Let’s Get It Started!
An in-depth kick-off to the FEA with Nastran Power Track

Sualp Ozel, PE

Product Manager

Safe Harbor

- We may make statements regarding planned or future development efforts for our existing or new products and services. These statements are not intended to be a promise or guarantee of future availability of products, services or features but merely reflect our current plans and based on factors currently known to us. These planned and future development efforts may change without notice. Purchasing decisions should not be made based upon reliance on these statements.

- These statements are being made as of Tuesday December 1, 2015 and we assume no obligation to update these forward-looking statements to reflect events that occur or circumstances that exist or change after the date on which they were made. If this presentation is reviewed after Tuesday December 1, 2015, these statements may no longer contain current or accurate information.

FEA with Autodesk Nastran Track Schedule

	1 Tuesday		2 Wednesday			3 Thursday	
8:00	**Class 1: Let's Get It Started! An in-depth kick-off to the FEA with Autodesk Nastran Power Track** *- Sualp Ozel*		**Class 5: The World is Nonlinear! Seeing and capturing nonlinear in real-world problems** *- Vince Adams & Dave Weinberg*			**Class 8: If your products make an impact, let me introduce you to Explicit Dynamics** *- Lee Taylor*	
9:00							
10:00			**Beyond Linear and Static: What all the other buttons in In-CAD are used for** *- Bart McPheeters*	**A Job Weld Done: Getting to the bottom of modeling welds in FEA…** *- Vince Adams*	**Innovation Forum**	**Class 9: Shaking All Over - Using simulation to understand vibrating products** *- Allen Fowkes*	
11:00	**Opening Session Keynote**						
12:00							
1:00						**Class 10: What do my answers mean? All about results in FEA** *- Jim Byrne*	**BAM! Let's Throw a Little In-CAD into your Simulation Soup** *- Andrew Sears*
2:00	**Class 2: All meshes aren't alike! Tips and tricks for getting the best mesh** *- Mitch Muncy*						
3:00	**Class 3: Prep School: Prepare Those Crazy Juvenile CAD Models for the Real World of Simulation** *- Tyler Henderson*	**Innovation Forum**	**Class 6: Goal Driven Design - Using Simulation and Optimization in the Design Process** *– Mike Smell*		**Innovation Forum**		
4:00							
5:00	**Class 4: Simulate what you test: Modeling assemblies for more realistic digital prototypes** *- Andrew Sartorelli*	**STRESSED - Take an Inventor Simulation Chill Pill!** - Wasim Younis	**Class 7: How do the experts see Simulation in the Future of Making Things?** *- Expert Panel – Angie Schrader, facilitator*			**Closing Keynote**	

Faculty Includes:

Sualp Ozel	Simulation Product Manager
Mitch Muncy	Nastran Product Manager
Tyler Henderson	User Experience Designer
Andrew Sartorelli	Technical Specialist
Vince Adams	Product Specialist
Dave Weinberg	Software Architect
Bart McPheeters	Technical Specialist
Mike Smell	Simulation Product Manager
Lee Taylor	Distinguished Research Engineer
Allen Fowkes	Technical Specialist
Jim Byrne	Technical Marketing Specialist
Andrew Sears	Sr. Software Quality Engineer

AU General Session
Track Course
Extra-track Opportunity

Class summary

This class will cover the basics of finite element analysis (FEA) and explore examples in order to gain additional insight and improve product design for oil and gas, and industrial machinery.

Key learning objectives

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

- Understand the basics of finite element analysis
- Learn how to generate a finite element mesh
- Learn how to set up a problem
- Learn how to post process results

Agenda

- Session Approach
- Finite Element Analysis (FEA) Overview
- FEA Parameters
- FEA Best Practices
- FEA Software Introduction
- Analysis Walkthrough

Session Approach

This session will not cover theoretical information… there's just not enough time to teach everyone matrix algebra

$$F = -kx$$

$$\Delta L = \frac{F}{EA}L = \frac{\sigma}{E}L.$$

$$G \stackrel{\text{def}}{=} \frac{\tau_{xy}}{\gamma_{xy}} = \frac{F/A}{\Delta x/l} = \frac{Fl}{A\Delta x}$$

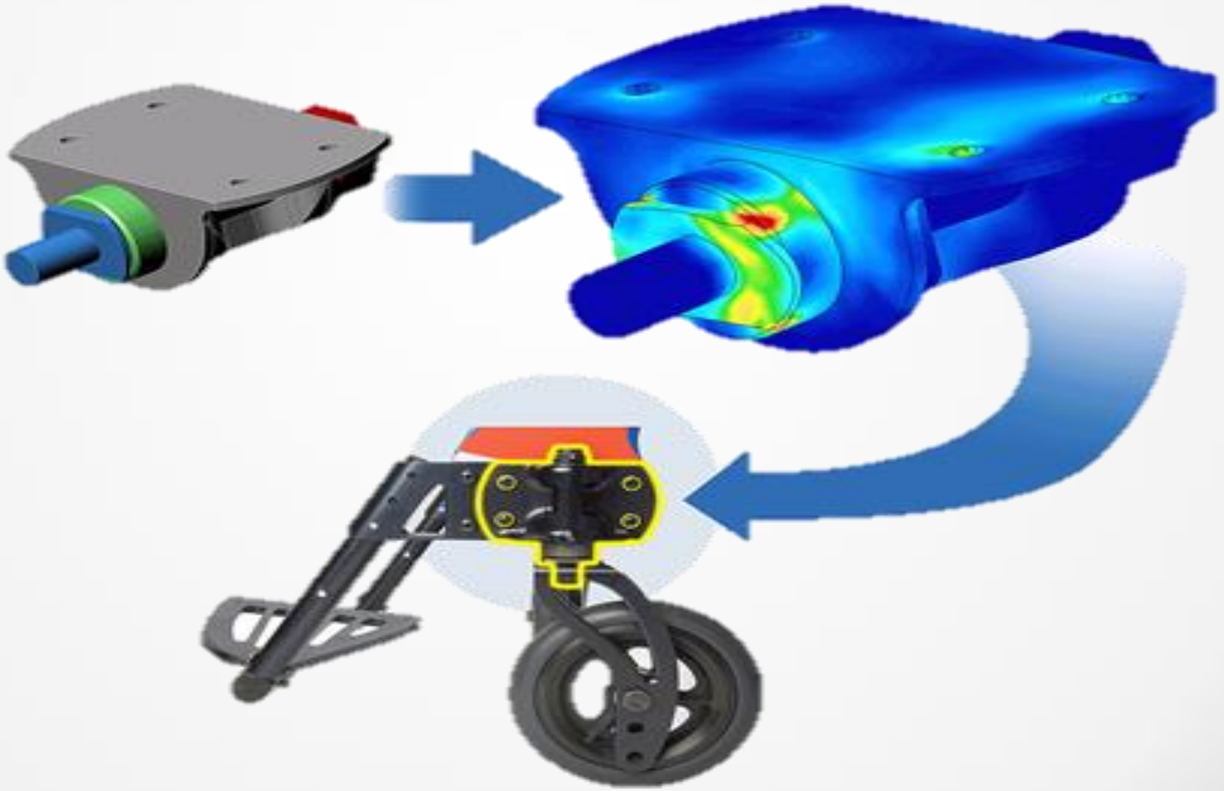
$$-\sum_{k=1}^{n} u_k \phi(v_k, v_j) = \sum_{k=1}^{n} f_k \int v_k v_j dx \text{ for } j = 1,\ldots,n. \quad (4)$$

$$\nu = -\frac{d\varepsilon_{\text{trans}}}{d\varepsilon_{\text{axial}}} = -\frac{d\varepsilon_{\text{y}}}{d\varepsilon_{\text{x}}} = -\frac{d\varepsilon_{\text{z}}}{d\varepsilon_{\text{x}}}$$

$$\begin{bmatrix} \varepsilon_{11} \\ \varepsilon_{22} \\ \varepsilon_{33} \\ 2\varepsilon_{23} \\ 2\varepsilon_{31} \\ 2\varepsilon_{12} \end{bmatrix} = \begin{bmatrix} \varepsilon_{11} \\ \varepsilon_{22} \\ \varepsilon_{33} \\ \gamma_{23} \\ \gamma_{31} \\ \gamma_{12} \end{bmatrix} = \frac{1}{E} \begin{bmatrix} 1 & -\nu & -\nu & 0 & 0 & 0 \\ -\nu & 1 & -\nu & 0 & 0 & 0 \\ -\nu & -\nu & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 2(1+\nu) & 0 & 0 \\ 0 & 0 & 0 & 0 & 2(1+\nu) & 0 \\ 0 & 0 & 0 & 0 & 0 & 2(1+\nu) \end{bmatrix} \begin{bmatrix} \sigma_{11} \\ \sigma_{22} \\ \sigma_{33} \\ \sigma_{23} \\ \sigma_{31} \\ \sigma_{12} \end{bmatrix}$$

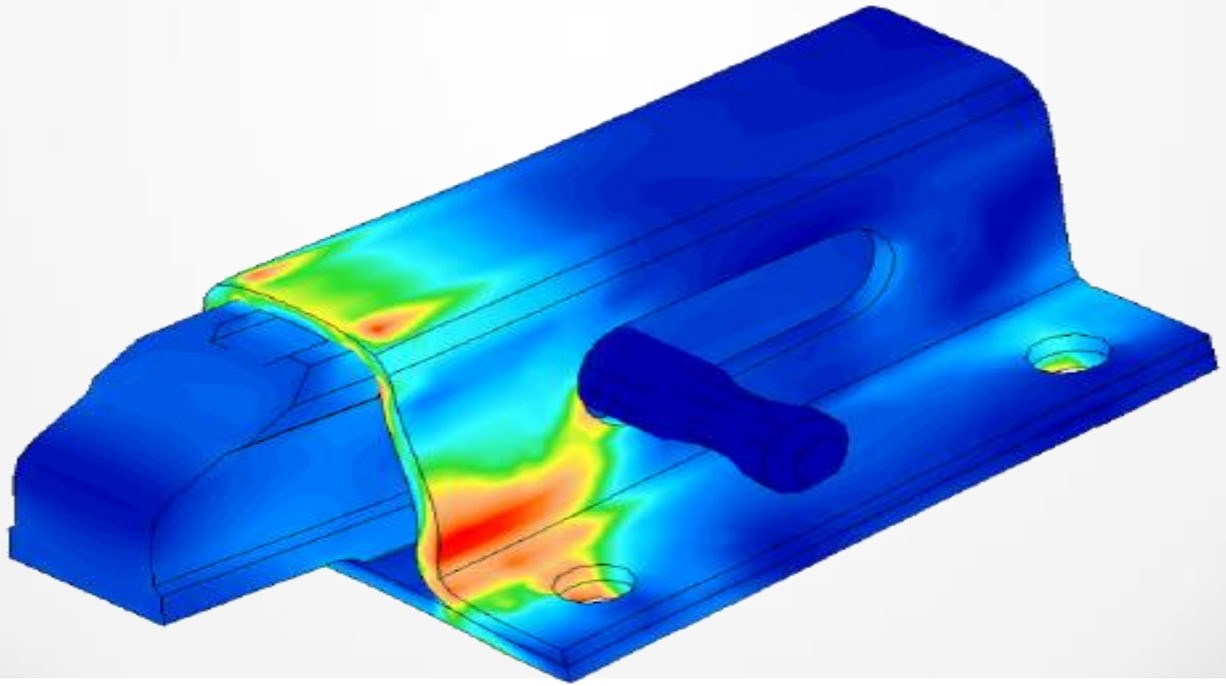
Session Approach

- We are going to apply and leverage modern technology to gain insights into the use cases and capabilities



