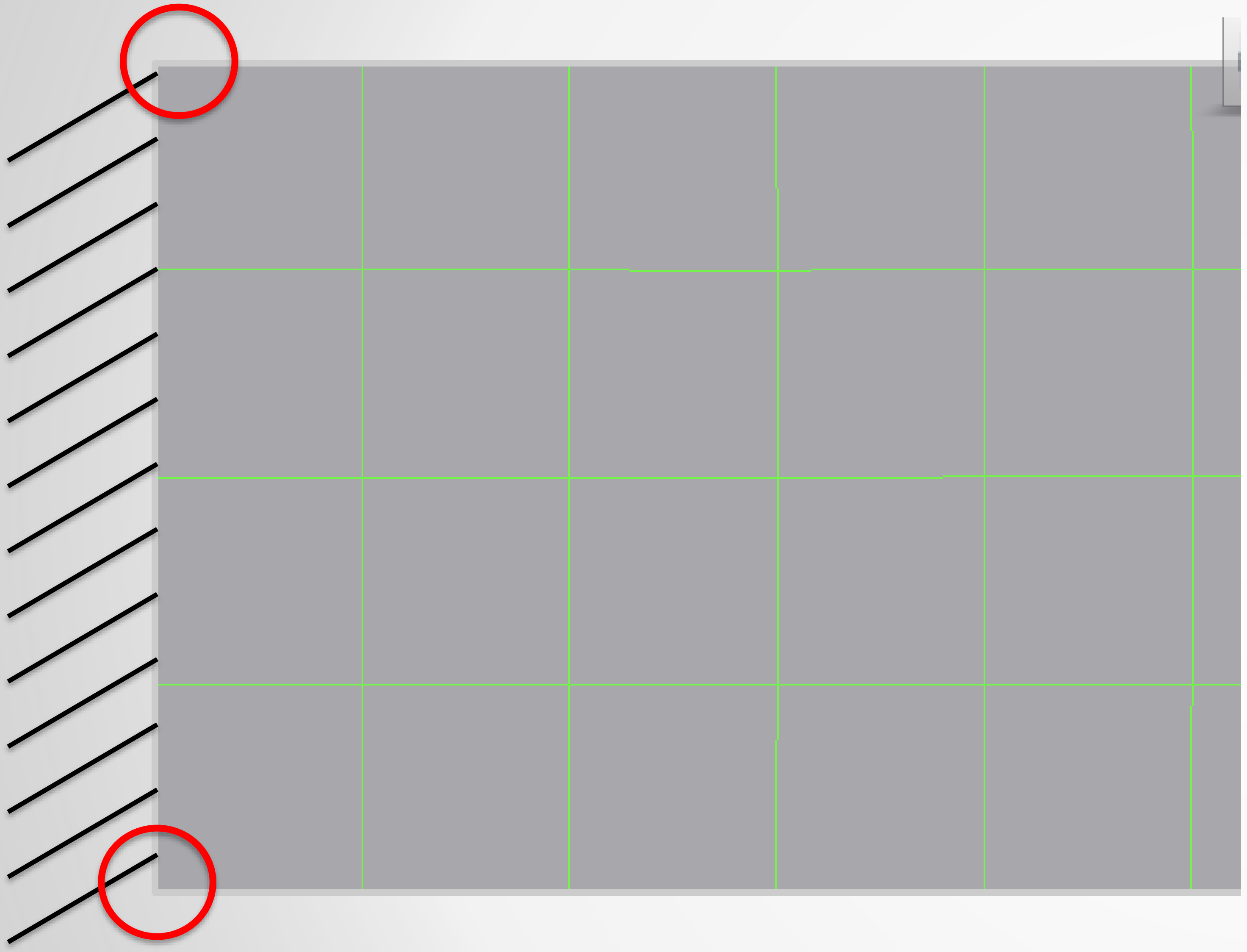
Fixed Constraint on Cantilevered Beam



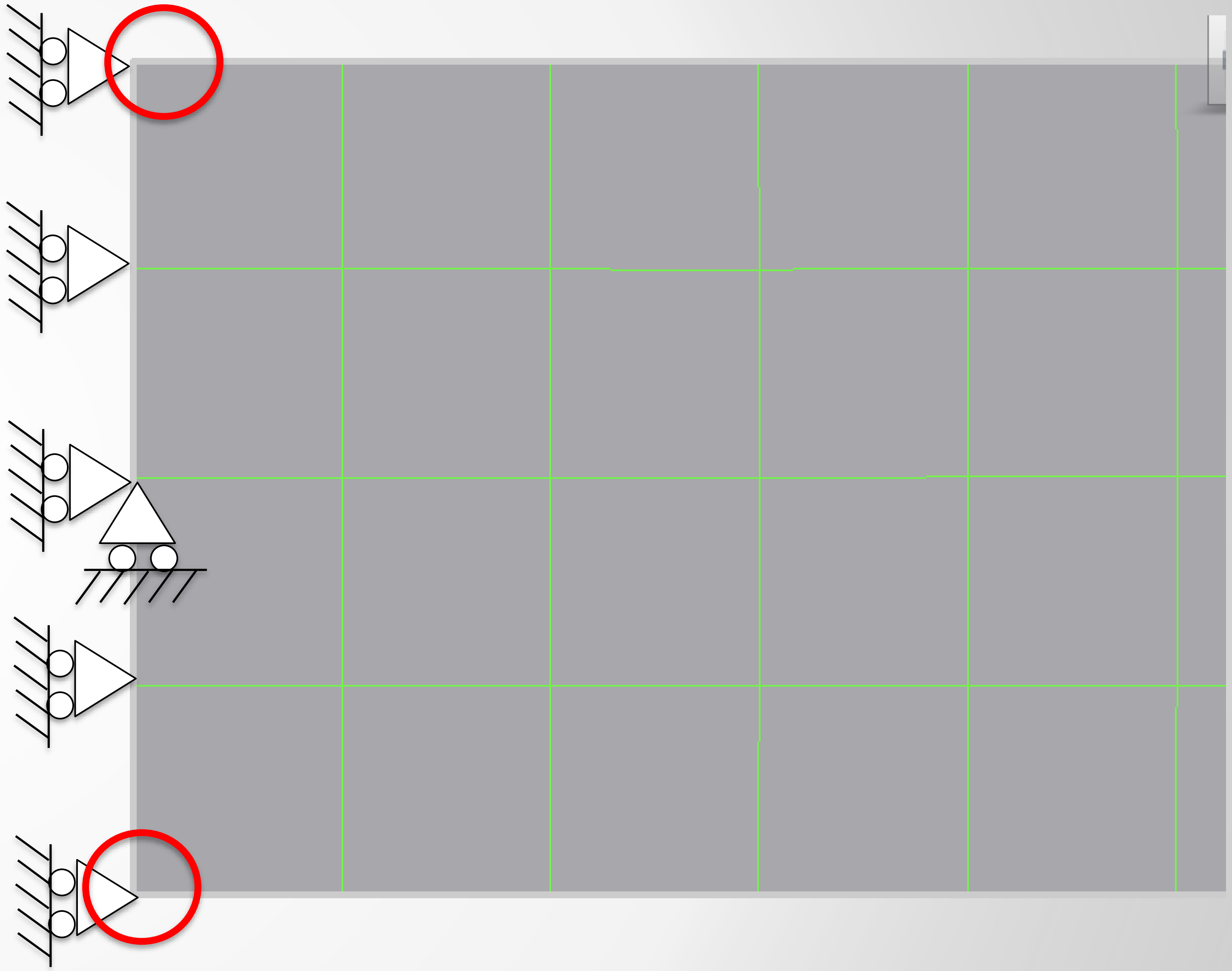
Per Beam Theory: Max Stress = 30ksi



Fixed Constraint on Cantilevered Beam

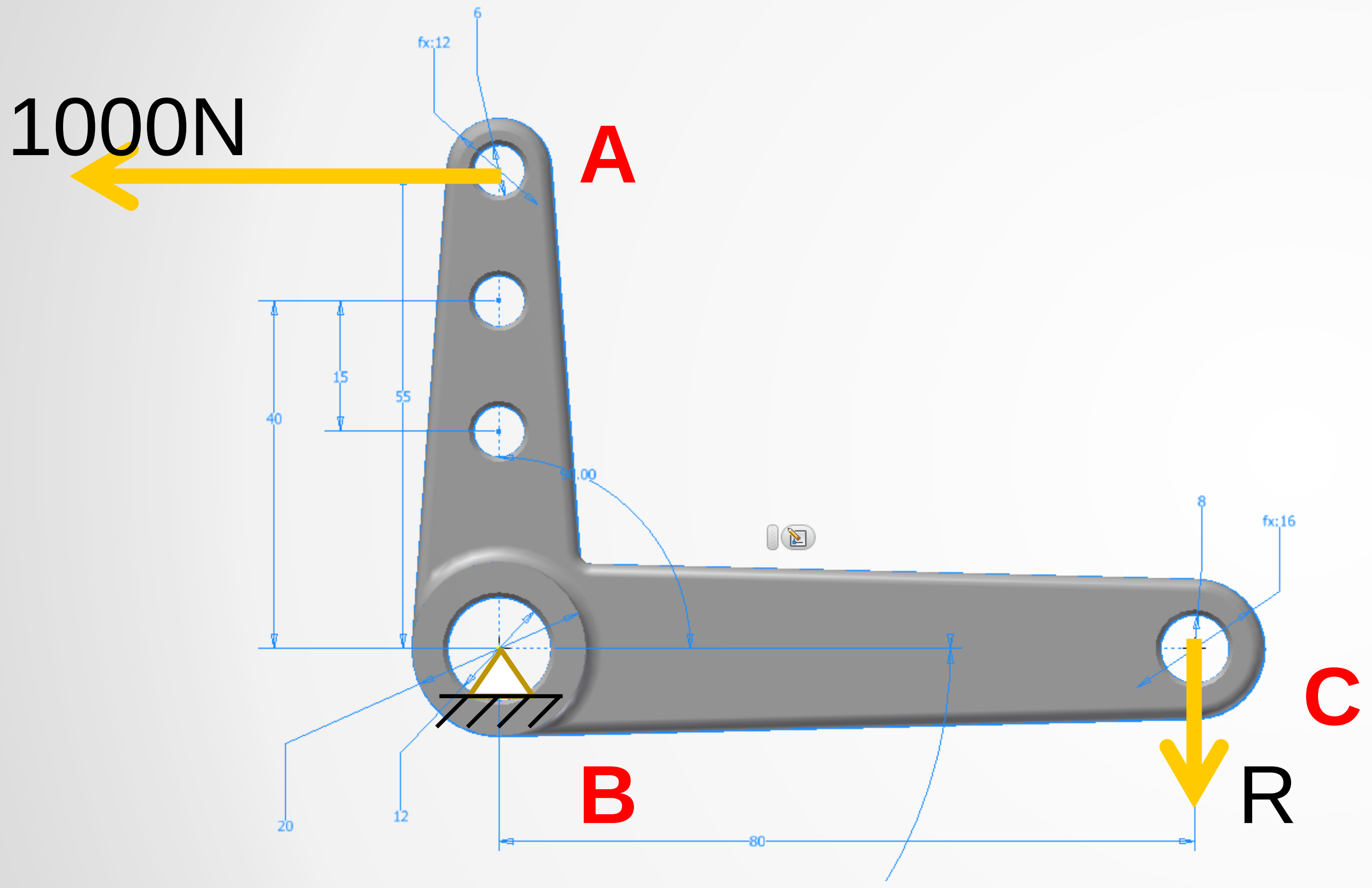


Poisson Effect in Corners



No Poisson Effect in Corners

Cast Lever



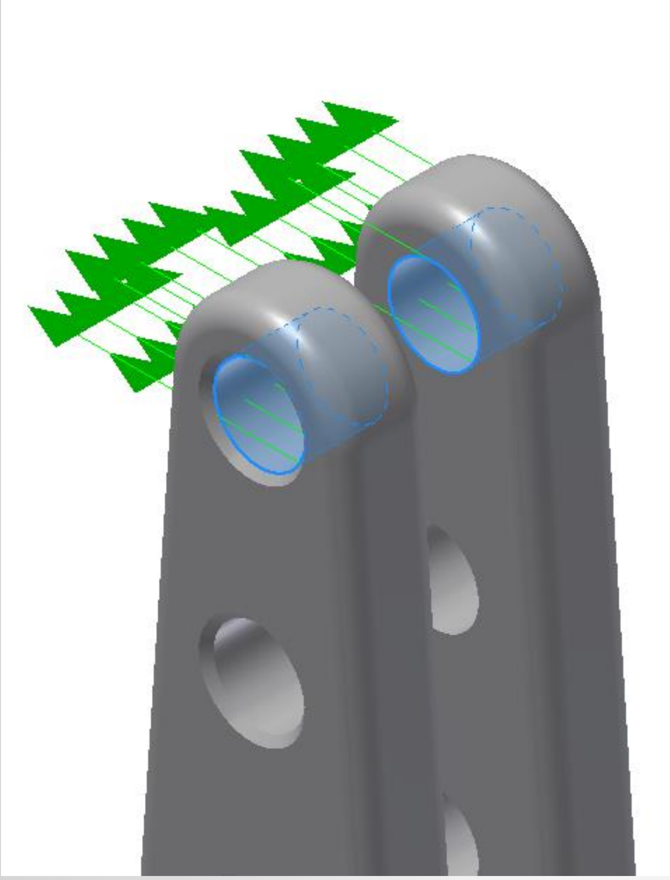
- Lever has 100N applied load in outermost position, Point A
- Lever is pinned at center hole (B) as shown
- Assume rod passes thru hole (C) and is locked against movement. Reaction, R , balances the loads so the part is in static equilibrium.
- Compute applied load, R