FEA Description

Finite Element Analysis (FEA) is a computerized method for predicting how a real-world object will react to forces, vibration, heat, etc. to determine whether or not it will function as planned



FEA Benefits

- Predict Product Performance
- Reduce Raw Materials
- Ensure Optimal Design
- Reduce Manual Testing and Prototypes
- Test What If Scenarios
- Shorten Design Cycle

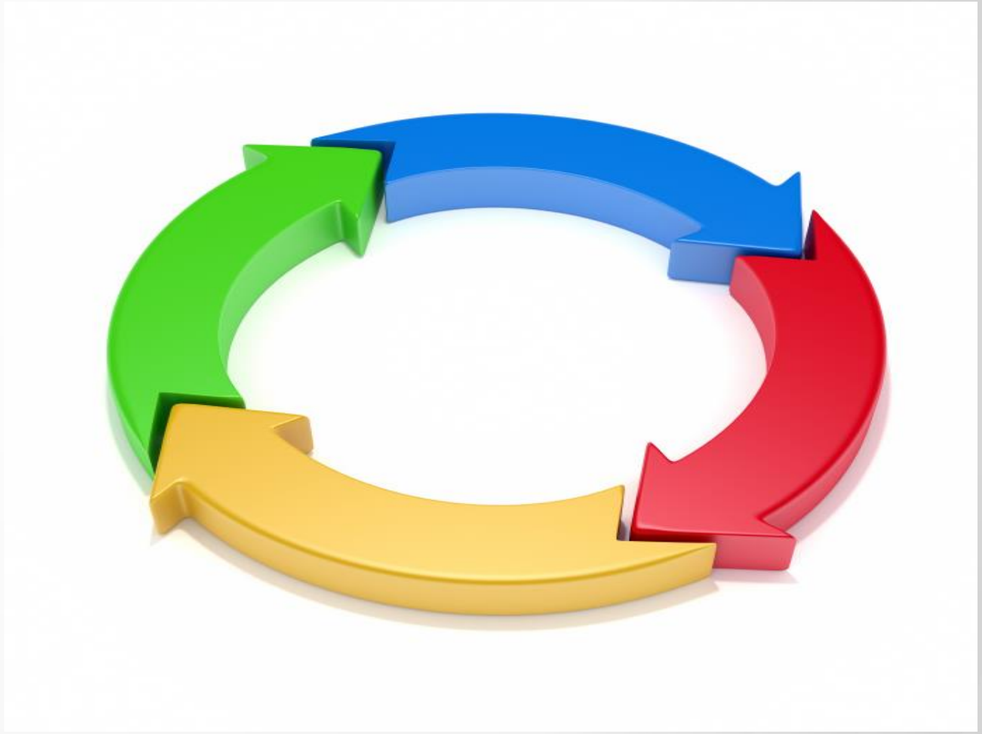
Who Uses Simulation?

The Engineer

The Analyst

FEA Process Overview

- CAD Model Creation / Simplification
- Simulation Setup
- Solve
- Review Results
- Optimize Design



Analysis Types

- Linear ← Focus for this presentation
- Nonlinear
- Thermal / Electrostatic
- Natural Frequency / Modal Analysis
- Vibrations
- Acoustics
- Fatigue Analysis

Linear vs. Nonlinear

Linear

Focus for this presentation

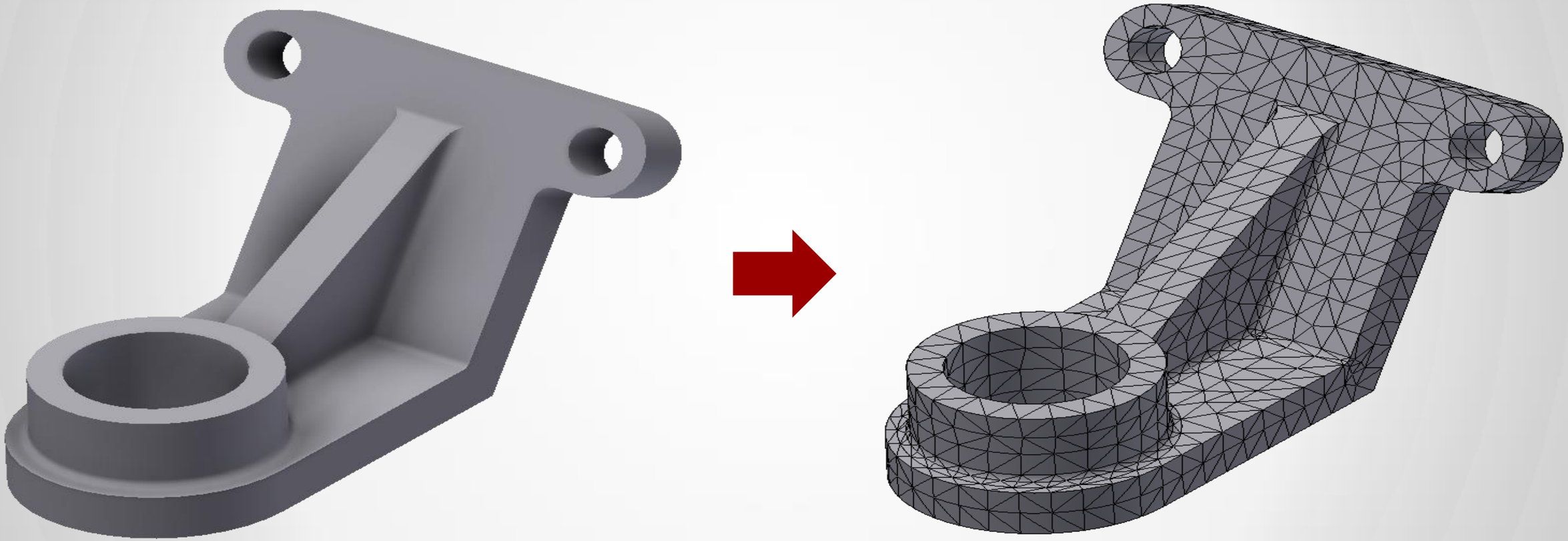
- Structure returns to original form
- Small changes in shape stiffness
- No changes in loading direction or magnitude
- Material properties do not change
- Small deformation and strain

Nonlinear

Wednesday 8:00 AM

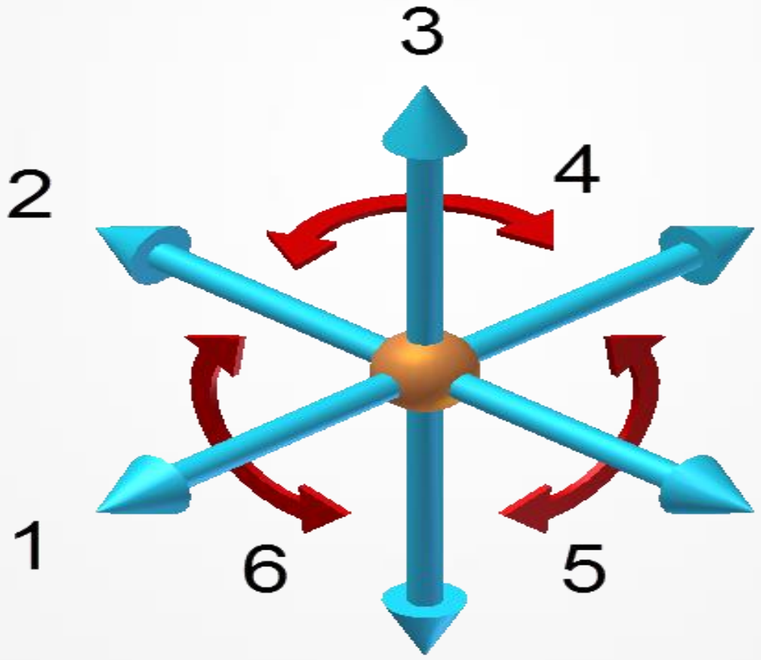
- Geometry changes resulting in stiffness change
- Material deformation that may not return to original form
- Supports changes in load direction and constraint locations
- Support of nonlinear load curves

Meshed 3D Model Example



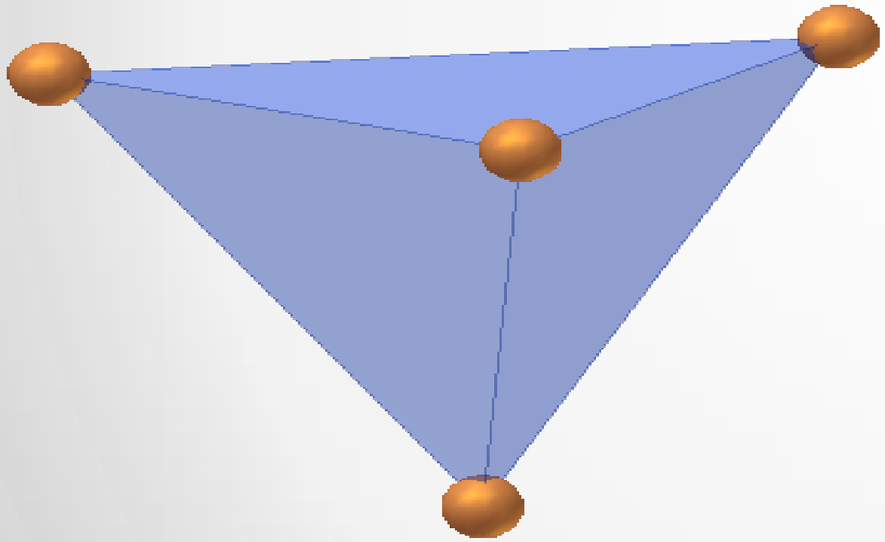
Node Overview

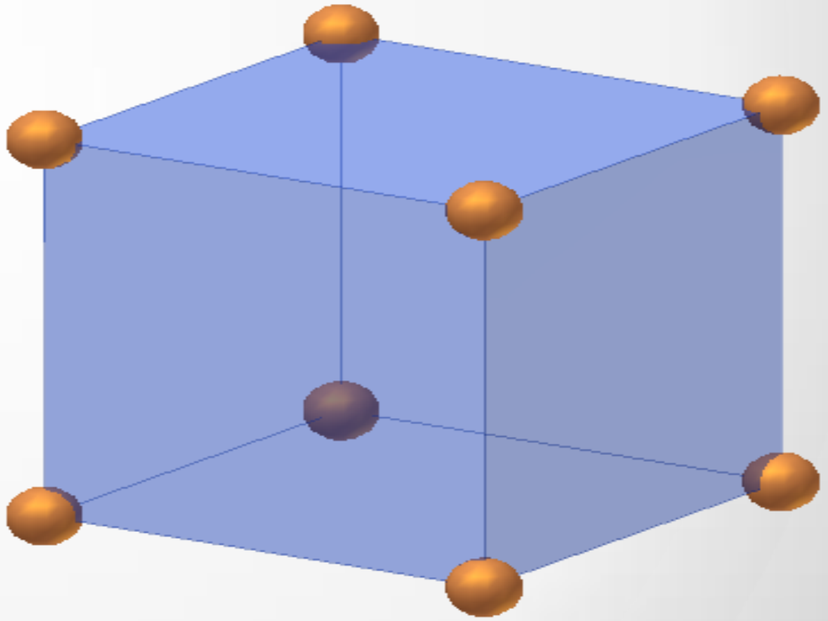
- A node is a coordinate location in space where the Degrees of Freedom (DOFs) are defined.



Element Overview

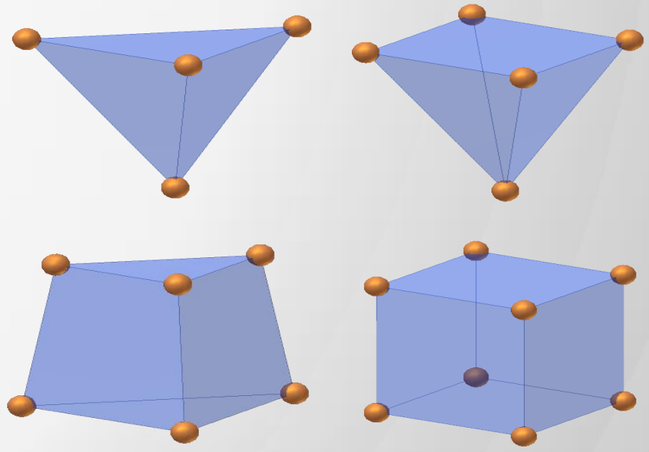
- An element is a mathematical relation that defines how the DOFs of one node relate to the next.





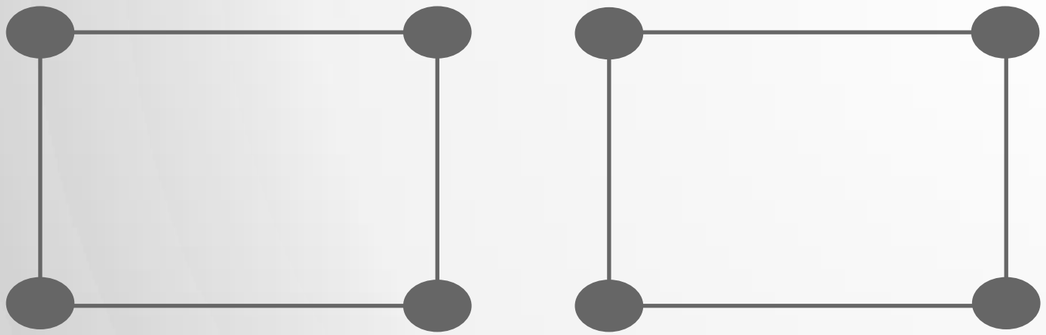
Types of Elements

- 1D elements
  - A line connecting 2 nodes only for items like beams and springs
- 2D elements
  - Planar or axisymmetric elements with either three or four edges enclosing an area
  - Plates or Shell Elements: Planar elements that are triangular or quadrilateral with a specified thickness
- 3D (solid) elements
  - Enclosed 3D volumes with 4, 5, 6 or 8 corner nodes

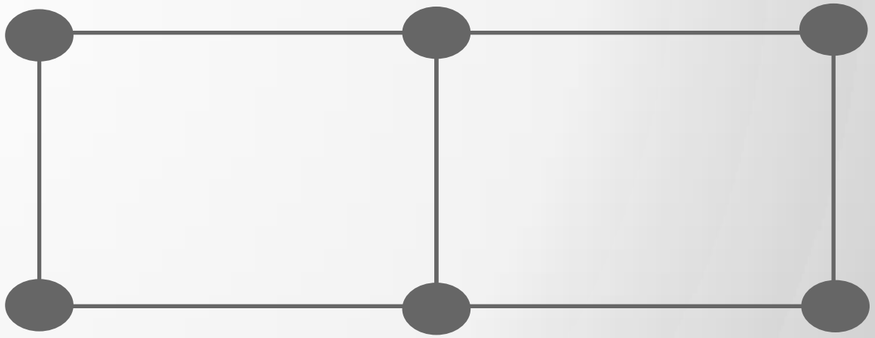


Element connectivity

- Elements within a single part body can only communicate to one another via common nodes for transferring data information



No Connection



Connected Nodes

Material Assignment

- Material properties define the structure characteristics of the part
- Material property information can be located at matweb.com

Mild Steel:

Physical

- Density = 0.284 lbmass/in^3

Linear Structural

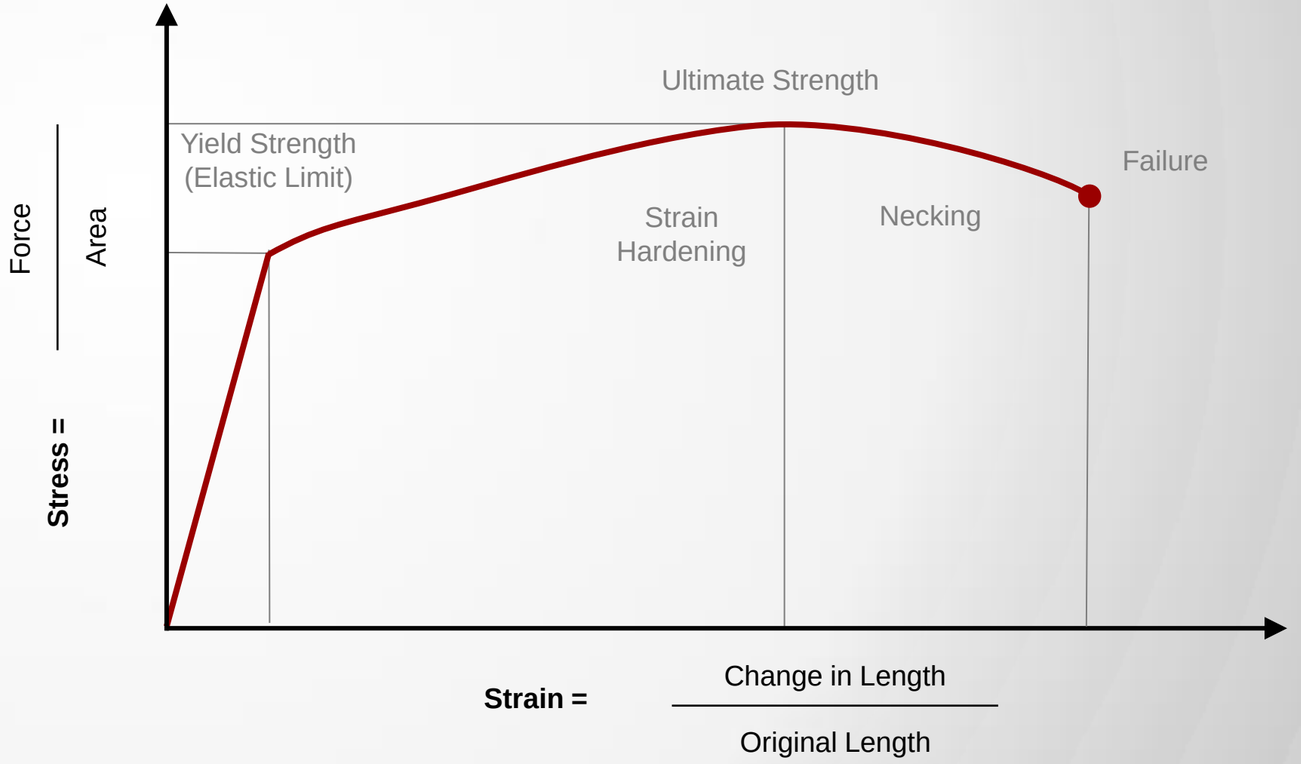
- Young's Modulus = 3,193 ksi
- Poisson's Ratio = 0.275

FOS

- Yield Strength = 30 ksi
- Ultimate Tensile Strength = 50 ksi

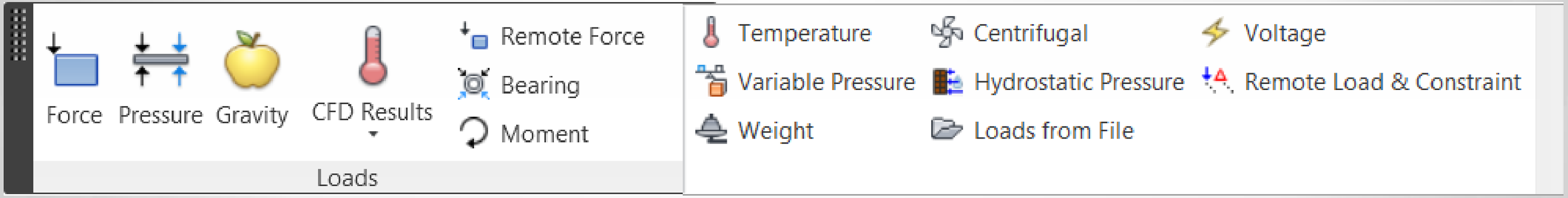
Thermal

- Thermal Conductivity = 1,259 Btu in/(ft^2 hr*F)
- Linear Expansion = 21.6E-6 in/(in*F)
- Specific Heat = 0.356 btu/(lbmass*F)