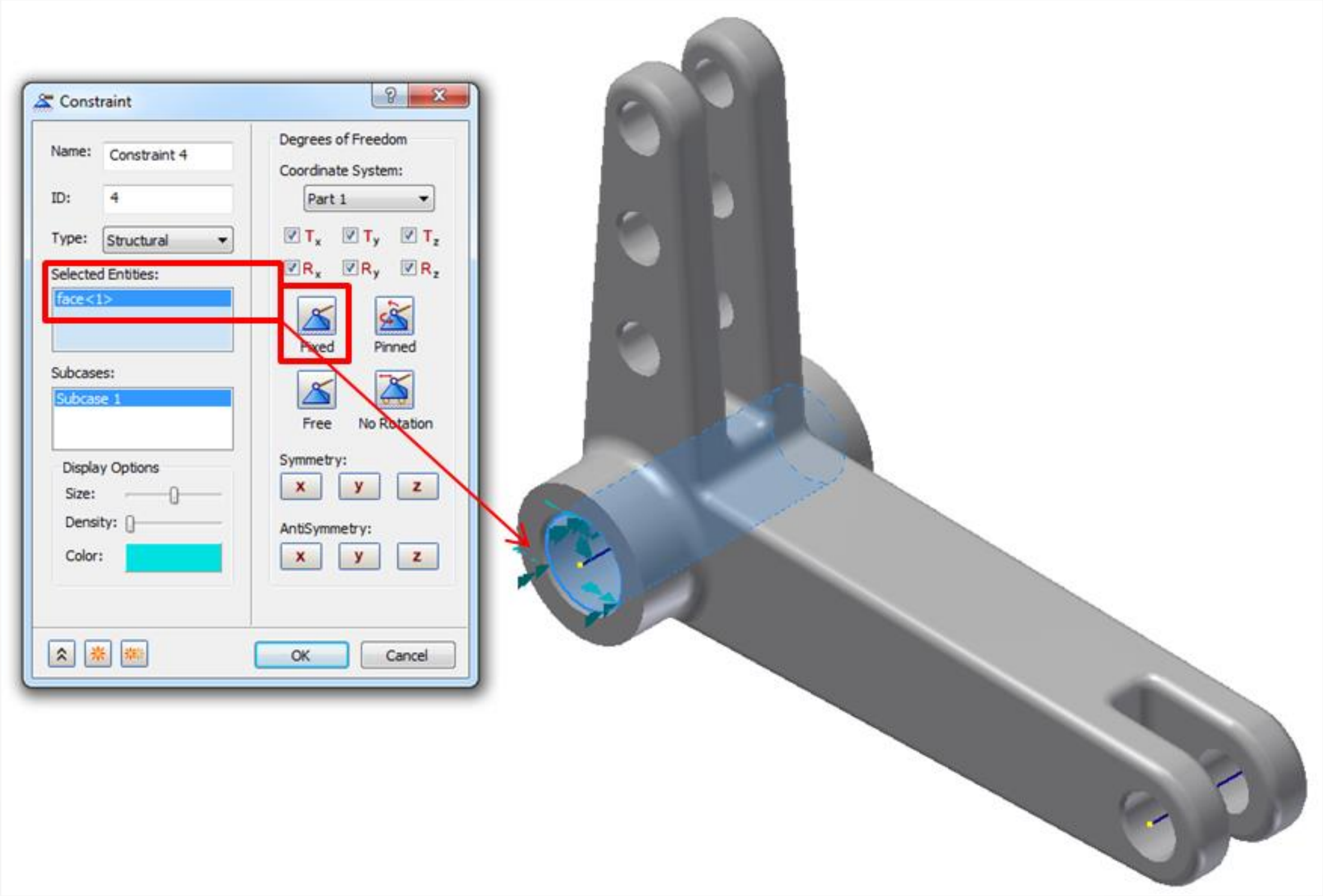
1,000N x 55mm = R x 80 mm

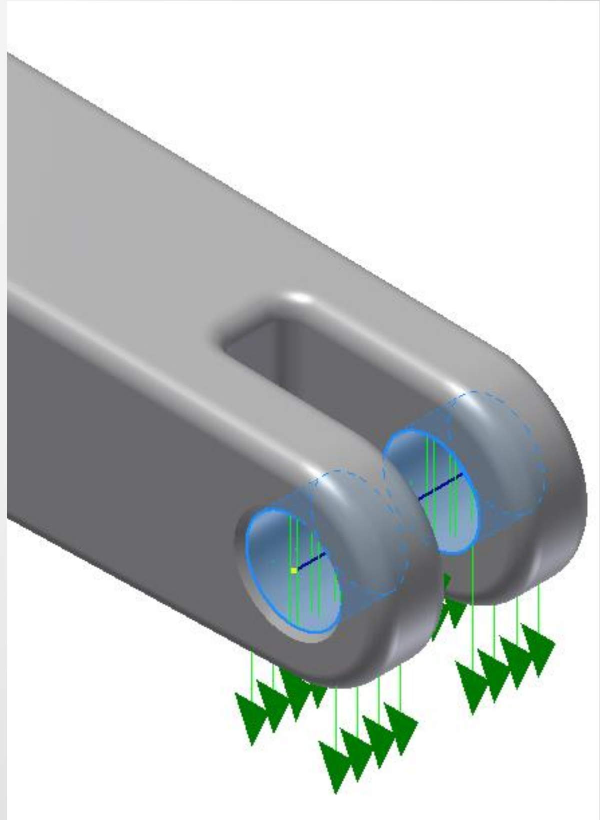
R = (1,000N x 55mm)/80mm

R = 687.5N

Cast Lever – Iteration 1: Fix Pivot

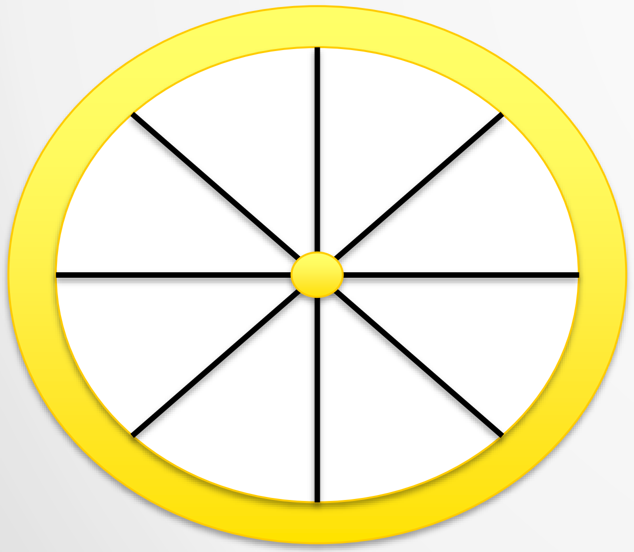


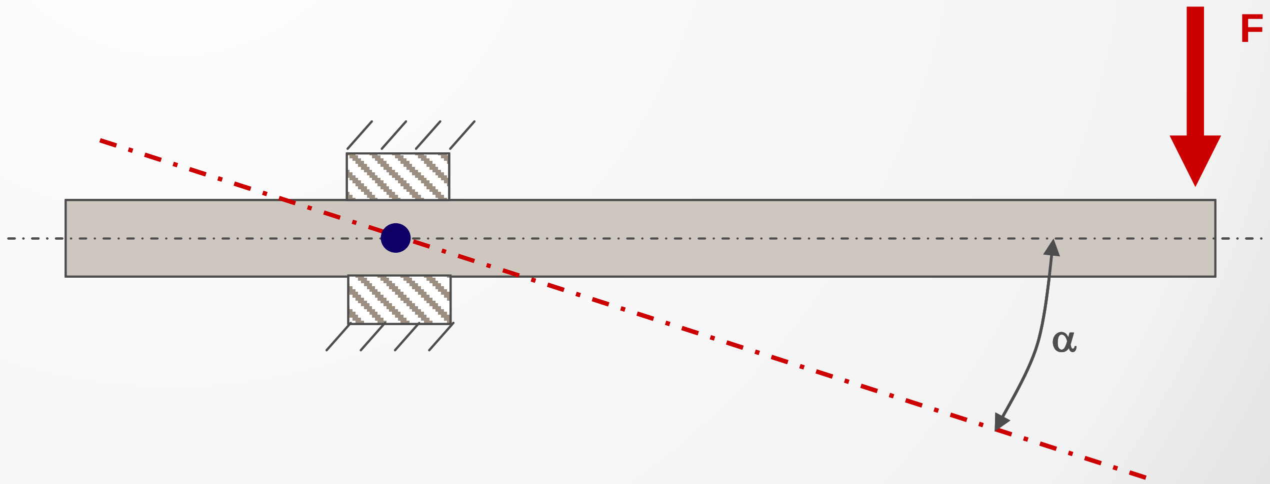




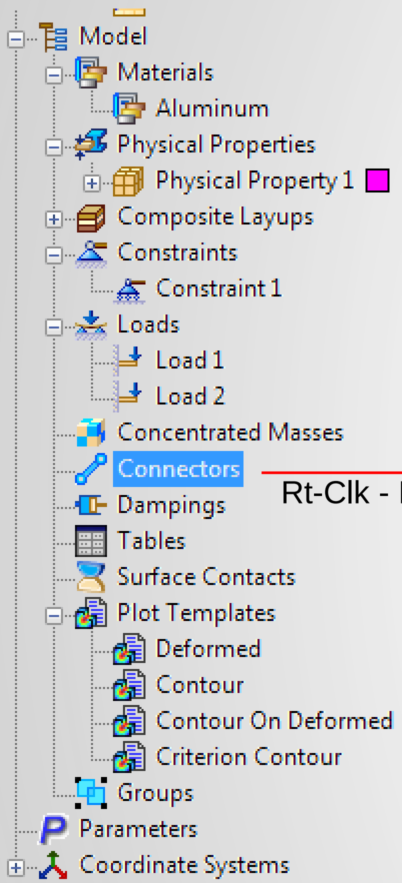
Cast Lever – Iteration 2: “Ball Joint Constraint”

- An important technique in FEA is using “ball joint” constraints to control rotations in a 3D mesh.
- These use rigid elements and are often called “spokes” or “Spiderwebs” to a control, or master, point.
- By tying the 3d movement of an edge or surface to a remote point, engineers are able to add in more natural movement in many situations.
- In Autodesk Nastran In-CAD, this is accomplished using a Rigid Connector

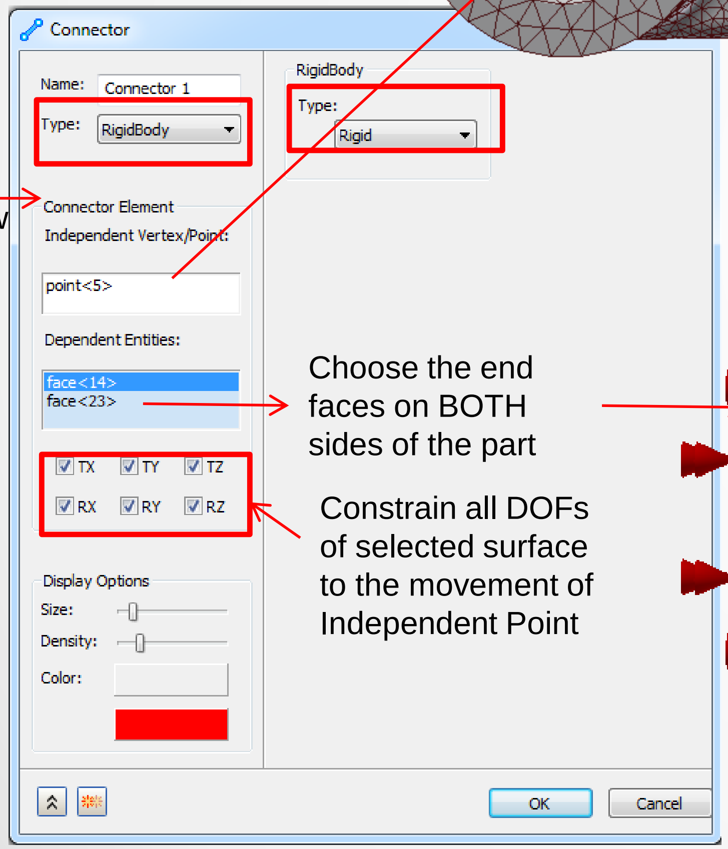


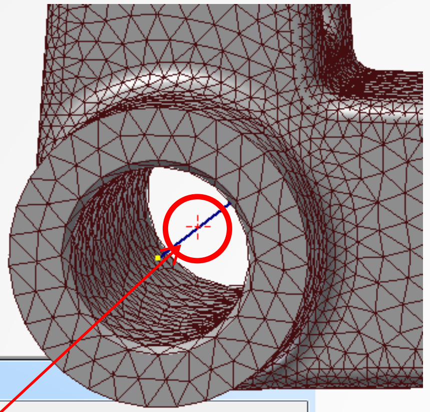


Cast Lever – Iteration 2: “Ball Joint” Constraint

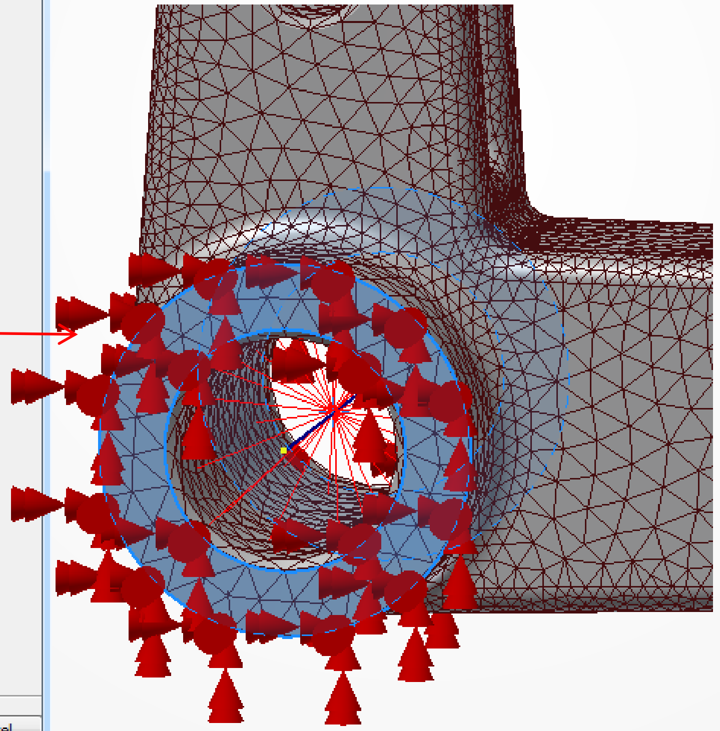


Rt-Clk - New





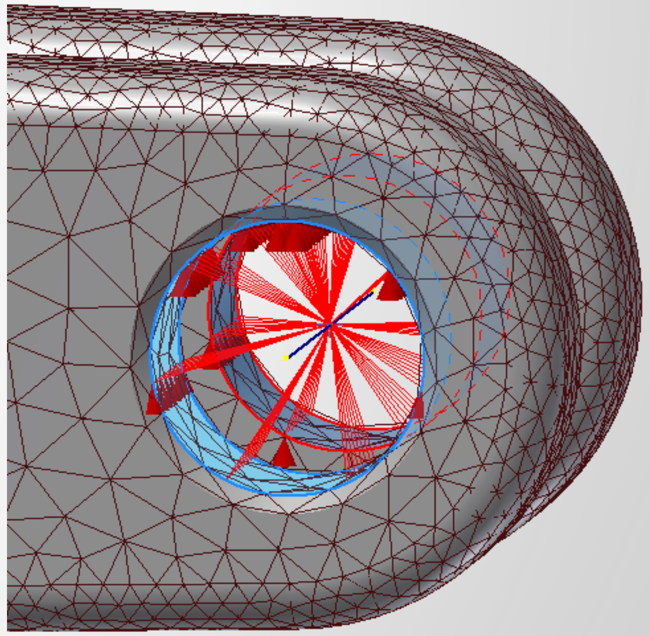
Ref Point located on axis at center of part



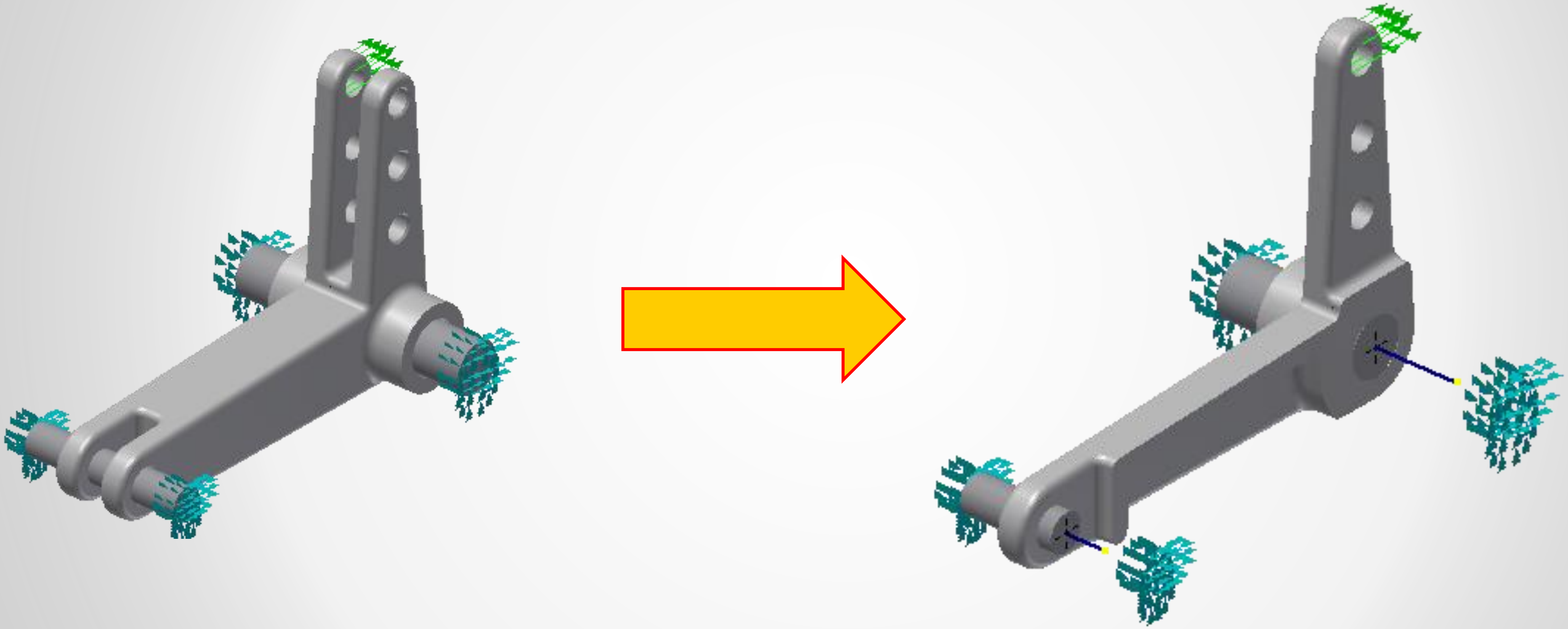
Choose the end faces on BOTH sides of the part