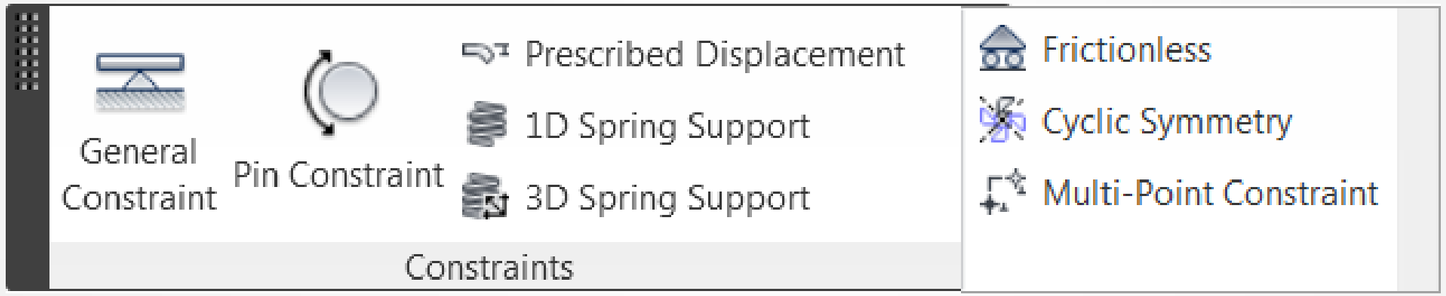
Loads

Structural loads are forces applied to a part or assembly during operation and cause the model to displace, deflect, and induce stresses and strains



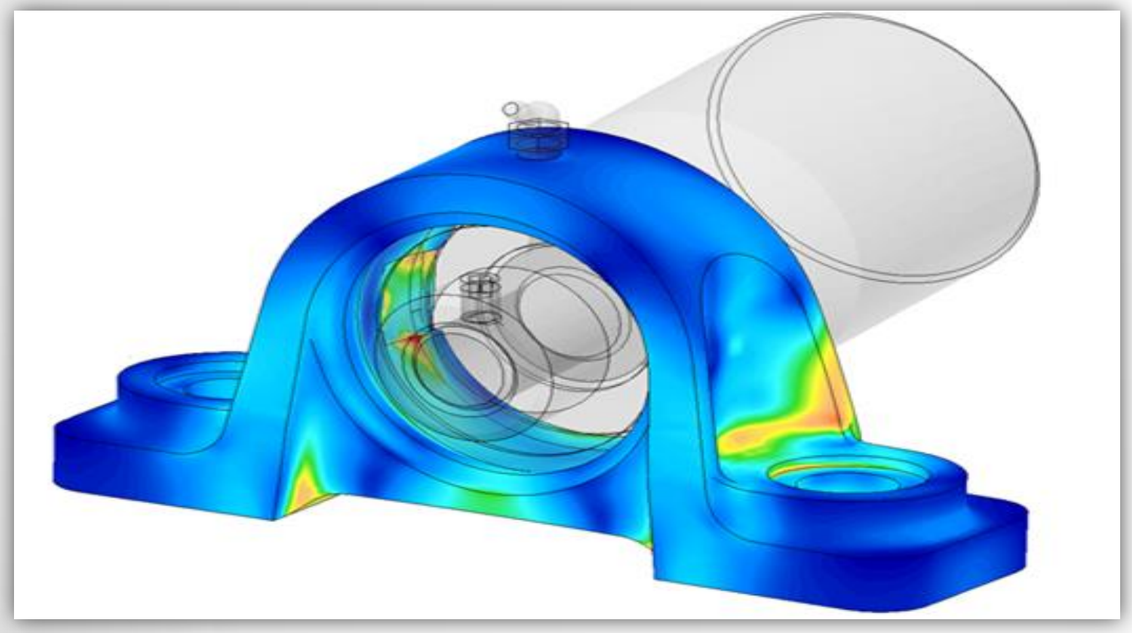
Constraints

Structural constraints restrict or limit the displacement of the model mesh nodes



Contact Conditions

Contact conditions are used to establish relationships between the nodes of contacting parts within an assembly



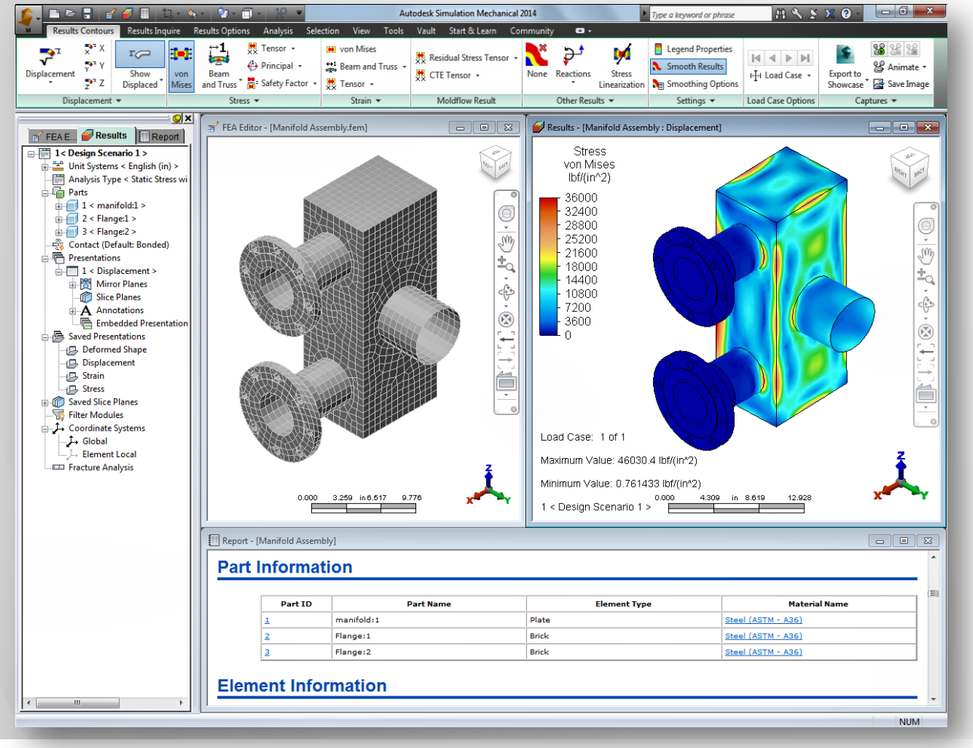
- Bonded
- Welded
- Free/No Contact
- Surface Contact
- Sliding/No Separation
- Separation/No Sliding
- Shrink Fit/Sliding
- Shrink Fit/No Sliding
- Edge Contact

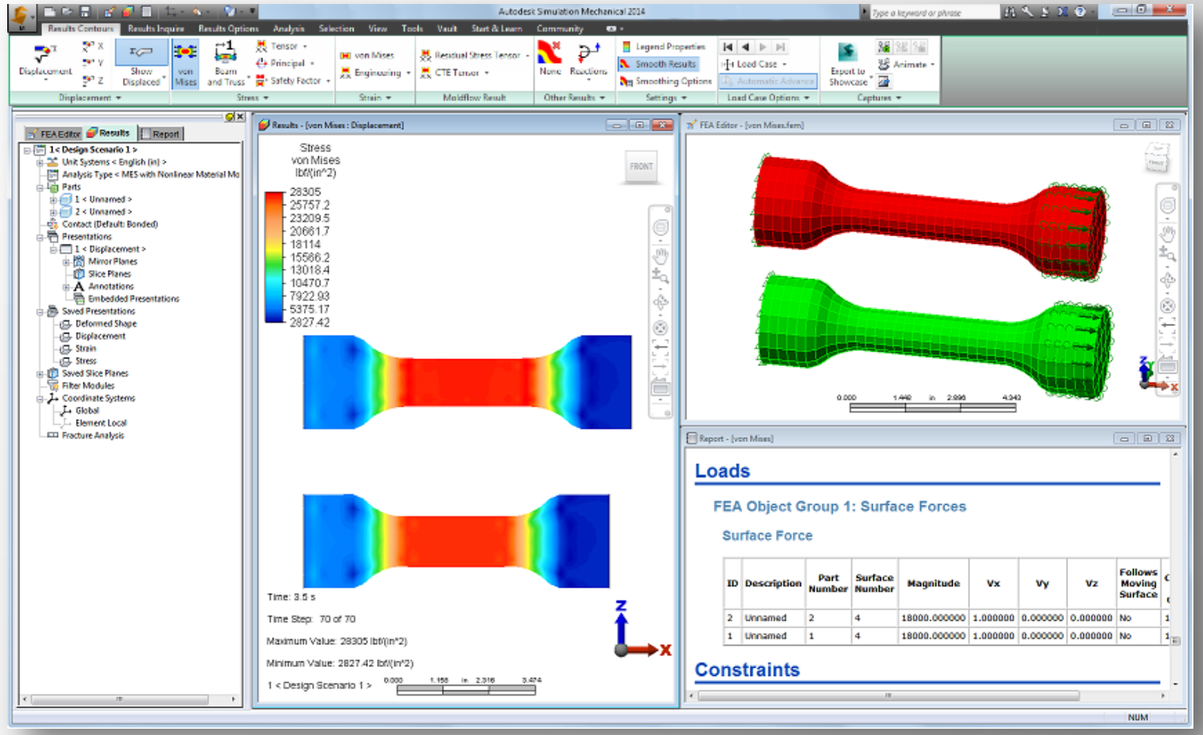
Simulation Solving

Running or solving the simulation processes and calculates the results based on the parameters established

Results

The simulation results can be viewed and exported as a report to make intelligent decisions