Constrain all DOFs of selected surface to the movement of Independent Point

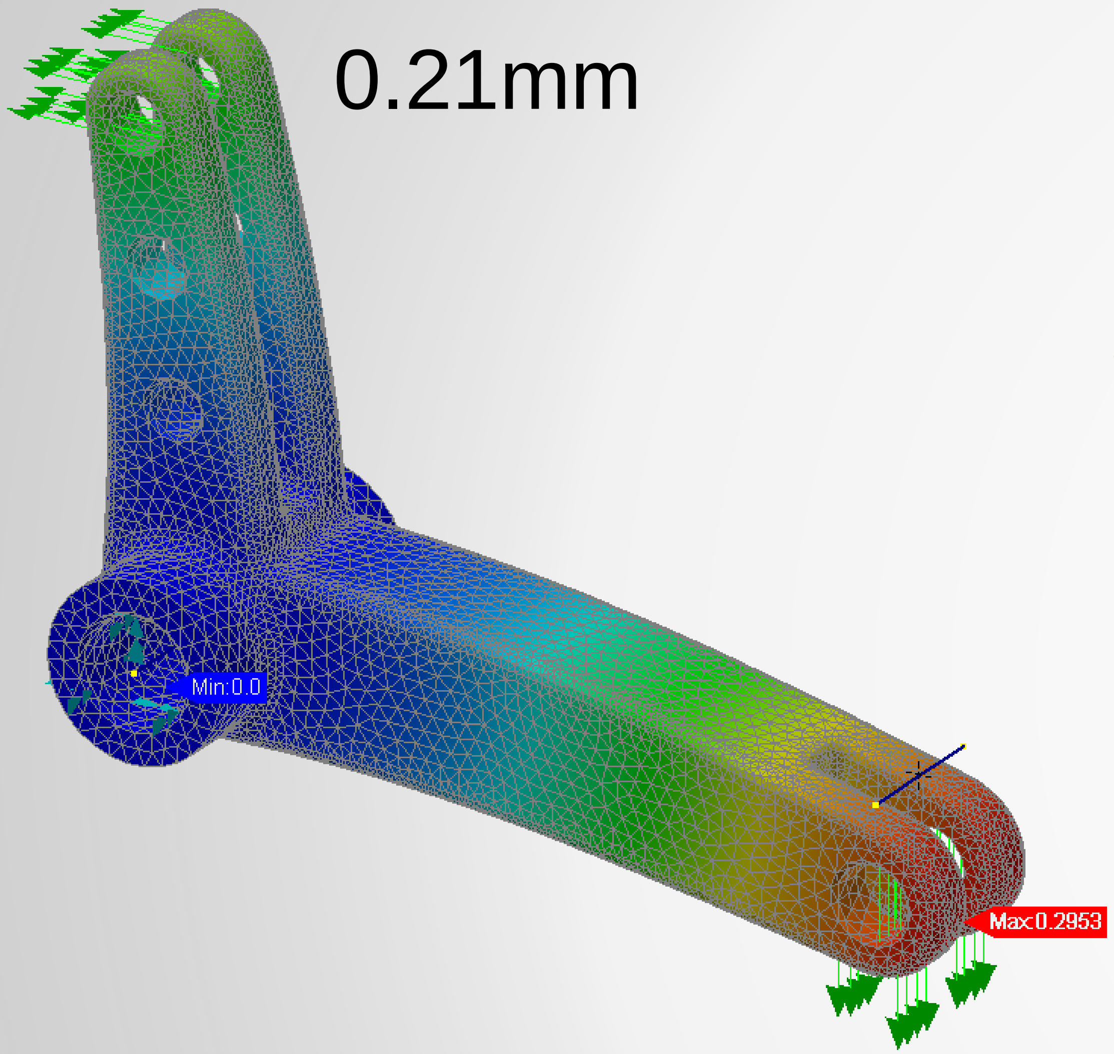
Repeat at Back Pin



Cast Lever – Iteration 3: Contact & Symmetry

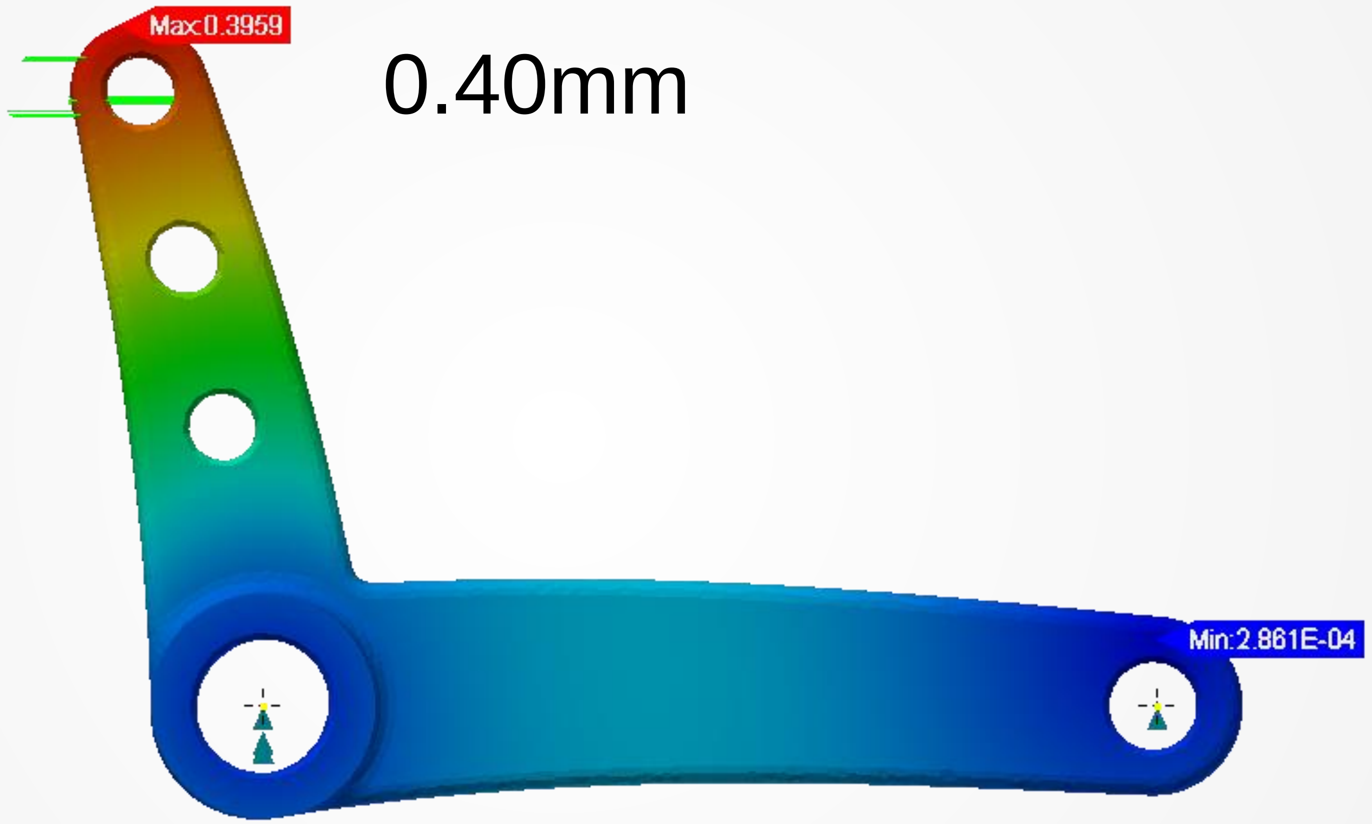


Cast Lever - Comparison



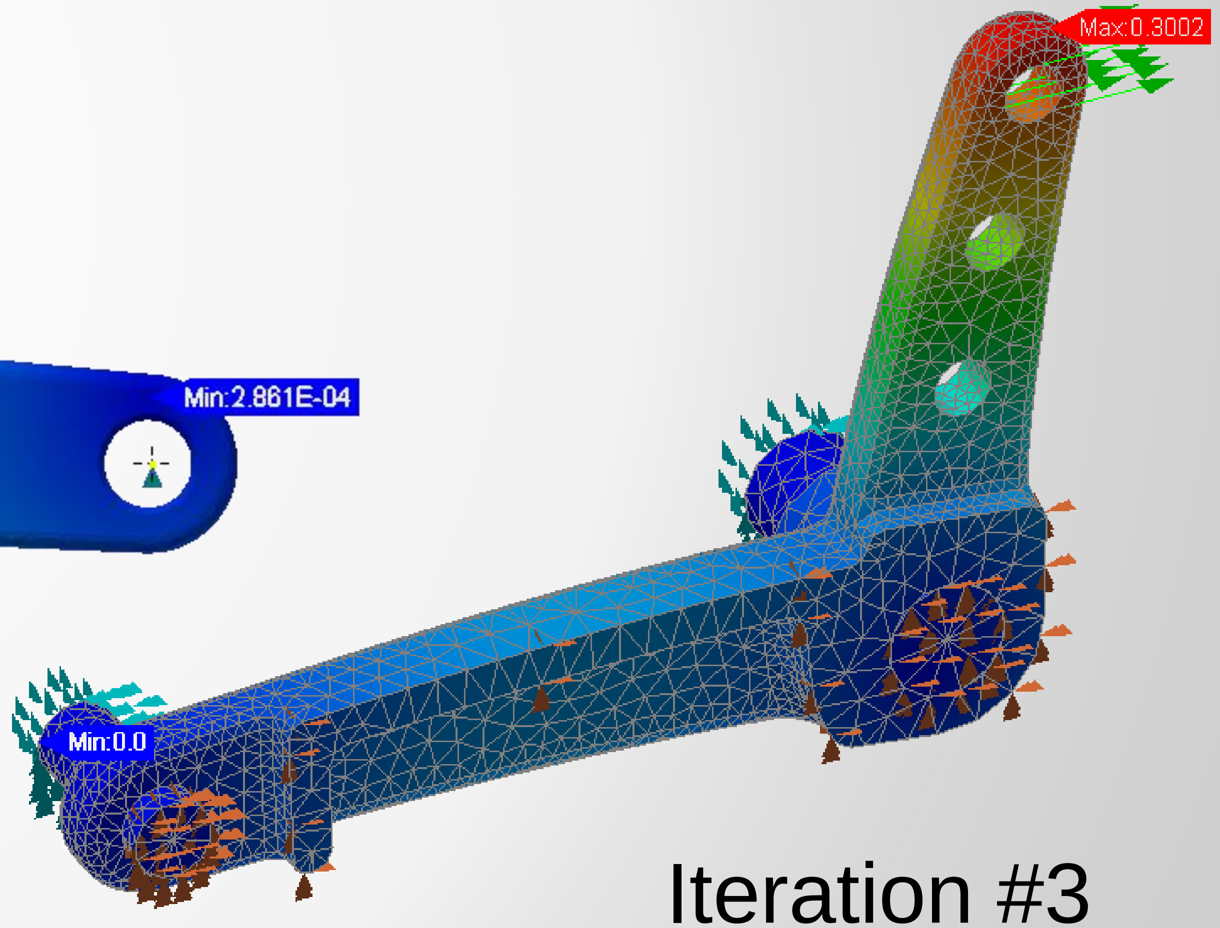
0.21mm

Iteration #1



0.40mm

Iteration #2



0.30mm

Iteration #3

Advanced Boundary Conditions - Summary

- Creative Constraints Discussed
  - Remove Poisson Effect Stress
  - “Ball Joint” Constraint
  - Symmetry
- BCs represent the Interactions of the Parts You Didn’t Model with the Parts You Did!
- There are numerous other BC techniques that allow for more realistic modeling every engineering using FEA should know.

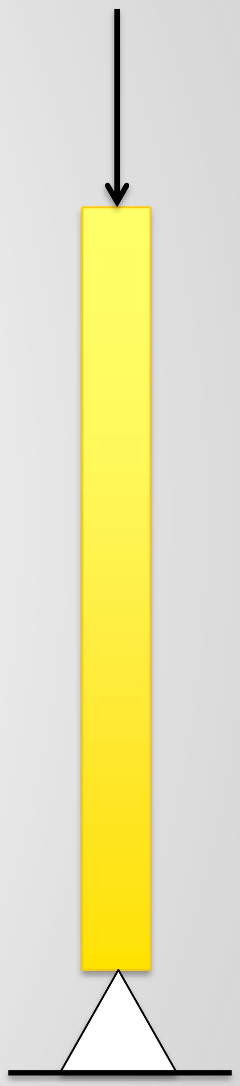
Buckling Analysis

Buckling Failure

http://youtu.be/HI-ENqgjQXM

Failure Analysis… Buckling Failure

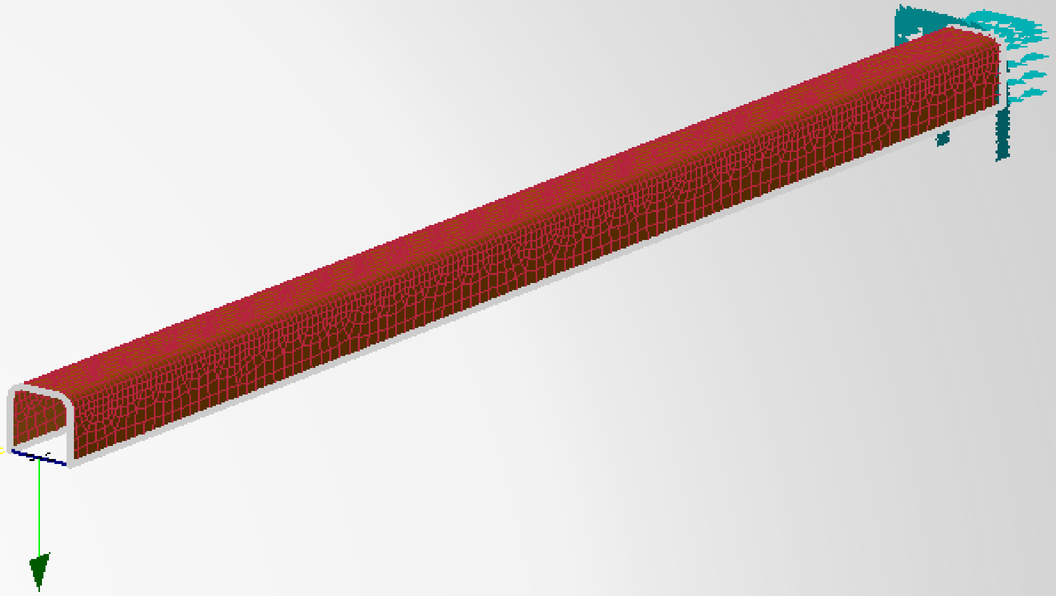
- Critical Load, Pc
  - The axial load which will hold a column in a deformed condition without the generated internal stresses causing it to straighten out. Any increase in axial load will cause immediate failure.
- A buckling analysis provides a load multiplier so a applied unit load will make for a more convenient conversion.