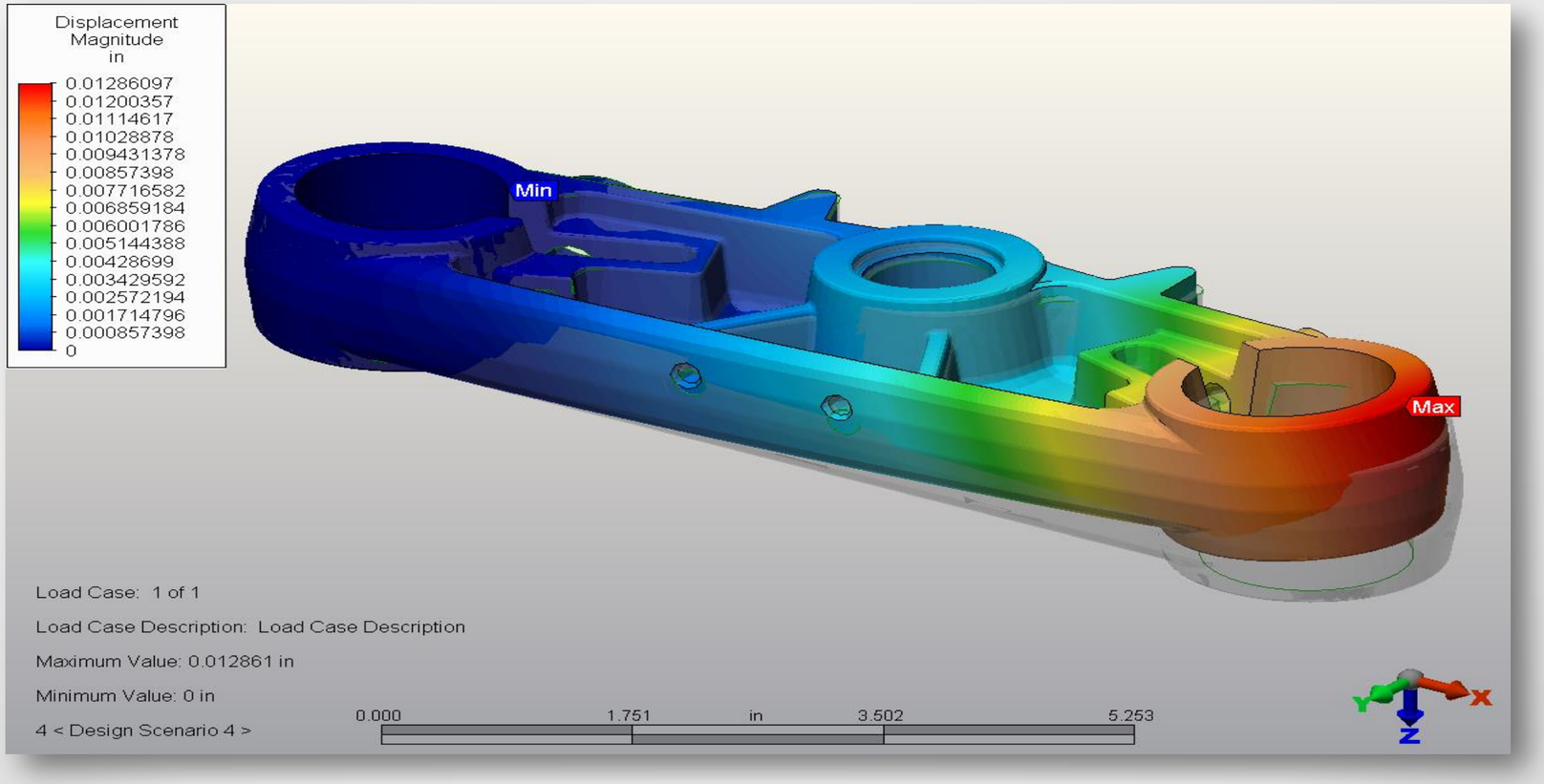


Reviewing Results

- Simulation does not always replace the need for physical testing
- The engineer / analyst still needs to interpret the results to make final decisions

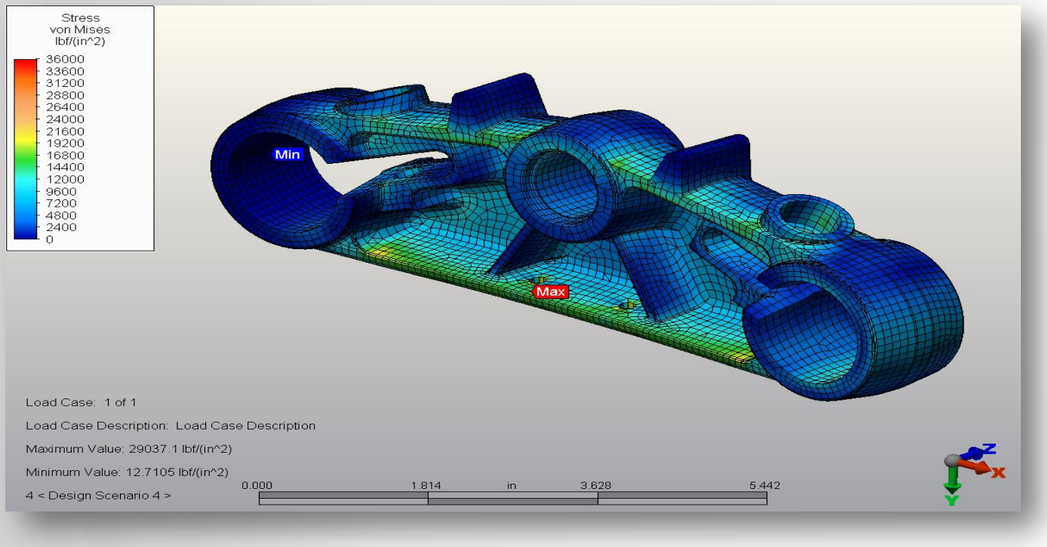
Displacement

The displacement results show the magnitude of the model deformation from the original shape



Von Mises Stress

Formula for combining three principal stresses into an equivalent stress to compare to the material stress properties



The equation used is:

$$\sqrt{0.5\left[(S_x - S_y)^2 + (S_y - S_z)^2 + (S_z - S_x)^2\right] + 3\left(S_{xy}^2 + S_{yz}^2 + S_{zx}^2\right)}$$

where Sx, Sy, and Sz are the axial stresses in the global directions, and Sxy, Syz, and Sxz are the shear stresses.

In terms of the principal stresses S1, S2 and S3:

$$\sqrt{0.5\left[(S_1 - S_2)^2 + (S_2 - S_3)^2 + (S_3 - S_1)^2\right]}$$

Note: von Mises value is always positive.

Safety Factor

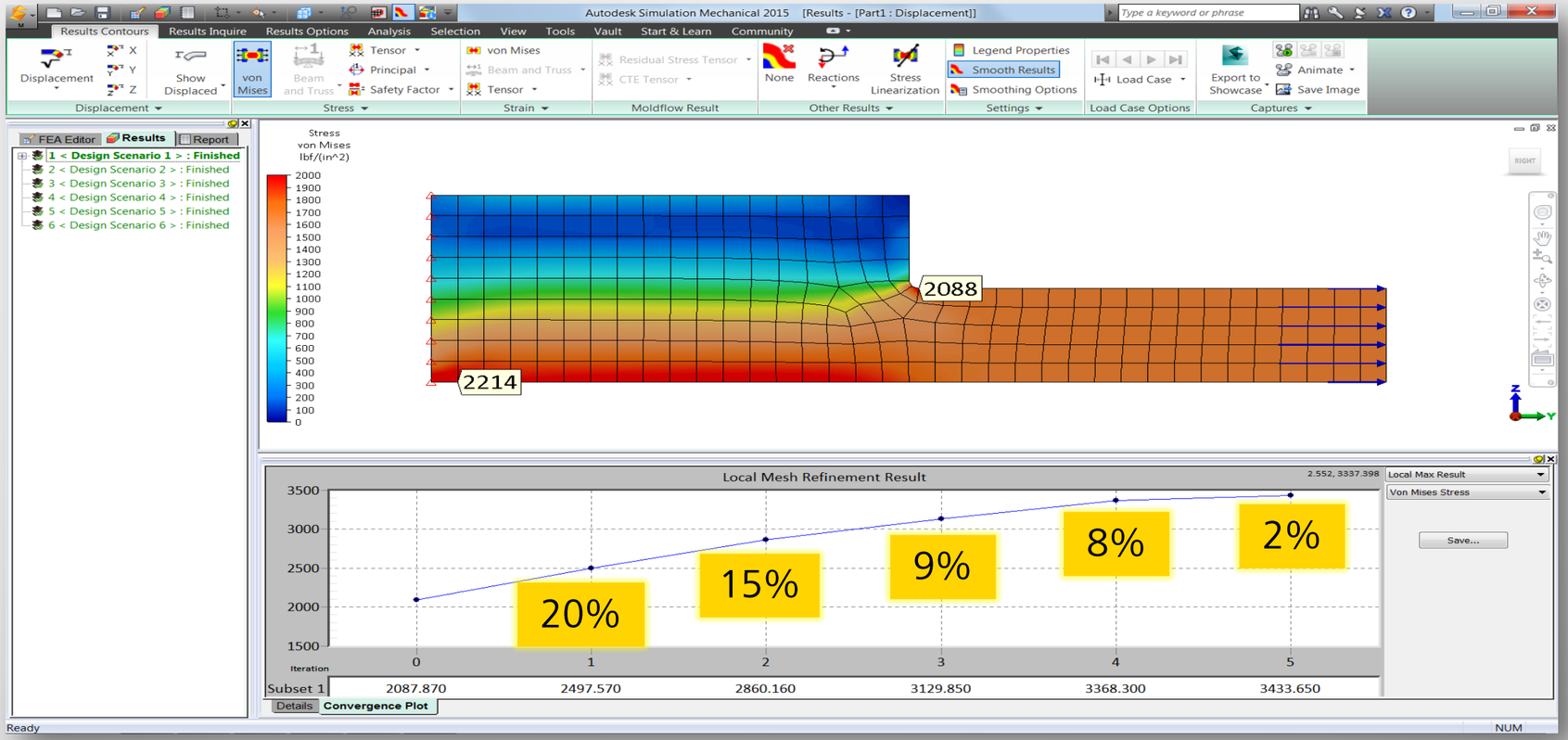
Provides a ratio of how much stronger the object is than it usually needs to be for an intended load

$$\text{Safety Factor} = \frac{\text{Material Yield Strength}}{\text{Maximum Von Mises Stress}}$$