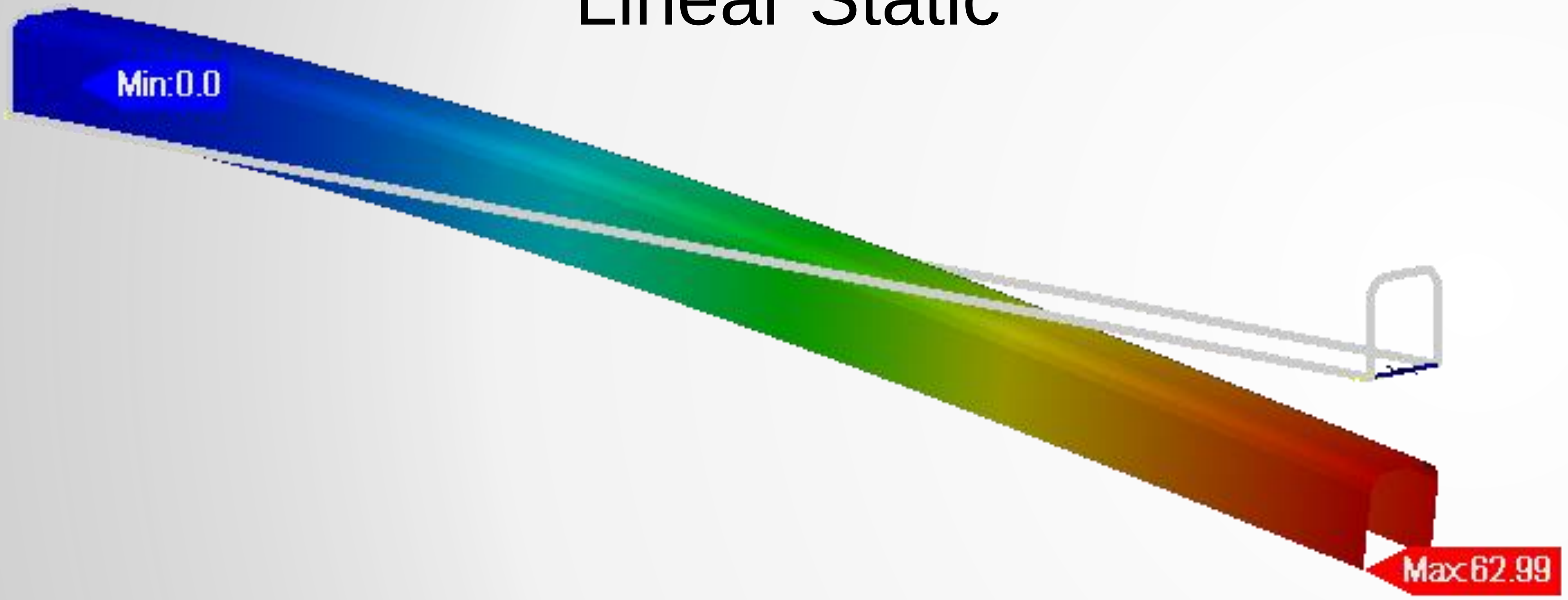
Lowest Critical Loads:

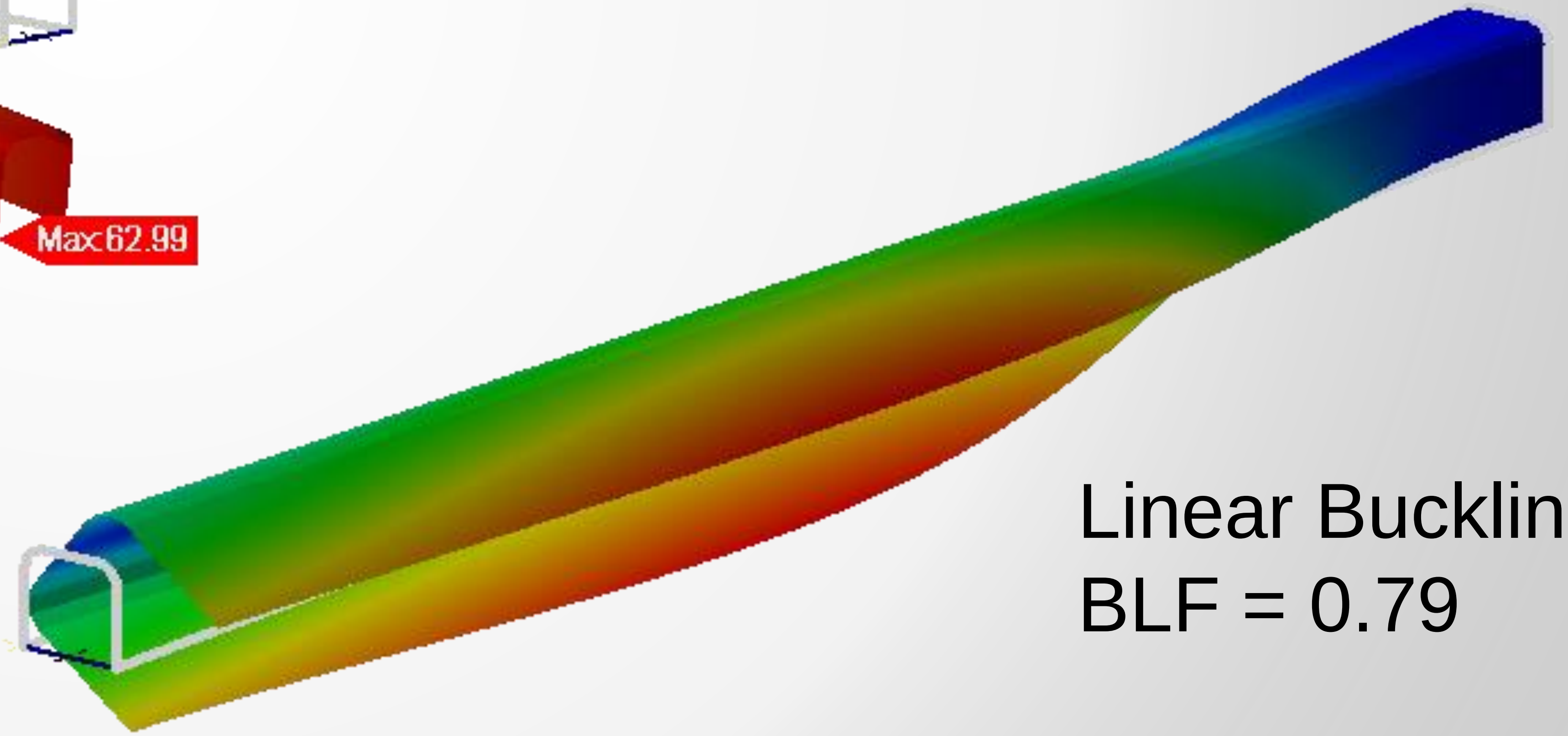
End Conditions	Critical Load
pinned-pinned	EIp^2/L^2
pinned-fixed	$2EIp^2/L^2$
fixed-fixed	$4EIp^2/L^2$

Failure Analysis… Buckling Failure



Linear Static





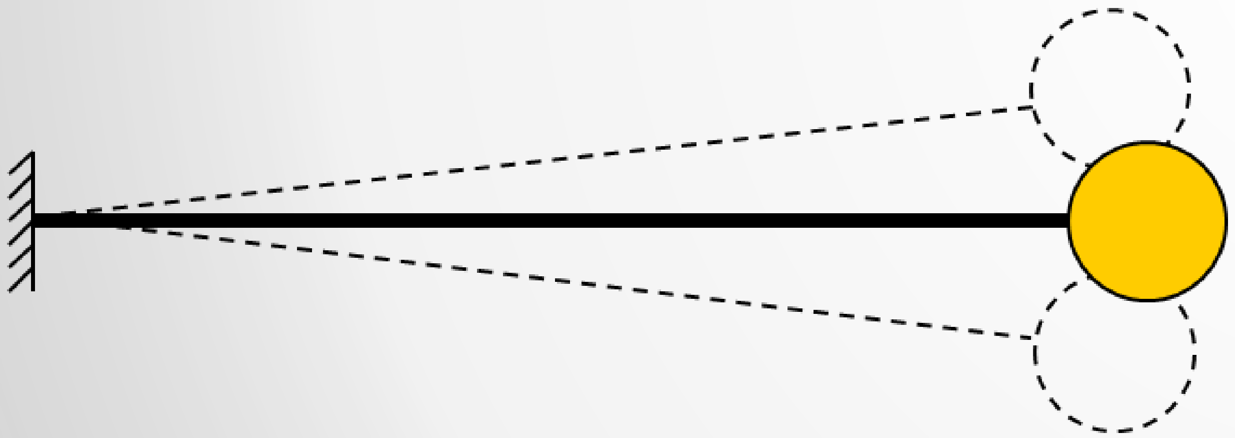
Linear Buckling
BLF = 0.79

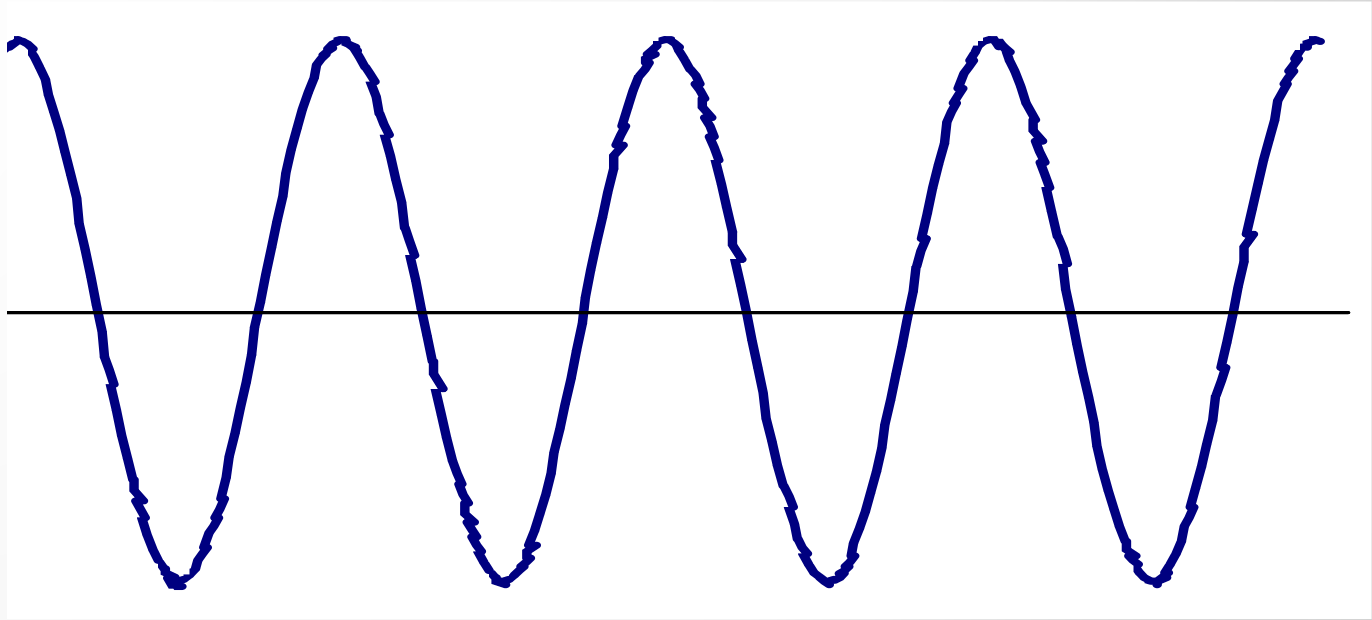
Vibration Analysis

Vibration Failure

Dynamic Analysis...

- Dynamic response is impacted by:
  - Mass (Weight)
  - Stiffness
  - Distribution of Mass



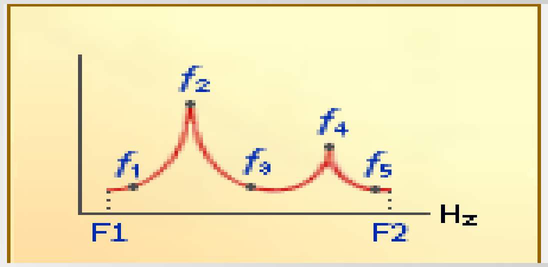


Dynamic Analysis...

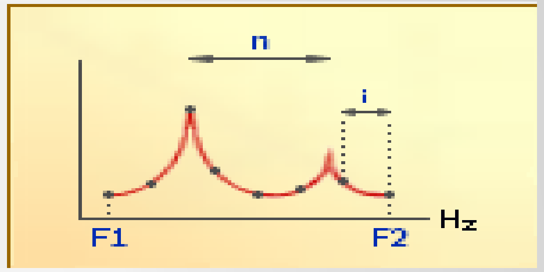
- Modal or Natural Frequency Analysis
  - Natural Frequencies & Mode Shapes
  - Benefits:
    - Avoiding Operating Speeds or Frequencies
    - Understanding Excited Modes
    - Controlling Mode Shapes at Specific Frequencies
- Frequency Response Analysis (Frequency Domain)
  - Stress & Displacement at Frequencies
  - Benefits:
    - Determine Damping Required
    - Avoid Fatigue or Cyclic Load Damage
    - Understanding Magnitude of Displacements
- Transient Analysis (Time Domain)
  - Stress due to Impact Loading & Settle Time and Characteristics
  - Benefits:
    - True dynamics response with phase content
    - System Response or Vulnerability to Drop or Impact

Dynamic Analysis Output

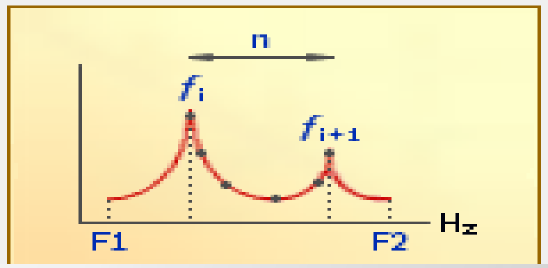
- Modal Analysis
  - Natural Frequencies (Hertz)
  - Mode Shapes (Non-Dimensional)
- Frequency Response Analysis
  - User-Defined Output Frequencies
  - No Phase Content or Load Reversals
  - Peak Responses
- Transient Response Analysis
  - User Defined Time Steps
  - Control Solution Accuracy + Results Insight



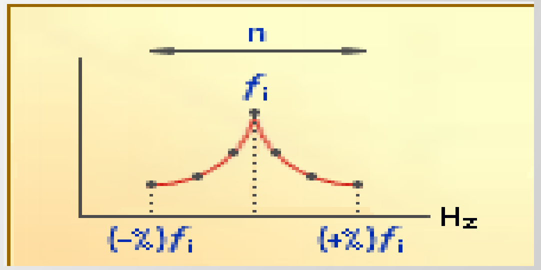
Only at Certain Frequencies



At Evenly Spaced Frequencies

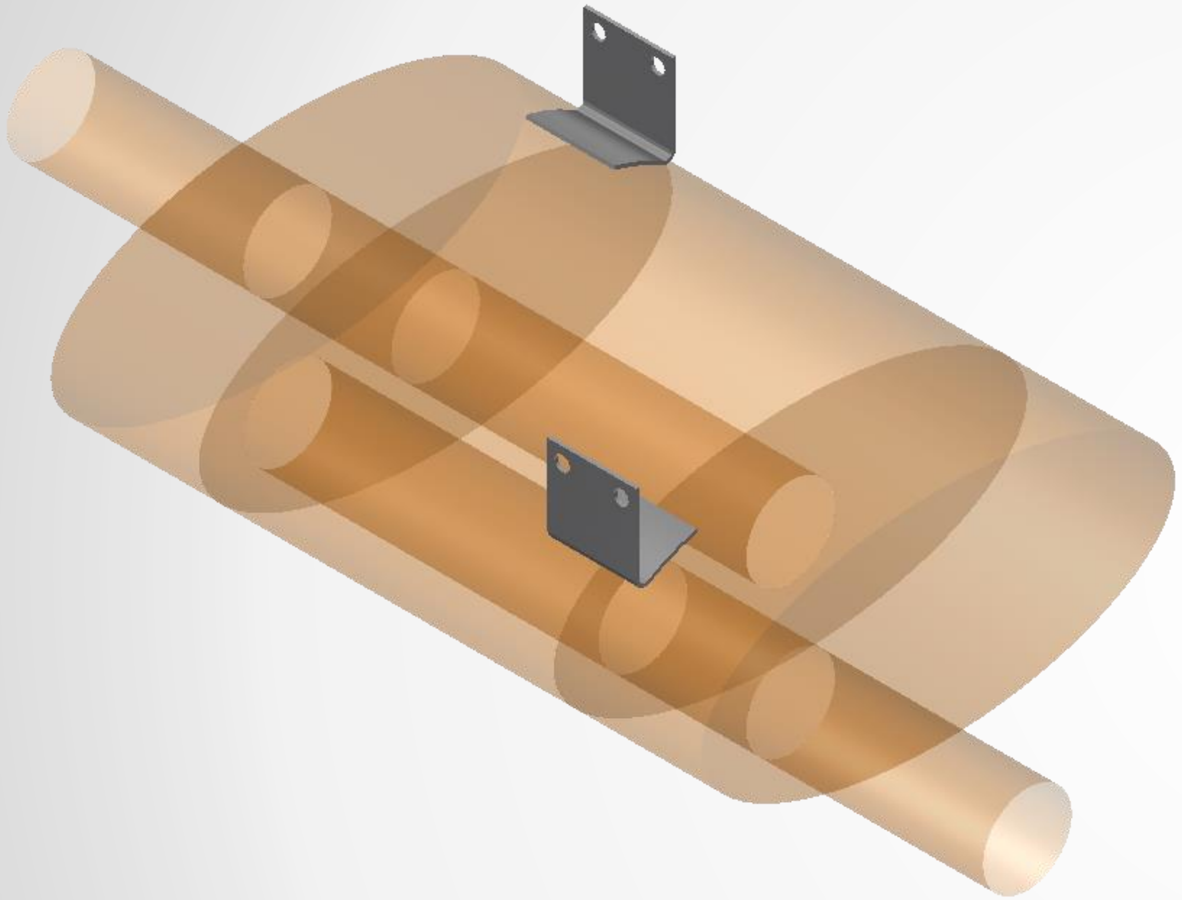


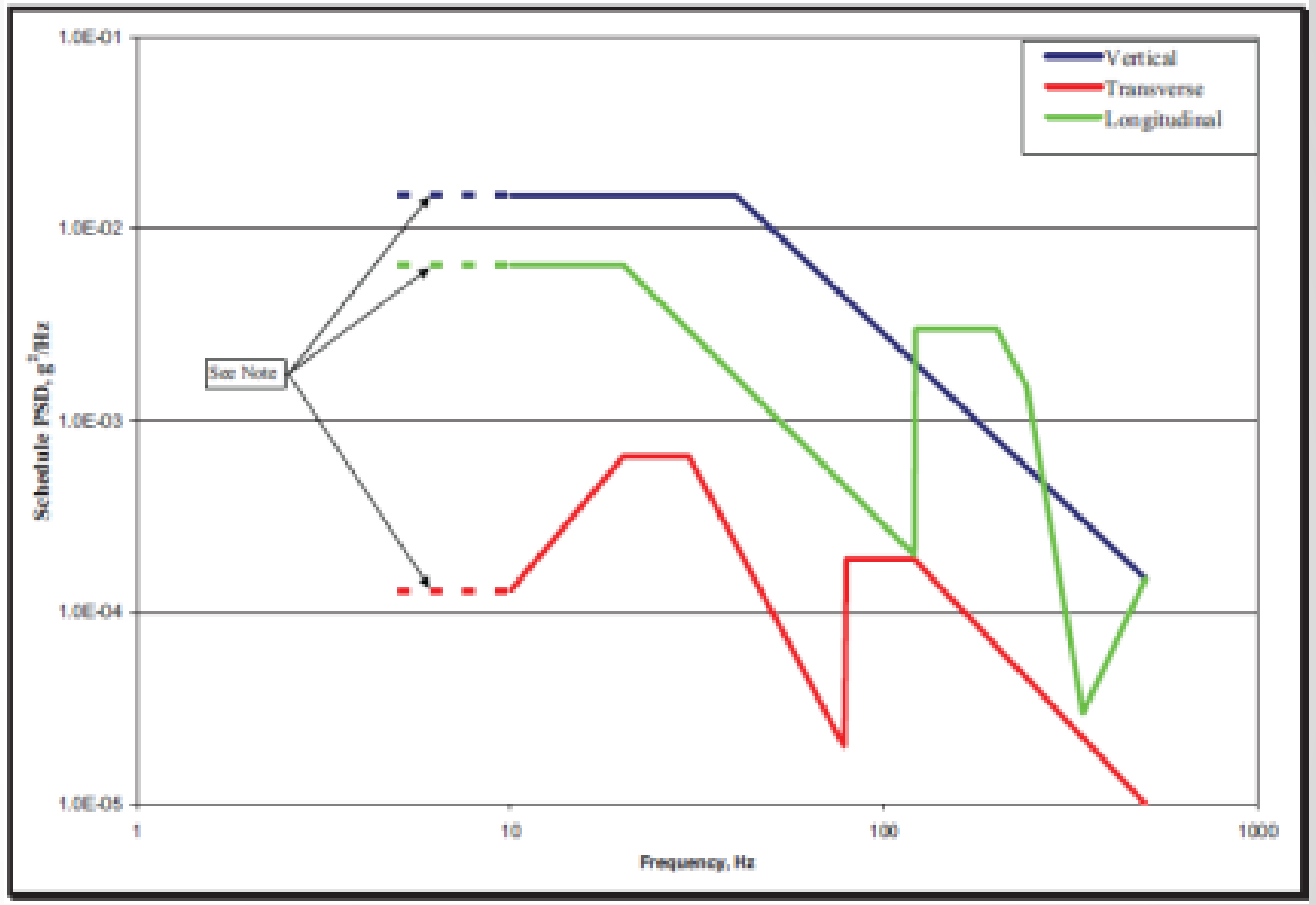
Spread Between Frequencies



Clustered Around Frequencies

Muffler Vibration

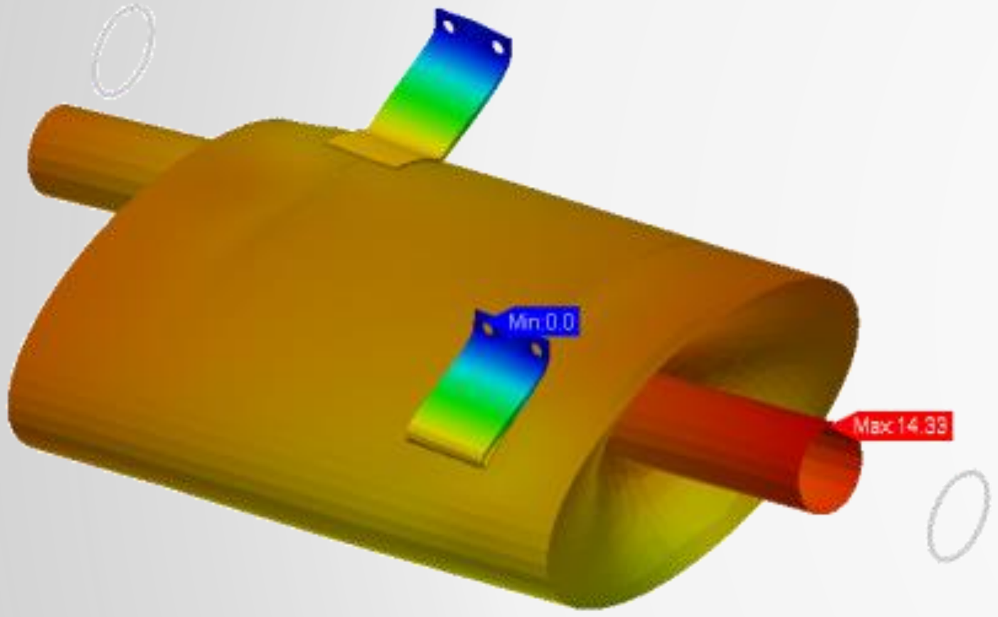




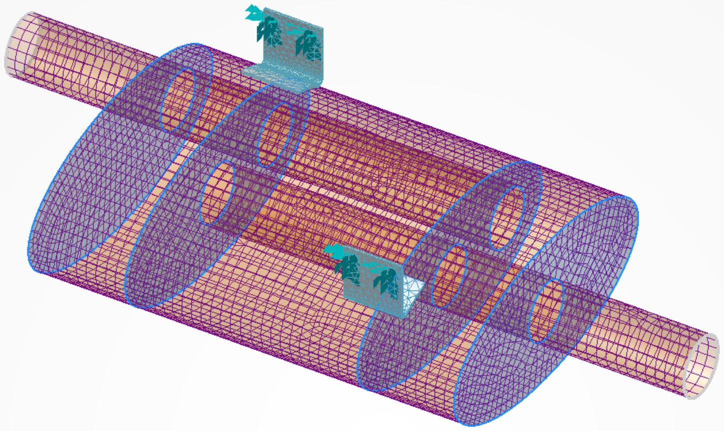
From MIL-STD-810G

1. Normal Modes Analysis and Modal Avoidance
2. Frequency Sweep to Identify Failure Zones
3. Random Response Analysis using actual MIL-STD Road Loads
4. Random Vibration Fatigue to assess damage due to road load

Muffler Vibration – Modal Results



Initial Results

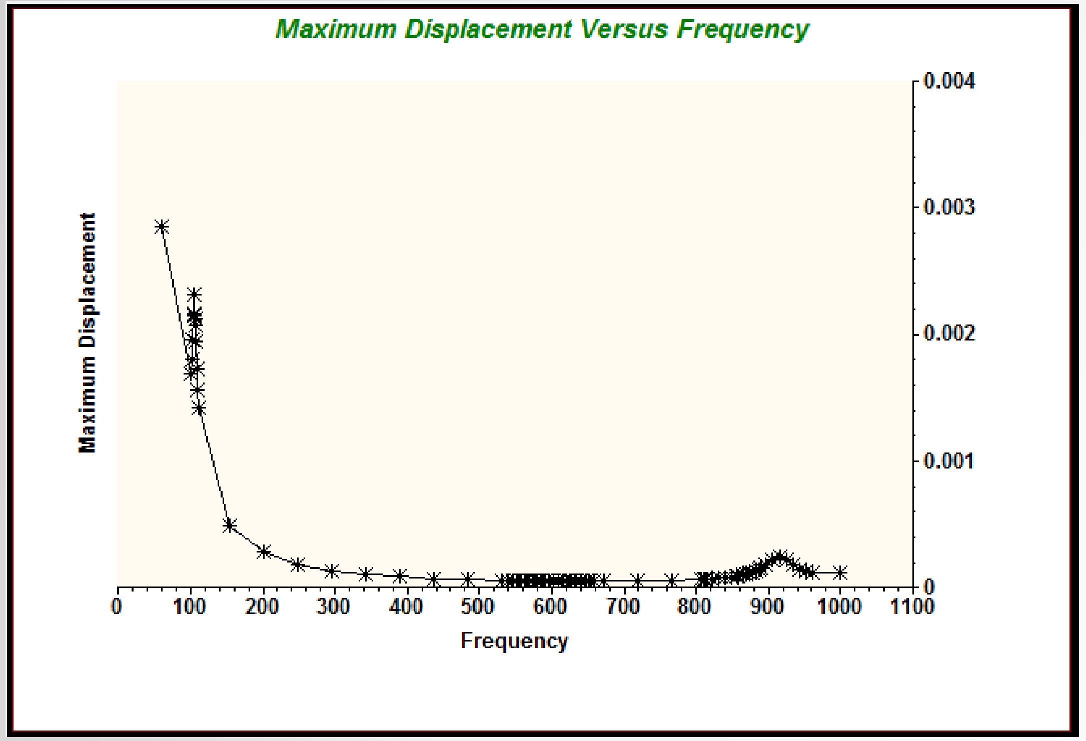


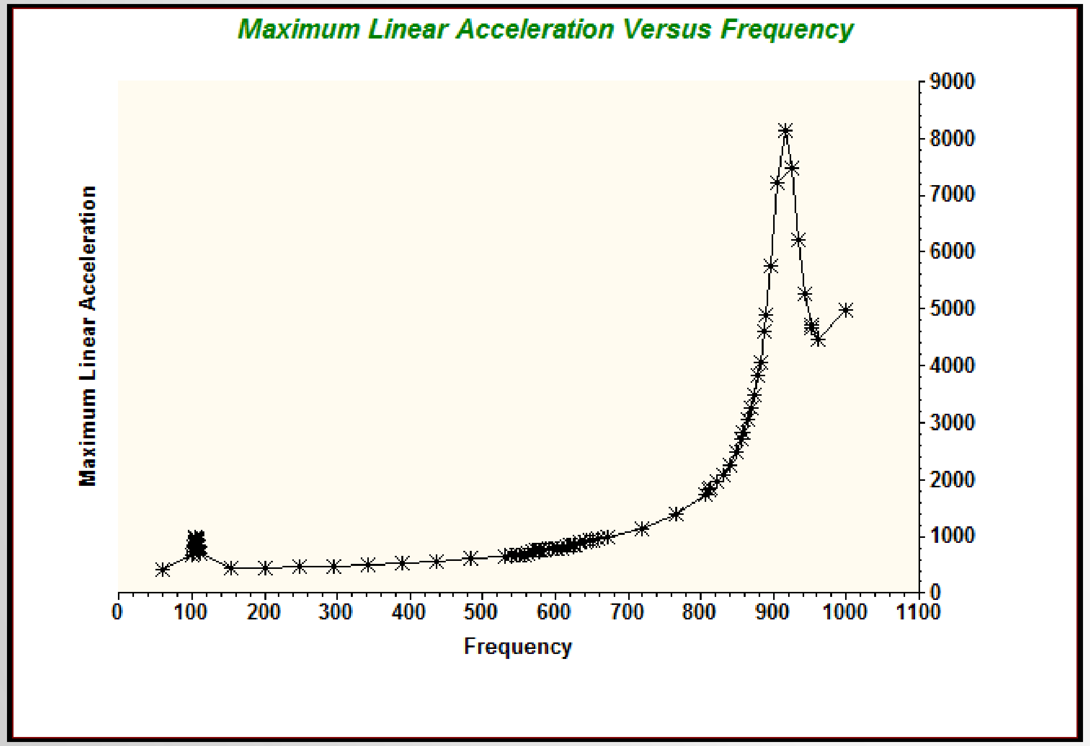
Design Changes

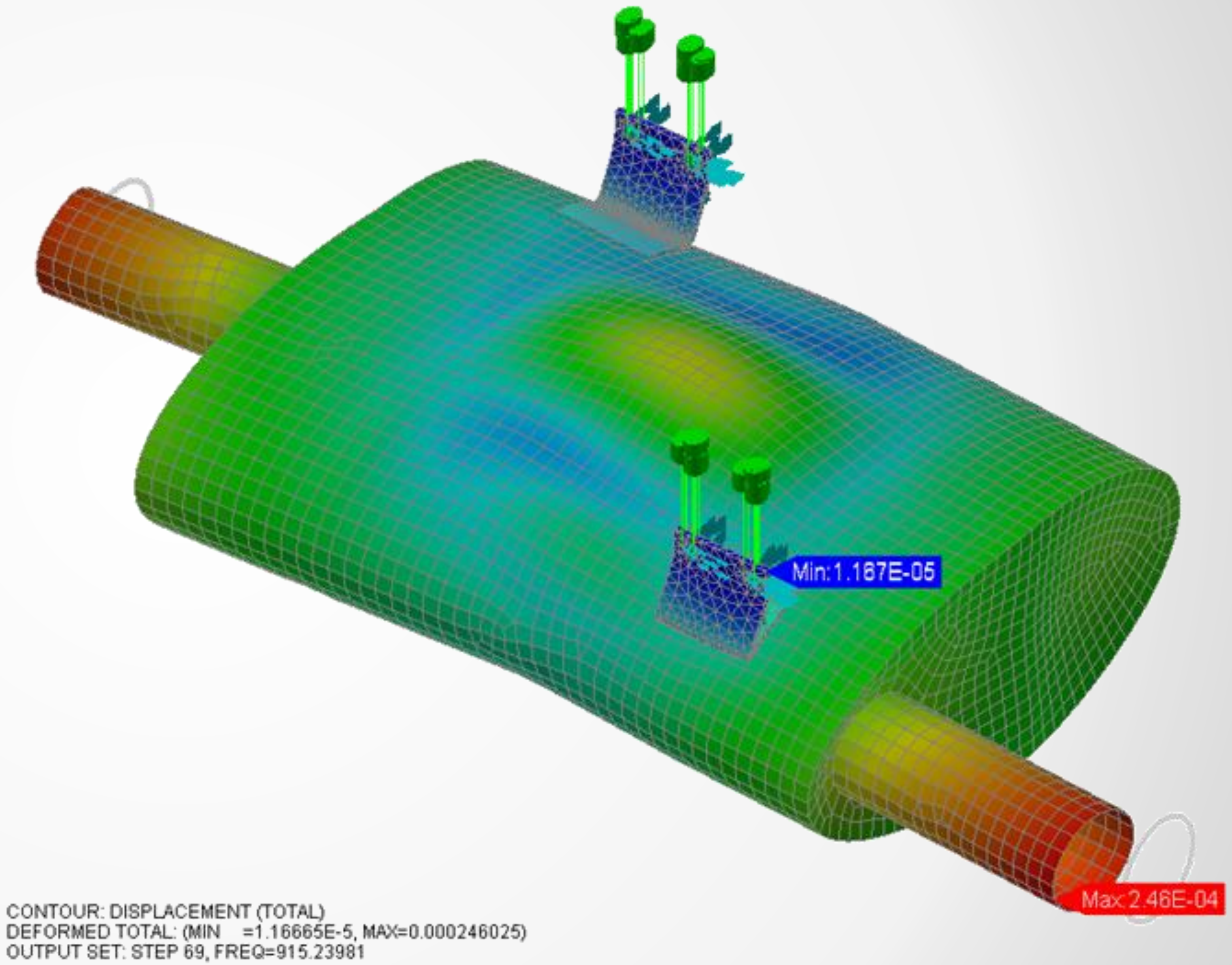
	First Design	Second Design	Mode Shape
Mode 1	102.0	106.2	Same
Mode 2	380.5	562.0	Transverse
Mode 3	410.1	626.6	Longitudinal Oil Canning