$$2 = \frac{40{,}000 \text{ psi}}{20{,}000 \text{ psi}}$$

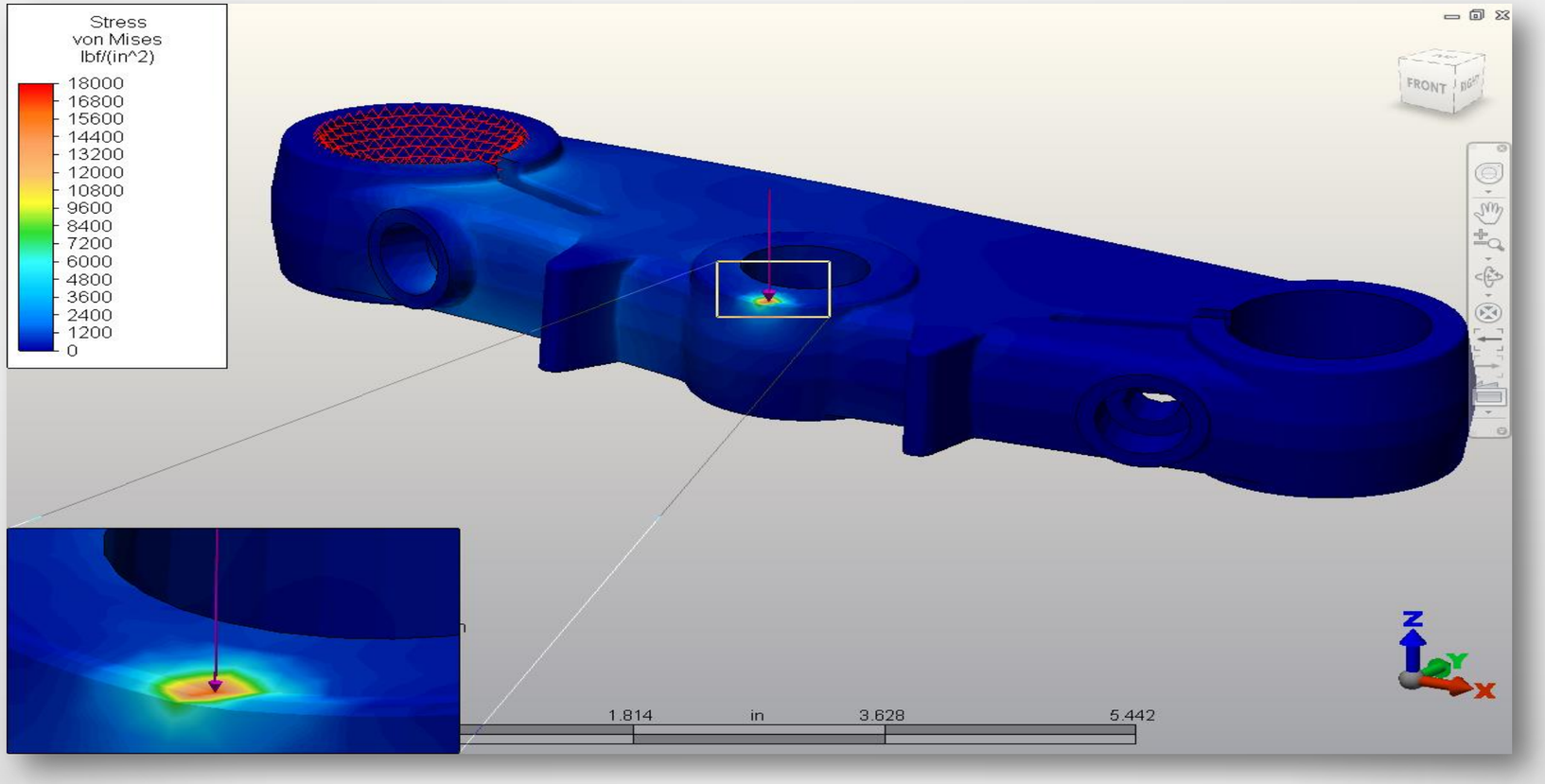
Convergence

Convergence is the process of altering element sizes in high stress areas to ensure the specified result criteria has converged



Stress Singularities

A localized high stress area where the stress becomes infinite resulting in distorted results



Best Practices

- Ensure solution type (Linear / Nonlinear)
- Setup simulation to match real world
- Verify material properties
- Avoid putting loads on nodes or small edges to avoid stress singularities
- Ensure your results converge

FEA Software

- Conceptual Simulation (Apps)
- FEA Features Built into Design Tools
- Purpose Built Simulation Software

Autodesk Mechanical simulation portfolio

Mechanical simulation

Use comprehensive Finite Element Analysis (FEA) to predict product performance through linear, nonlinear, thermal, and dynamic analysis. Optimize designs and validate product behavior before manufacturing.

Simulation Mechanical

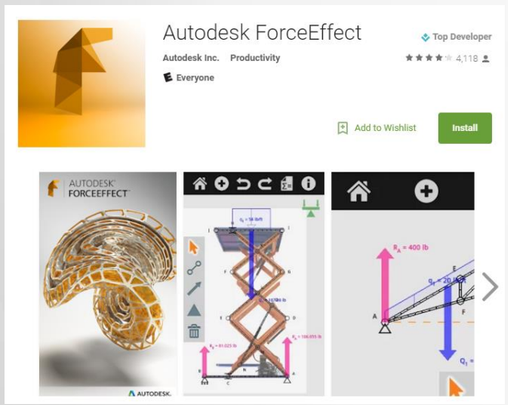
Study finite element analysis (FEA) and mechanical event simulation.

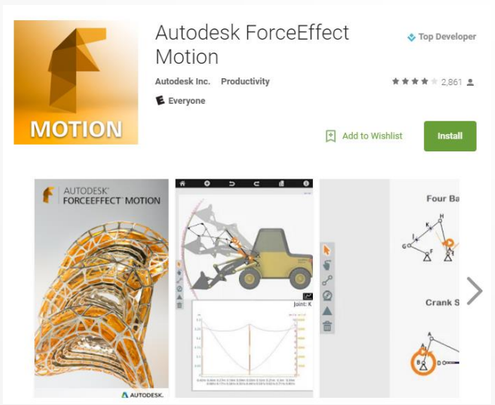
Autodesk Nastran In-CAD

CAD-embedded FEA simulation, powered by our Autodesk Nastran solver.

Autodesk Nastran

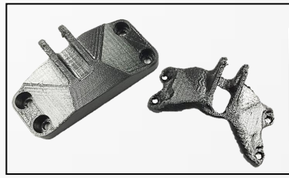
FEA solver delivers accurate results for complex simulations.





Fusion 360

Inventor Professional



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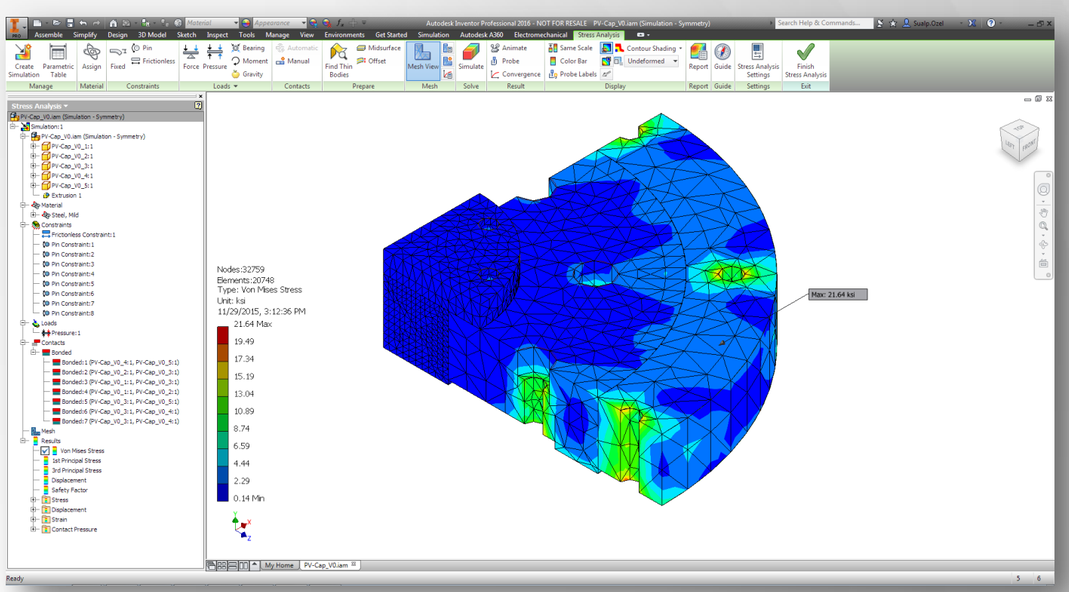
Walkthrough

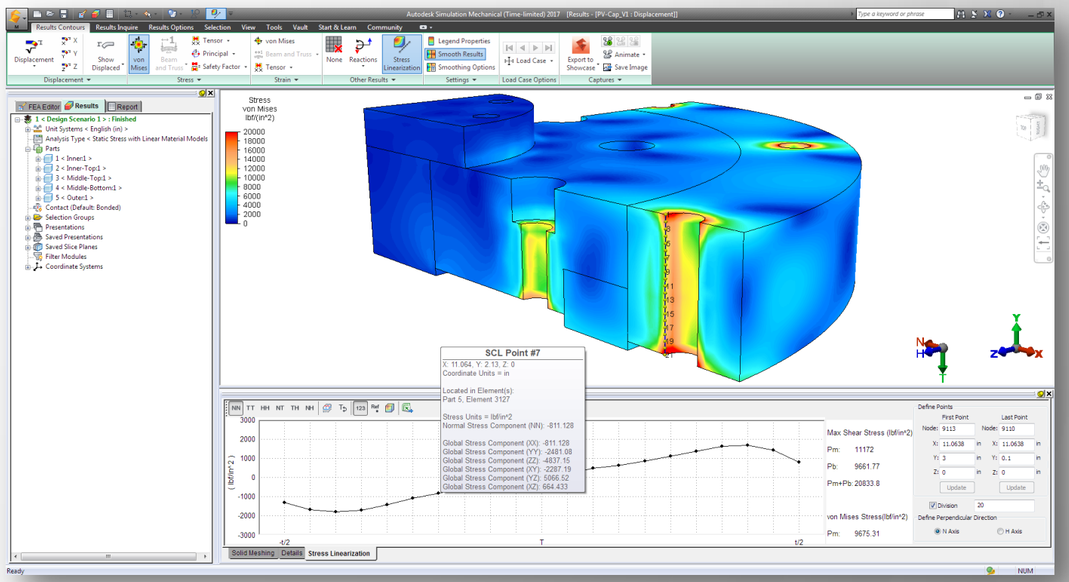
1st pass

- Start with geometry
- Simplify
- Assign loads and constraints
- Perform a first pass analysis



Deep dive

- Review the setup
- Refine the mesh
- Add connectors if needed
- Verify against ASME code



Recap

- Finite Element Analysis (FEA) Overview
- FEA Parameters
- FEA Best Practices
- FEA Software Introduction
- Analysis Walkthrough

Thank You!

Questions?

- Contact: sualp.ozel@autodesk.com
- Products: http://autodesk.com/simulation
- Community: http://simhub.autodesk.com

Don’t miss our speaker panel!

How do the experts see Simulation in the Future of Making Things?

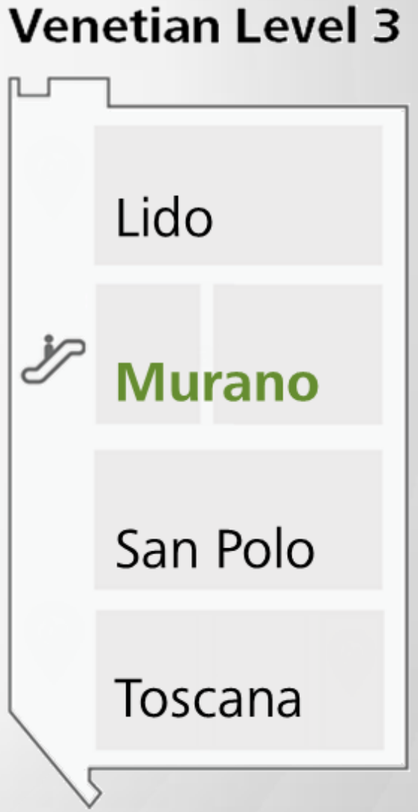
Wednesday, Dec. 2nd
4:30 – 5:30 PM
Murano 3301 Level 3

Scott Borduin
CTO
Manufacturing Product Group, Autodesk

Greg Fallon
Vice President
Simulation Product Group, Autodesk

Roger Corn
Mechanical Engineer
Sony Visual Products

Rick Arthur
Director
Advanced Computing Research, General Electric



Check out our newest thing…

AUTODESK®

PROJECT ARRO

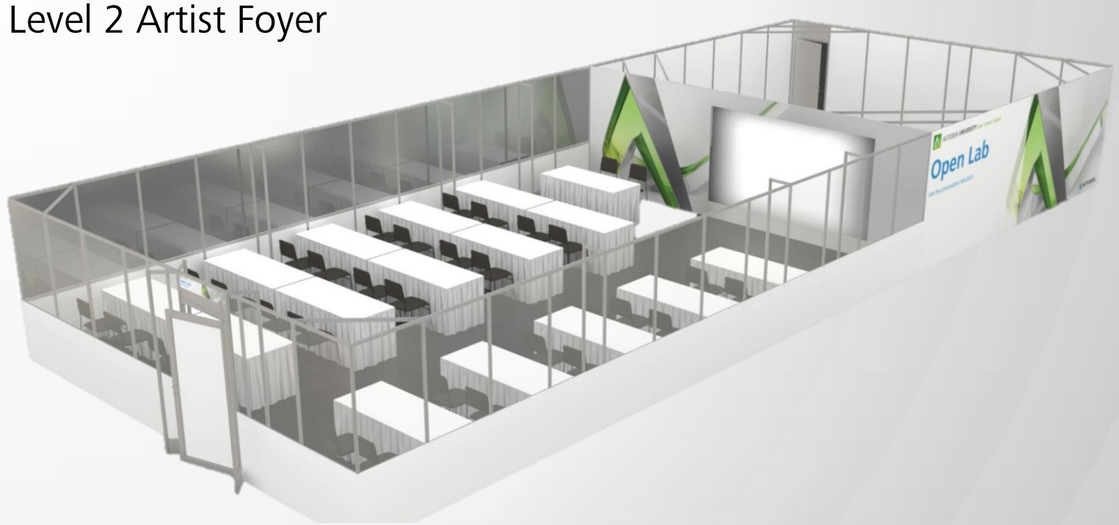
Attend a Class

Goal-Driven Design—Using Simulation and Optimization in the Design Process

Wednesday, Dec. 2nd
3:00 – 4:00 PM
Murano 3203 Level 3

Participate in an Open Lab

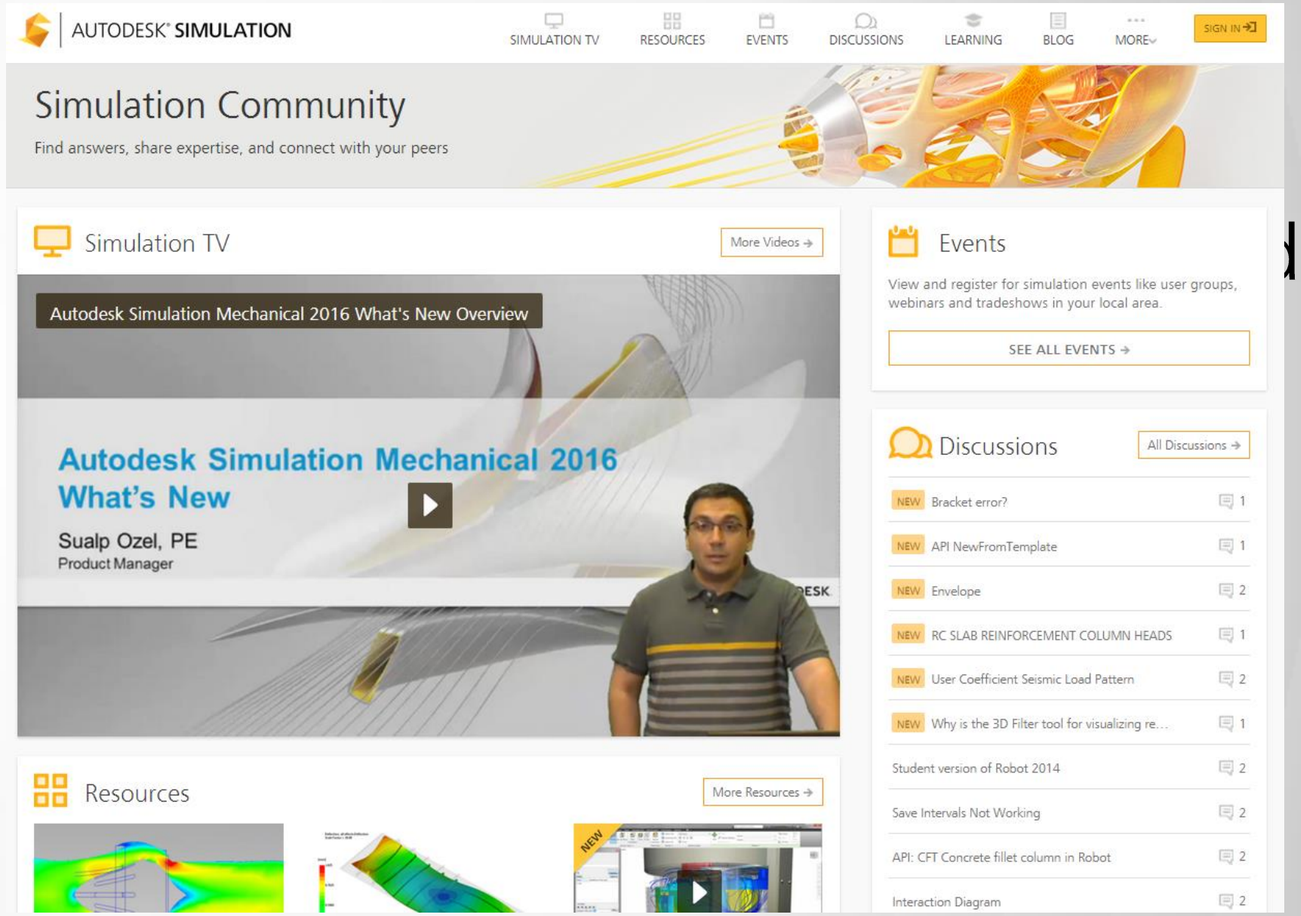
Thursday, Dec. 3rd
10:00 – 10:30
Level 2 Artist Foyer



Resources – SimHub

simhub.autodesk.com

Simulation TV	Functionality Features and What's New videos
Resources	White papers and validation documents
Forum and Idea Station	Ask questions, share your knowledge and ideas
Blog	Read feature stories, learn tips and tricks or get the latest news
Learning	Archive of AU-online presentations