Compare Results

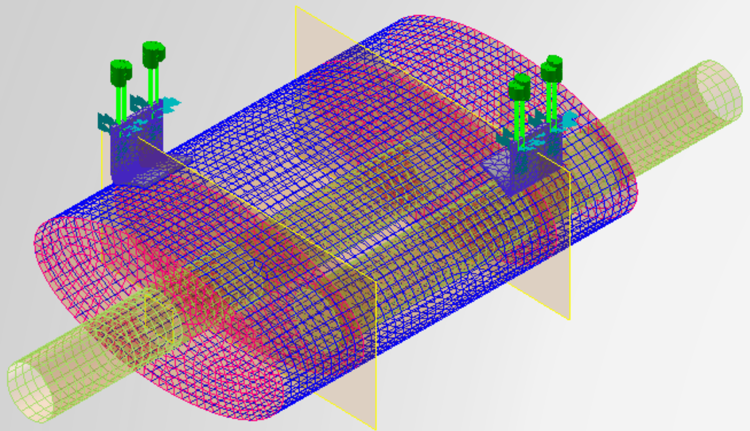
Muffler Vibration – Frequency Sweep Results

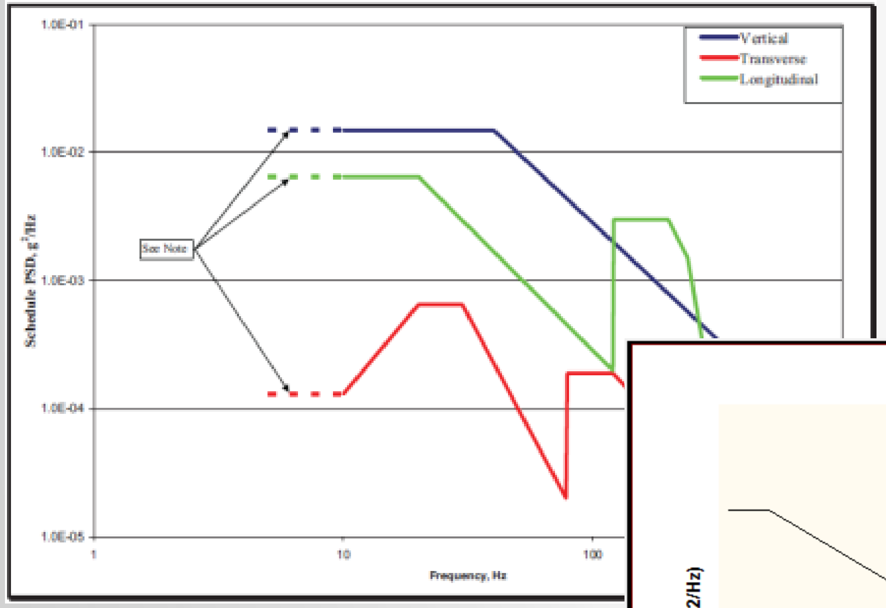


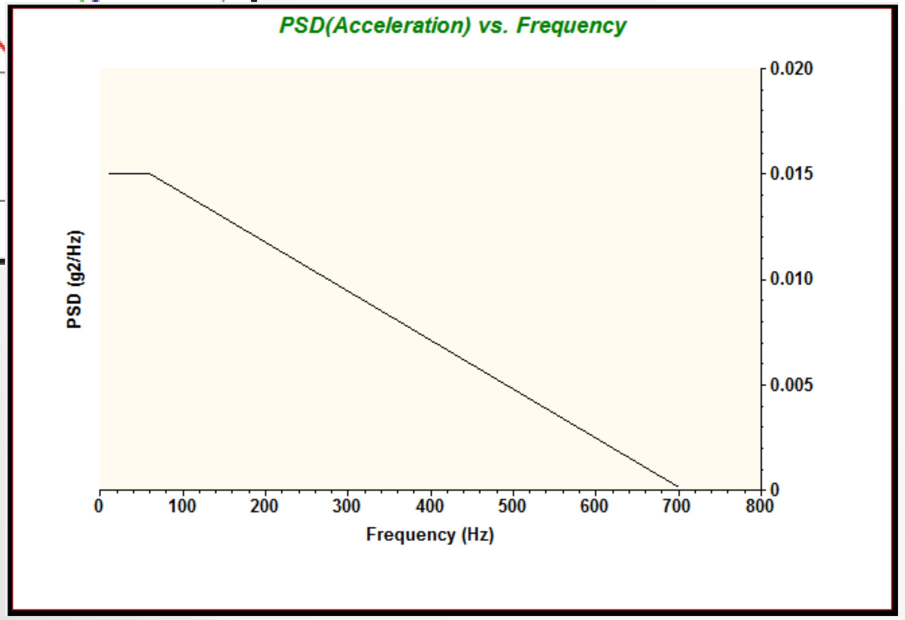


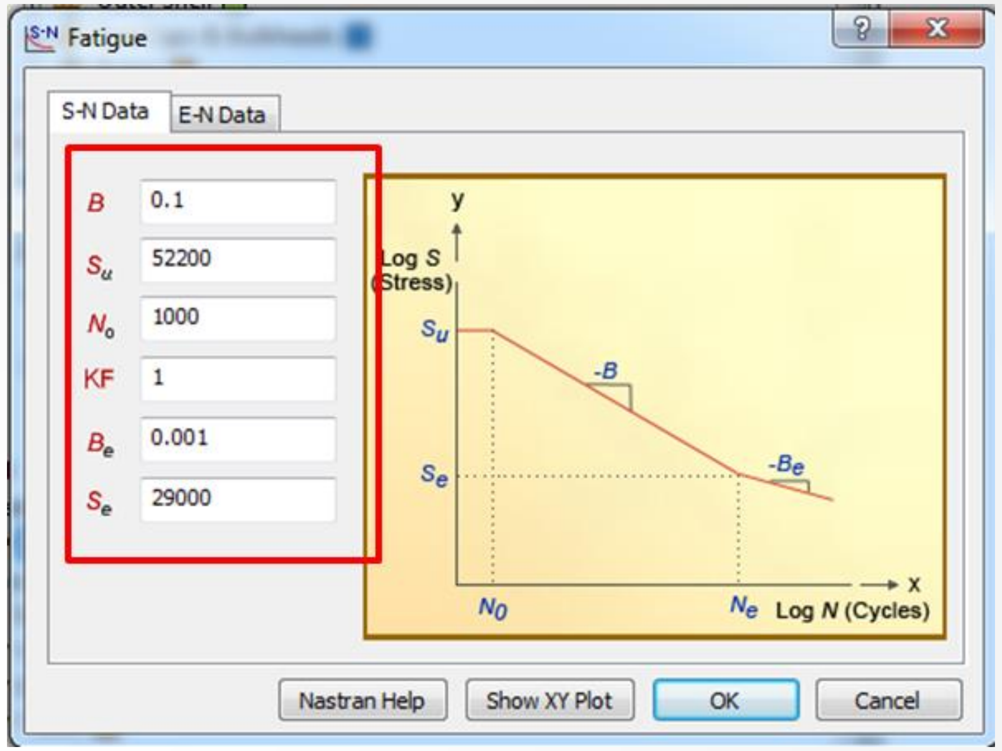


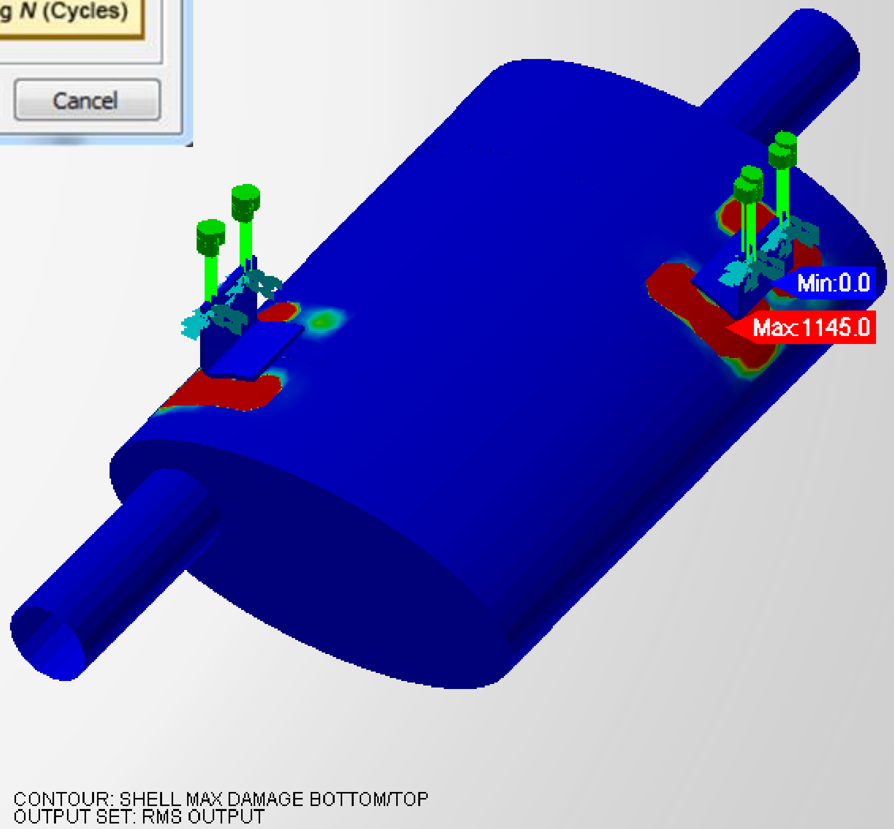
Muffler Vibration – Random Response & Fatigue











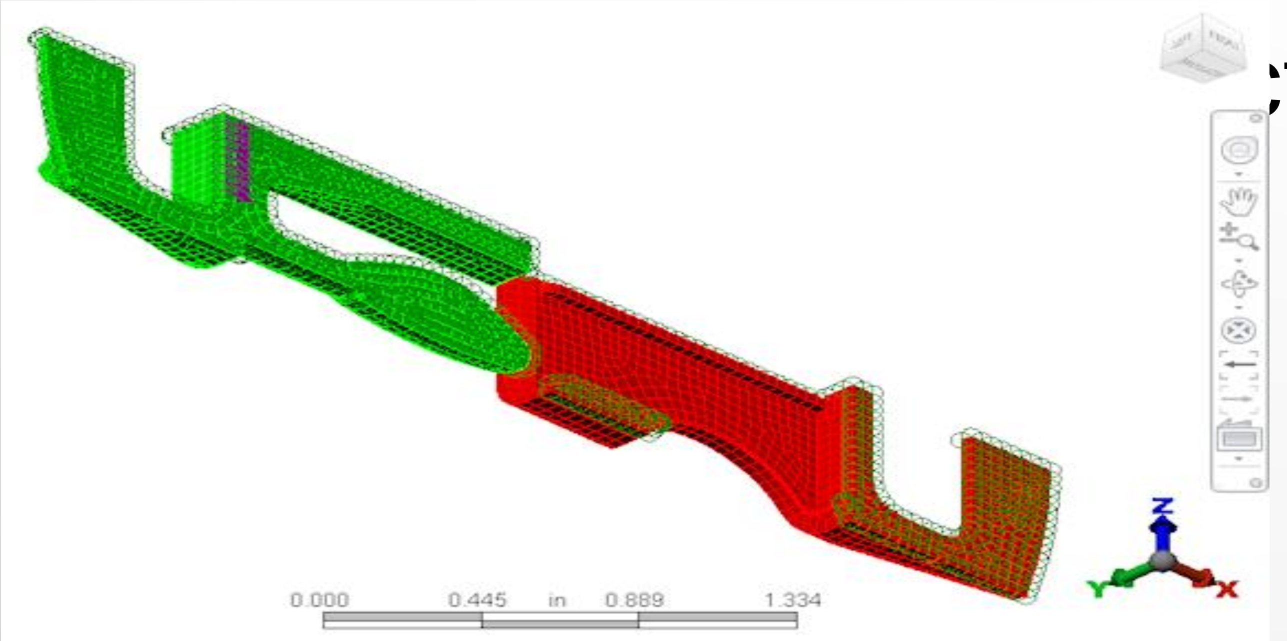
Nonlinear Analysis

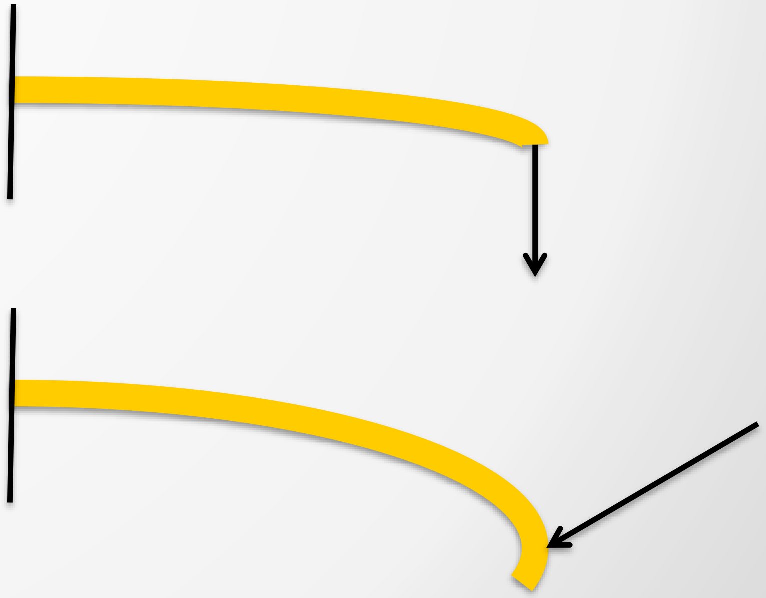
Nonlinearity in Structural Analysis

- "Linear" assumes:
  - Material remains linear; stress proportional to strain
  - Deformations are small so that the final shape is very similar to the initial shape; thus stiffness is not affected by the changing stresses
  - Loads (Magnitude, Orientation, Distribution) never change during the solution
- Consequently, structural nonlinearities show up as:
  - Material Nonlinearities
  - Geometric (Large Displacement) Nonlinearities
  - Boundary (Load) Nonlinearities
- Many problems exhibit all of these!

Boundary Nonlinearity

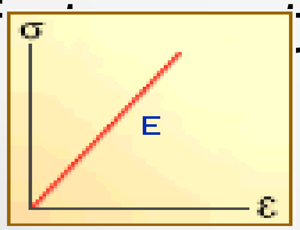
- A model exhibits boundary nonlinearity when the loads, restraints, or load path change throughout the course of the solution:
  - Contact
  - Follower Forces
- Use these nonlinear techniques when standard loads and restraints either violate the linear guidelines or the interaction is di … ct



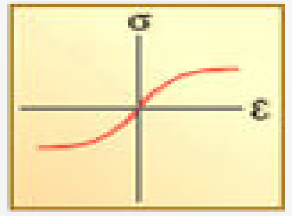


Material Nonlinearity

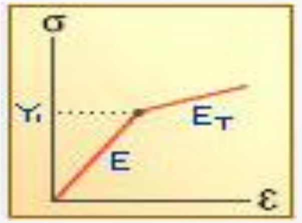
- There can be a significant difference between the linear and nonlinear material responses
- For any material besides steel, reviewing the SS curve is the best way to understand the nonlinearity of the problem
  - Even if you are using a linear material model, knowing nonlinearity is important for interpreting results
- A linear model can provide valid data for many materials
  - At low strains
  - For trend comparisons
- Linear Elastic vs. Nonlinear Plastic Response
  - A linear analysis can only predict the onset of yielding
  - A nonlinear plasticity analysis can only predict the onset of fracture
  - Once the limits of the analysis are exceeded, correlation degrades with the complexity of ate.



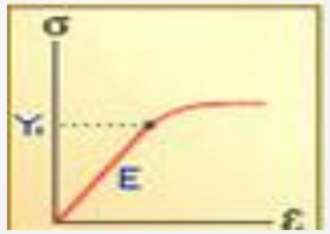
Linear Elastic



NonLinear Elastic

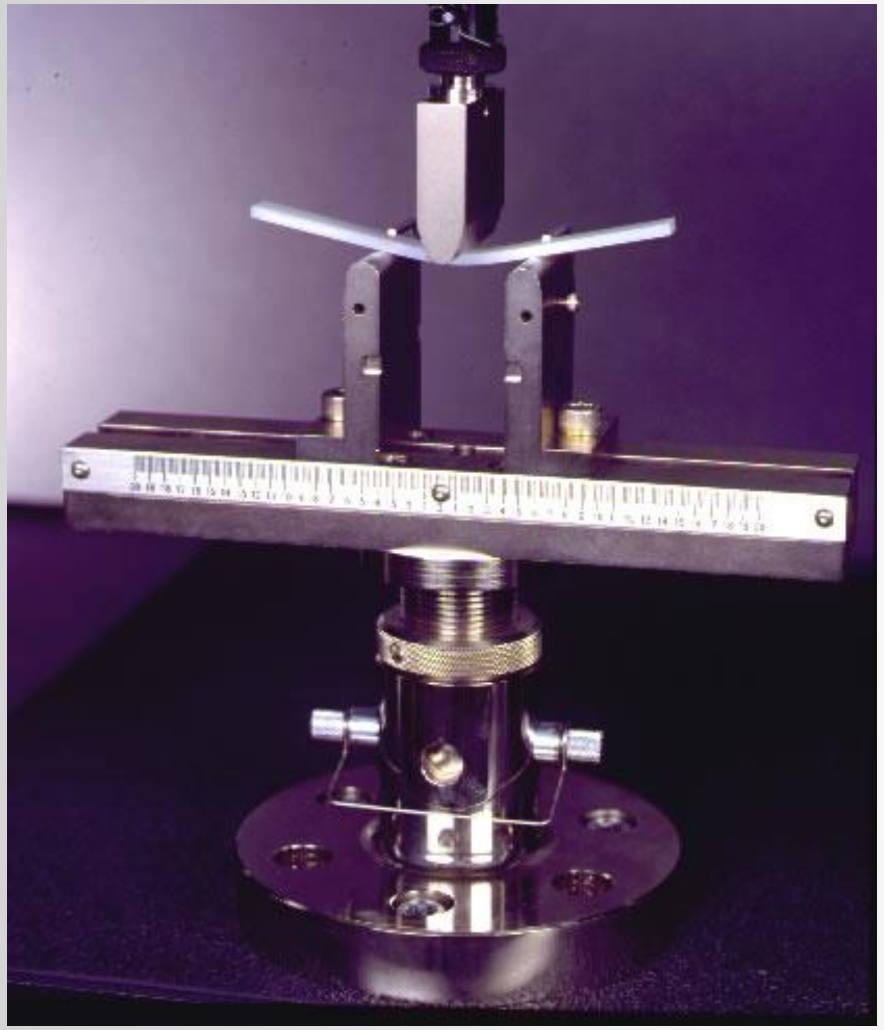


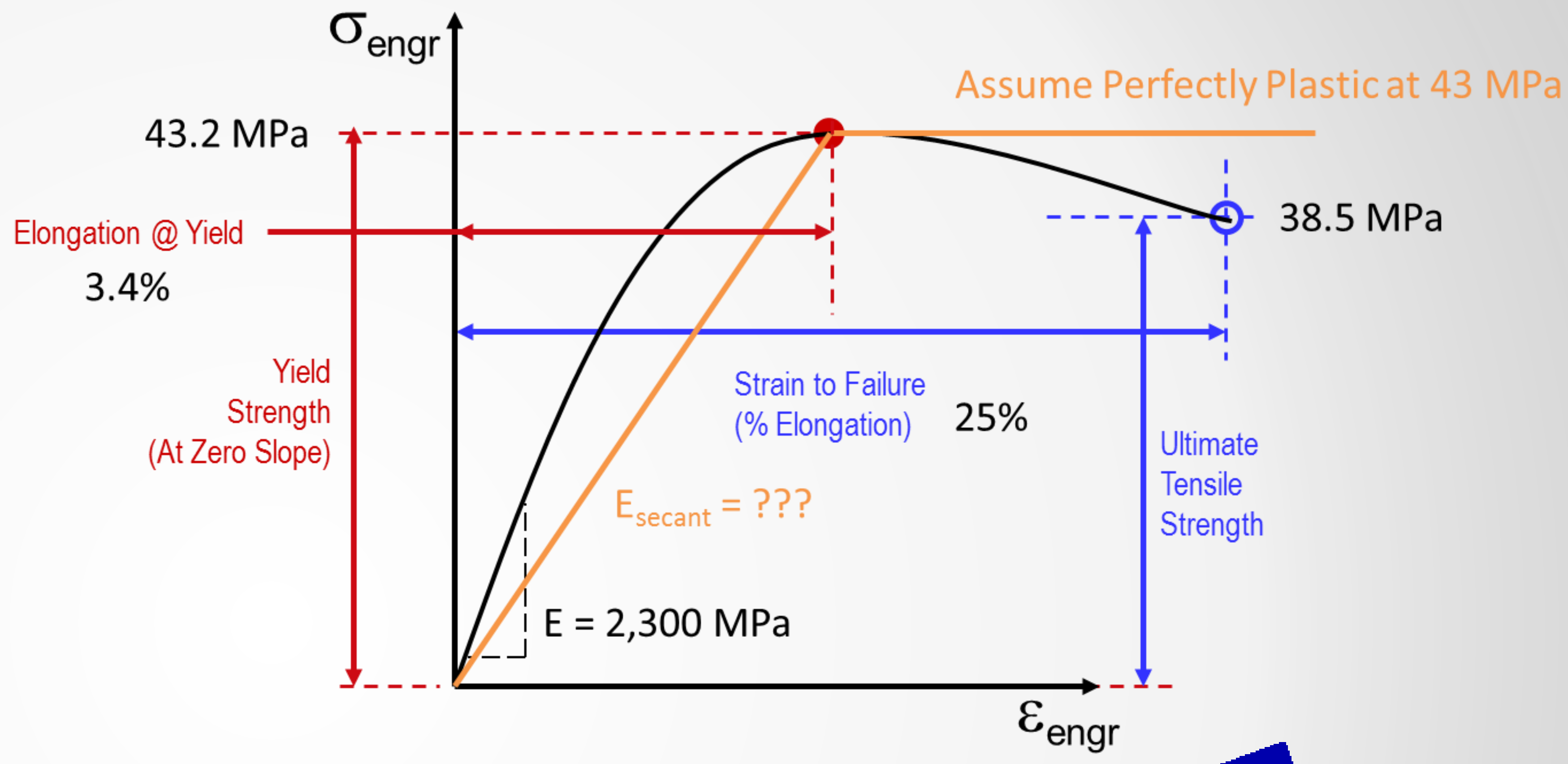
Bi-Linear Elasto-Plastic

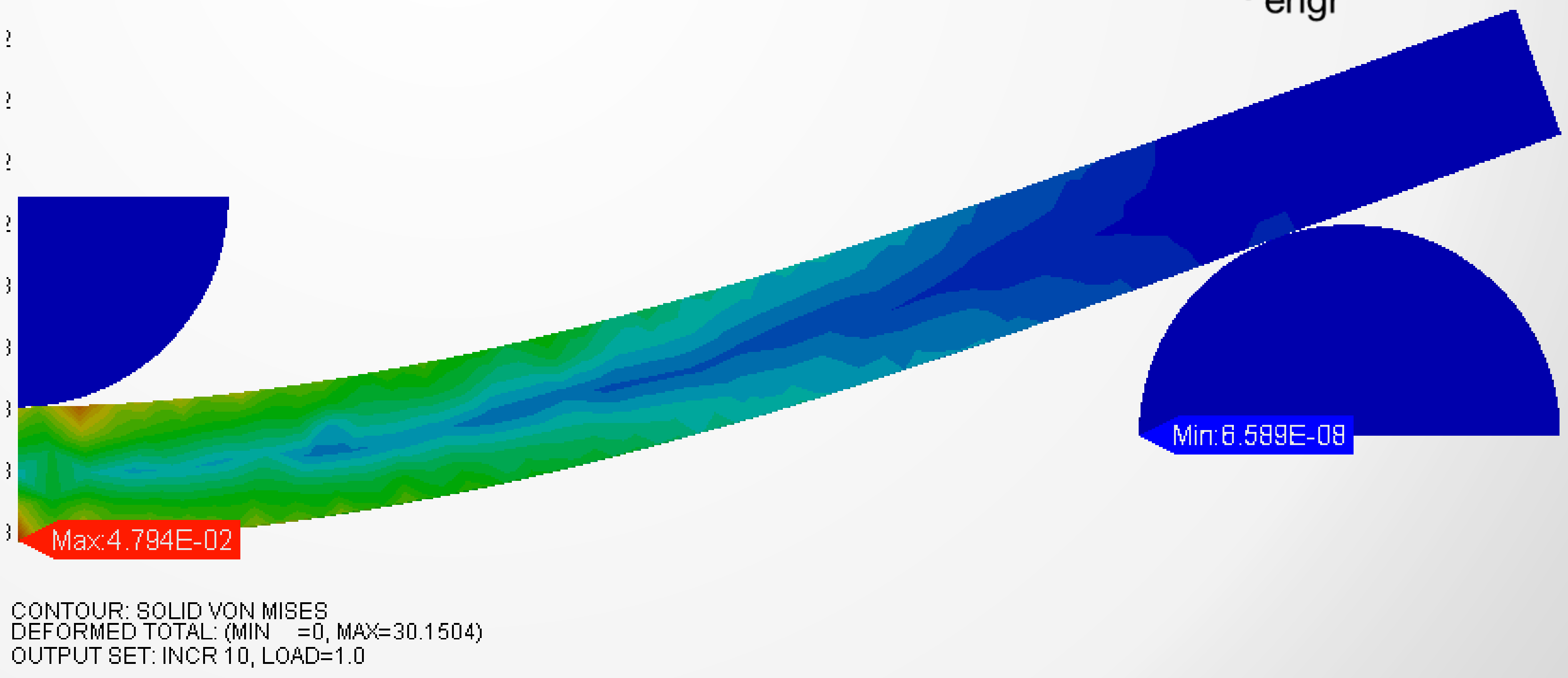


Multi-Linear Plastic

Material Nonlinearity – Flex Test

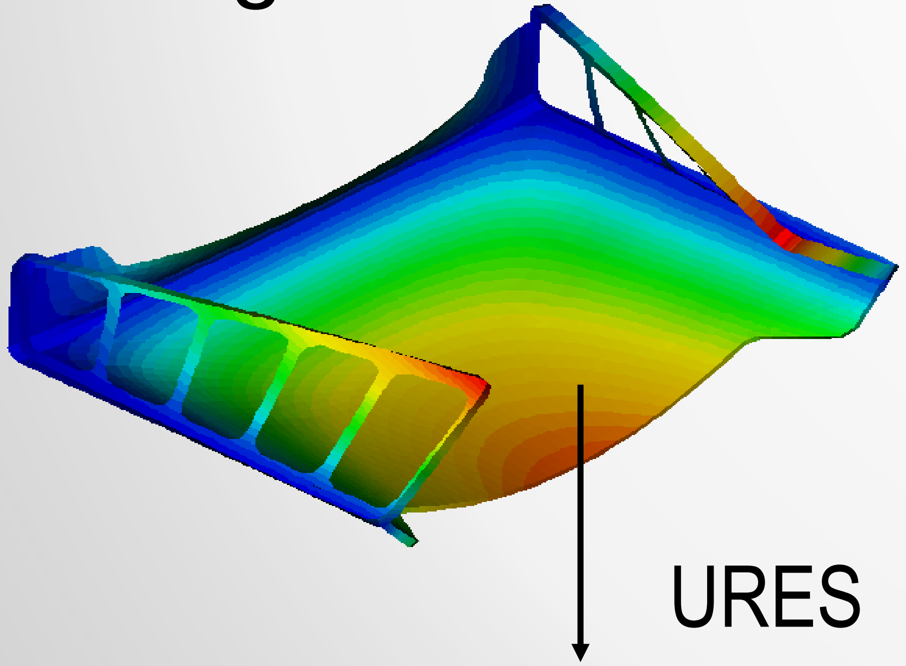


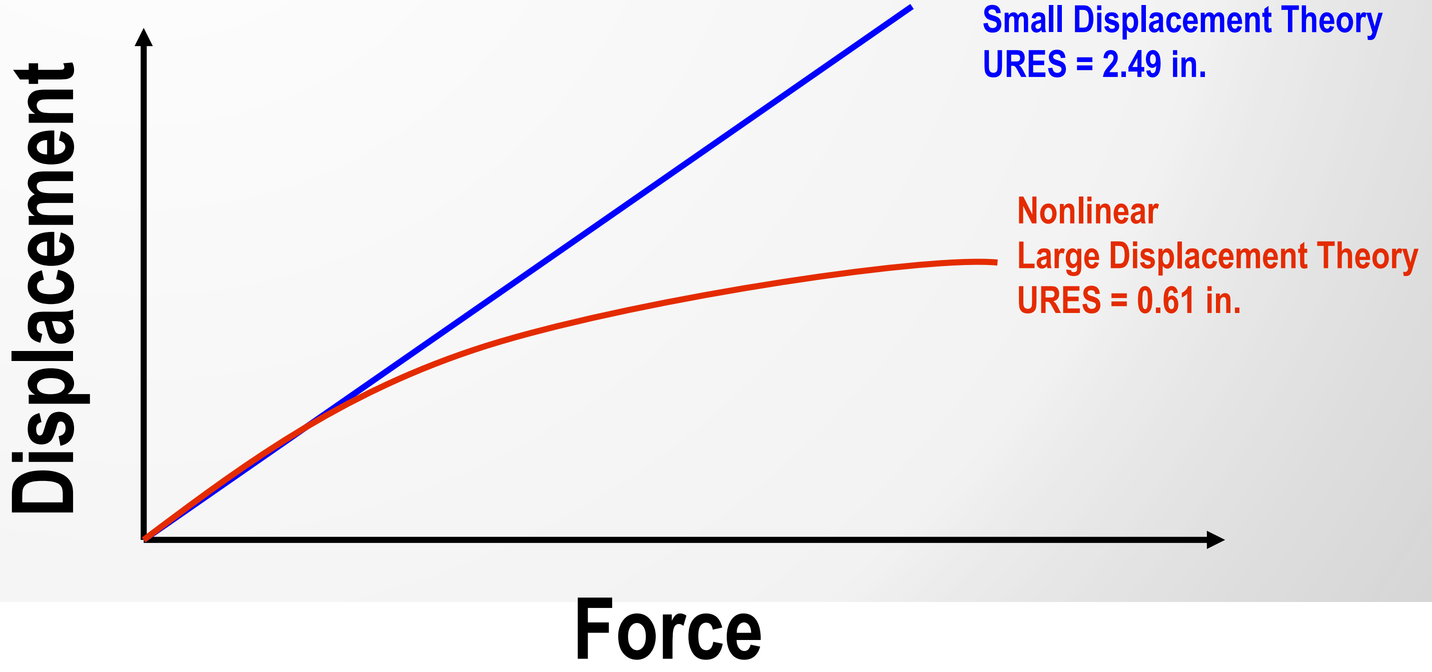




Geometric Nonlinearity

- Geometric nonlinearity becomes a concern when the part(s) deform so much that the initial model assumptions are no longer valid
  - Stress Stiffening / Softening
  - Snap-Thru
  - Buckling
  - Large Strain

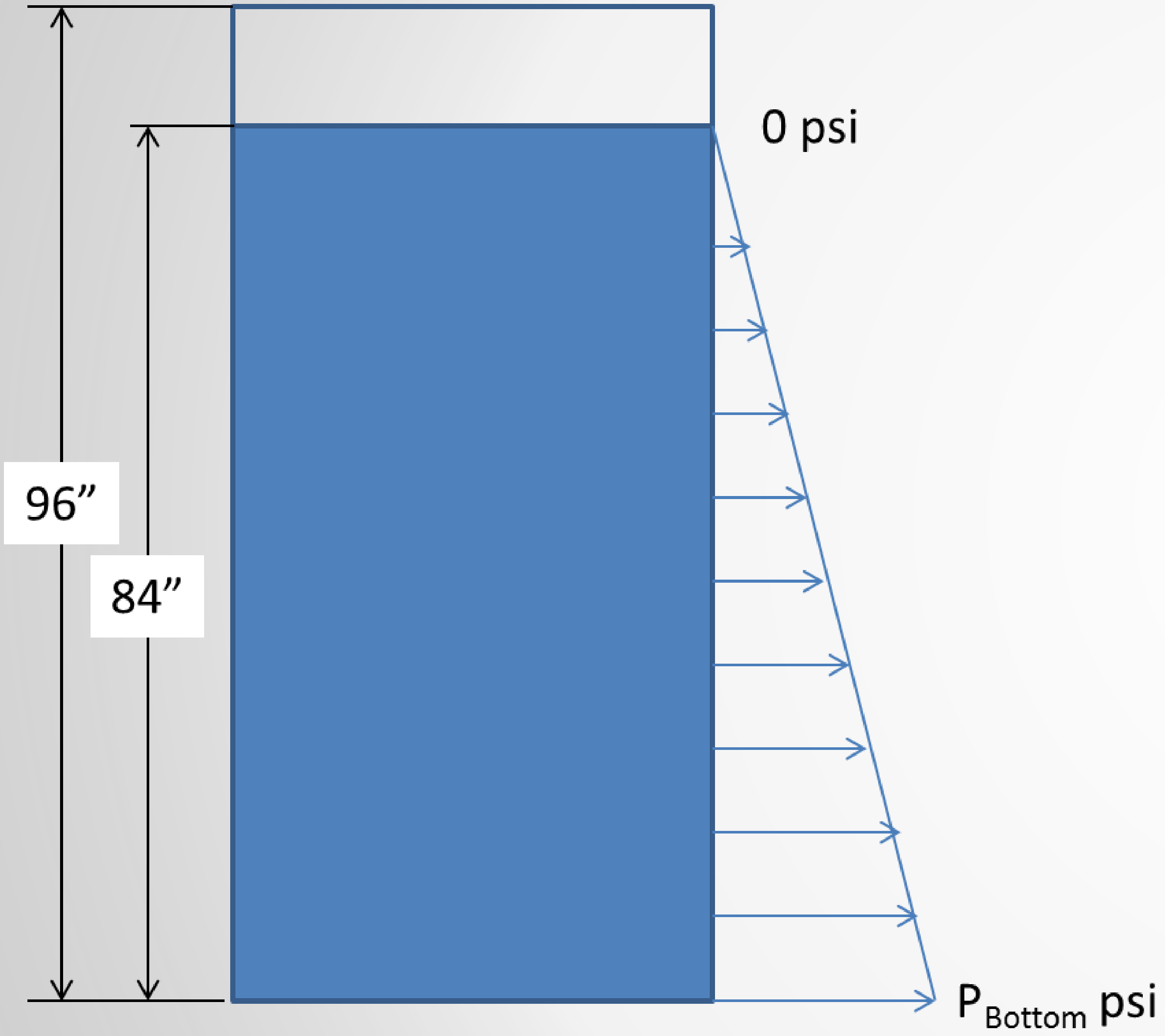


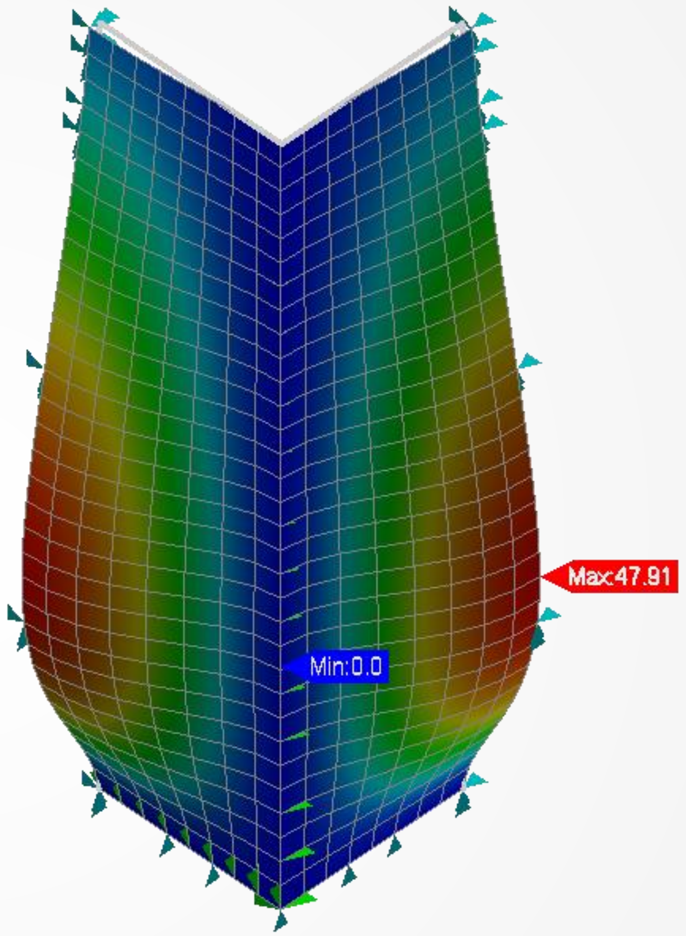


Geometric Nonlinearity

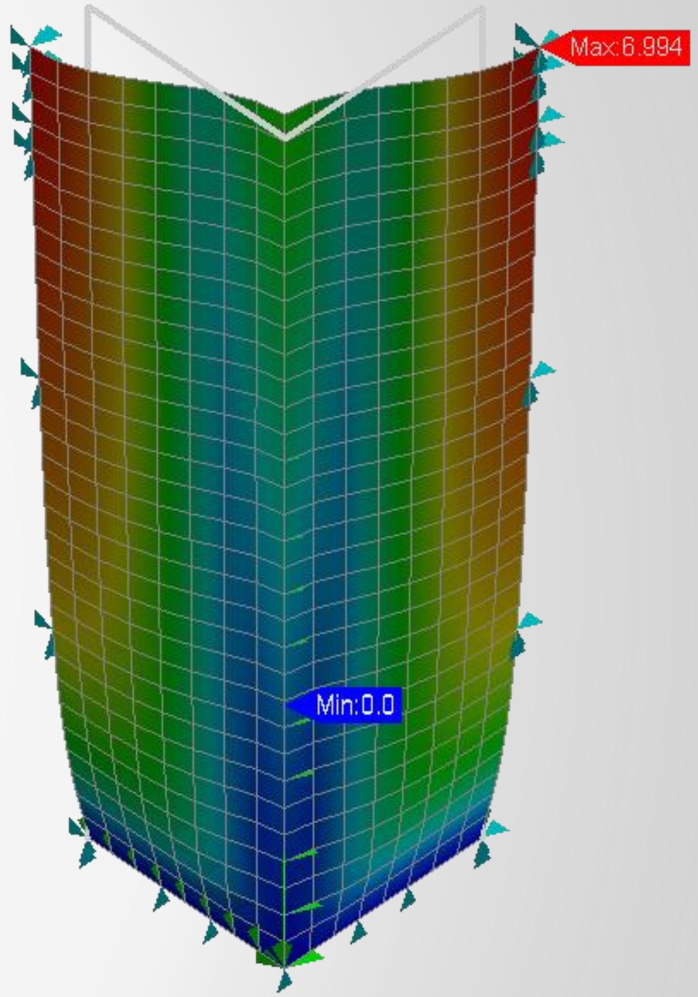
- Large Displacement / Stress Stiffening is not caused by displacement but by tensile stress
- The only way to determine if LD effects come into play is by comparing the SD and LD results
  - Simplified models can often be used to determine significance
- If SD & LD results differ ONLY in magnitude, trends using SD results will be valid

Geometric Nonlinearity – Flat Walled Tank





Linear Results – 48 inches

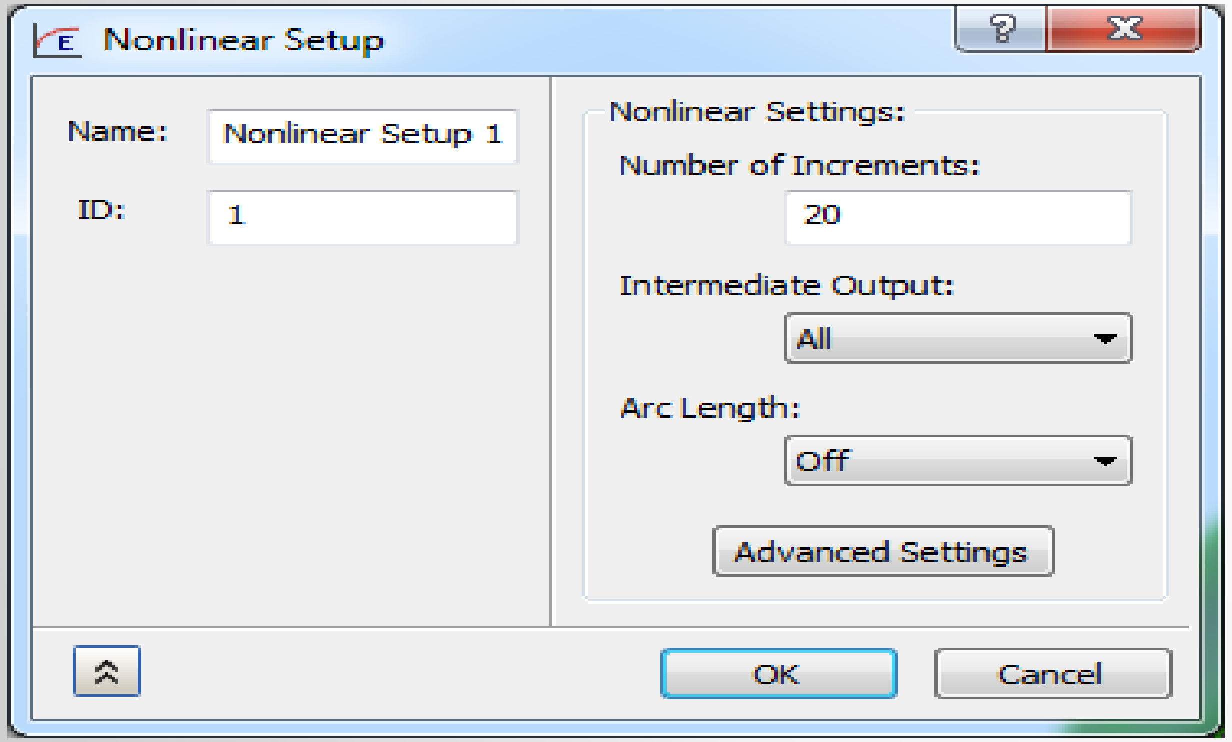


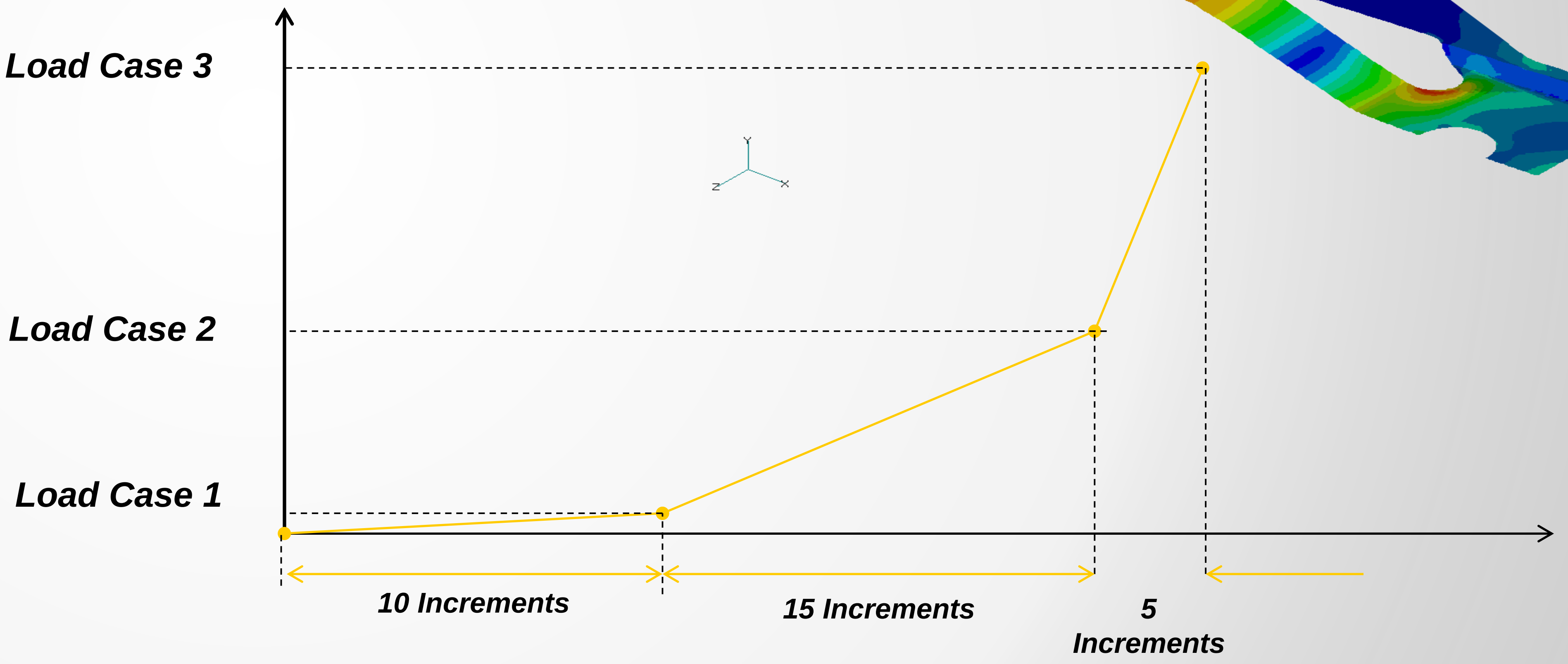
Nonlinear Results – **7 inches**

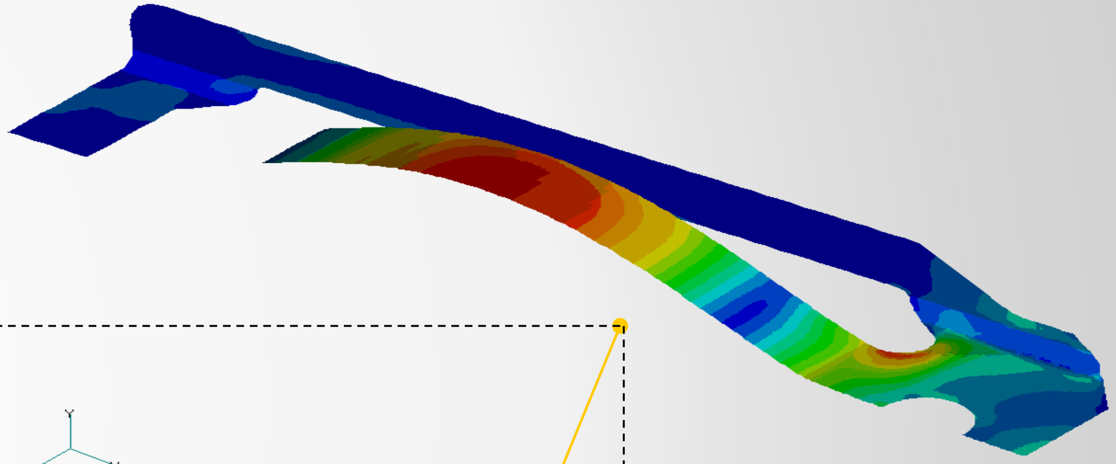
Nonlinear Analysis…

Common Tools in Nonlinear Analysis…

- Load Case Sequencing
- Load Step Control
- Displacement Control







Course Summary

- Innovation means *"Who knows what's next?"*
- The need for advanced simulation exists on the most simple parts and assemblies
- Engineering judgments, not software cost or complexity, makes FEA a tool for all design engineers.
- Autodesk Nastran In-CAD now brings all the power of advanced simulation to the Inventor desktop
- Speak to an Autodesk or Channel Partner simulation expert about your analysis opportunities.

Session Feedback

- Via the Survey Stations, email or mobile device
- AU 2015 passes given out each day!
- Best to do it right after the session
- Instructors see results in real-time

AUTODESK®