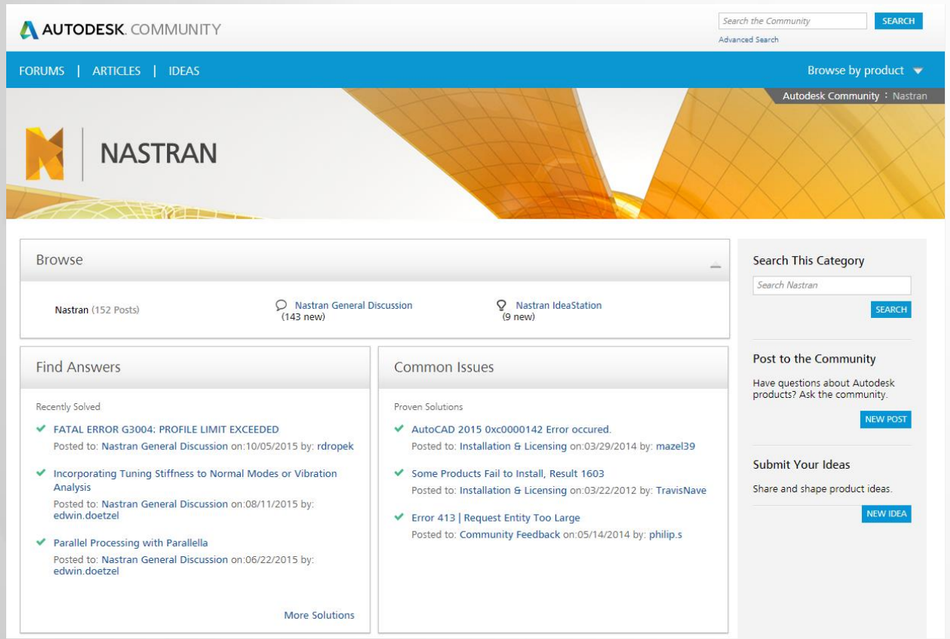


→ Ask a question of the SimSquad

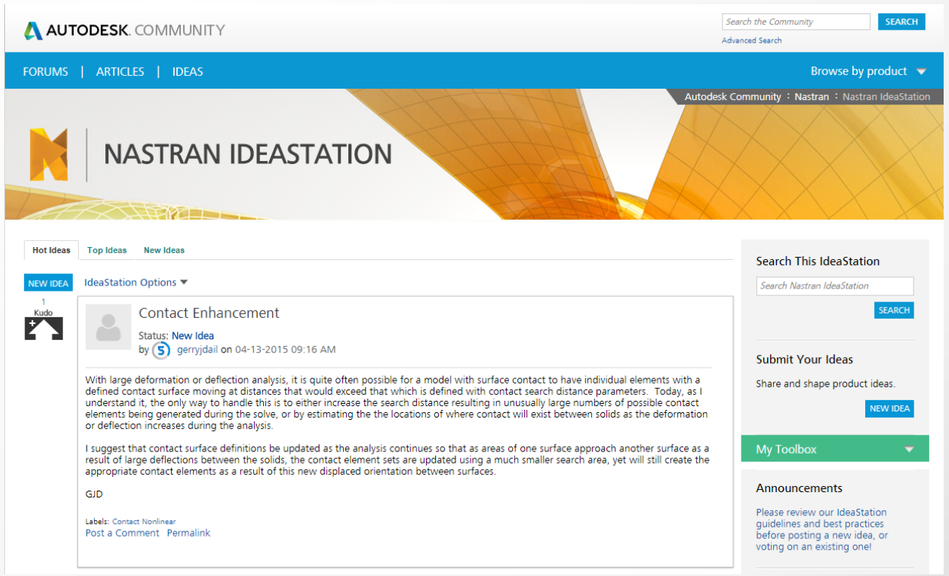
Resources – Forum and IdeaStation

- Autodesk customers and industry partners ask questions and share information about Autodesk products.
- Regularly monitored by Autodesk employees

Autodesk Nastran Forum

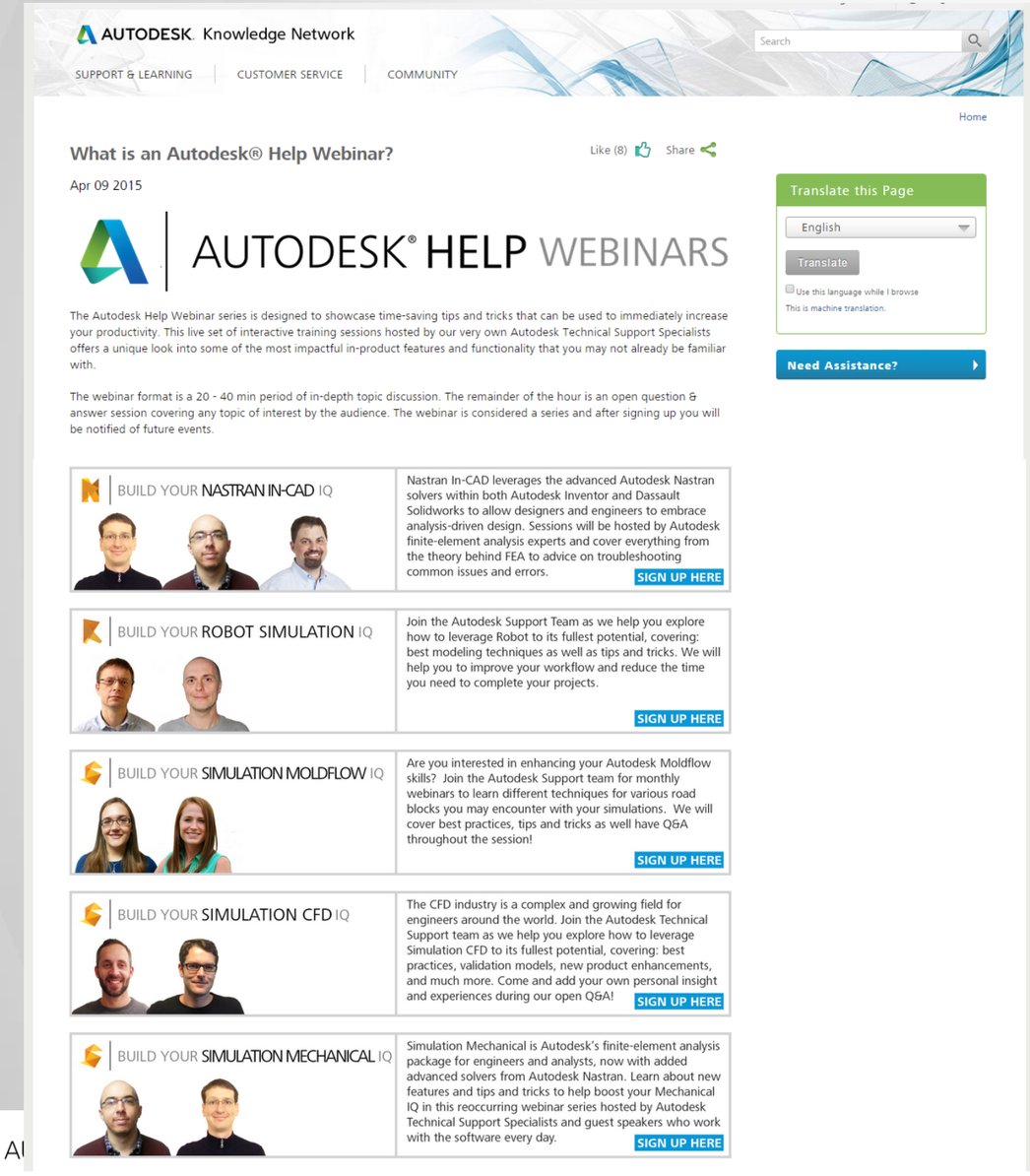


Autodesk Nastran IdeaStation

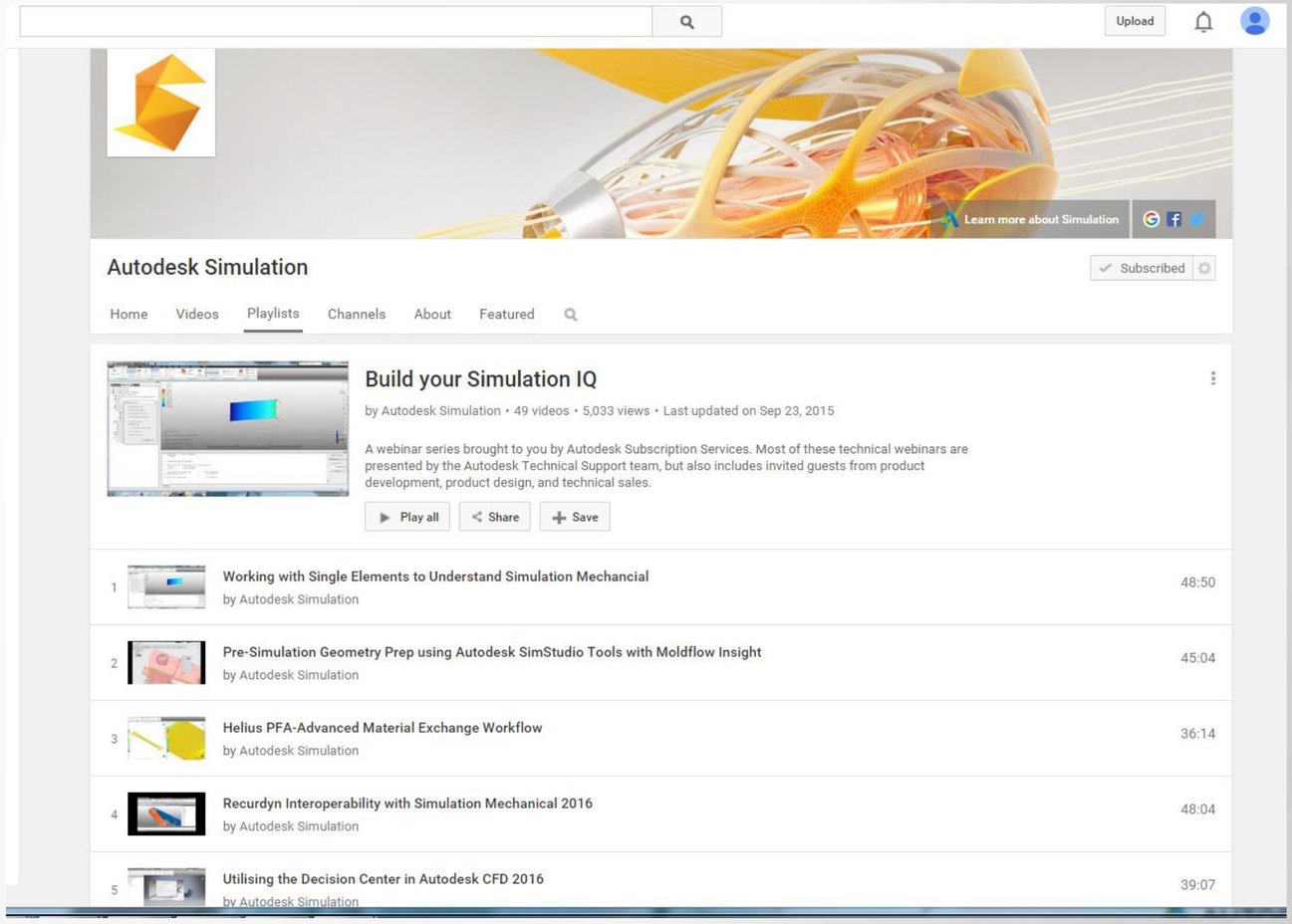


→ Can be found via the Knowledge Network or the SimHub

Resources – Build Your Simulation IQ Webinars



Register for live webinars, or watch them on-demand on Youtube.



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- Via the Survey Stations, email or mobile device.
- AU 2016 passes awarded daily!
- Give your feedback after each session.
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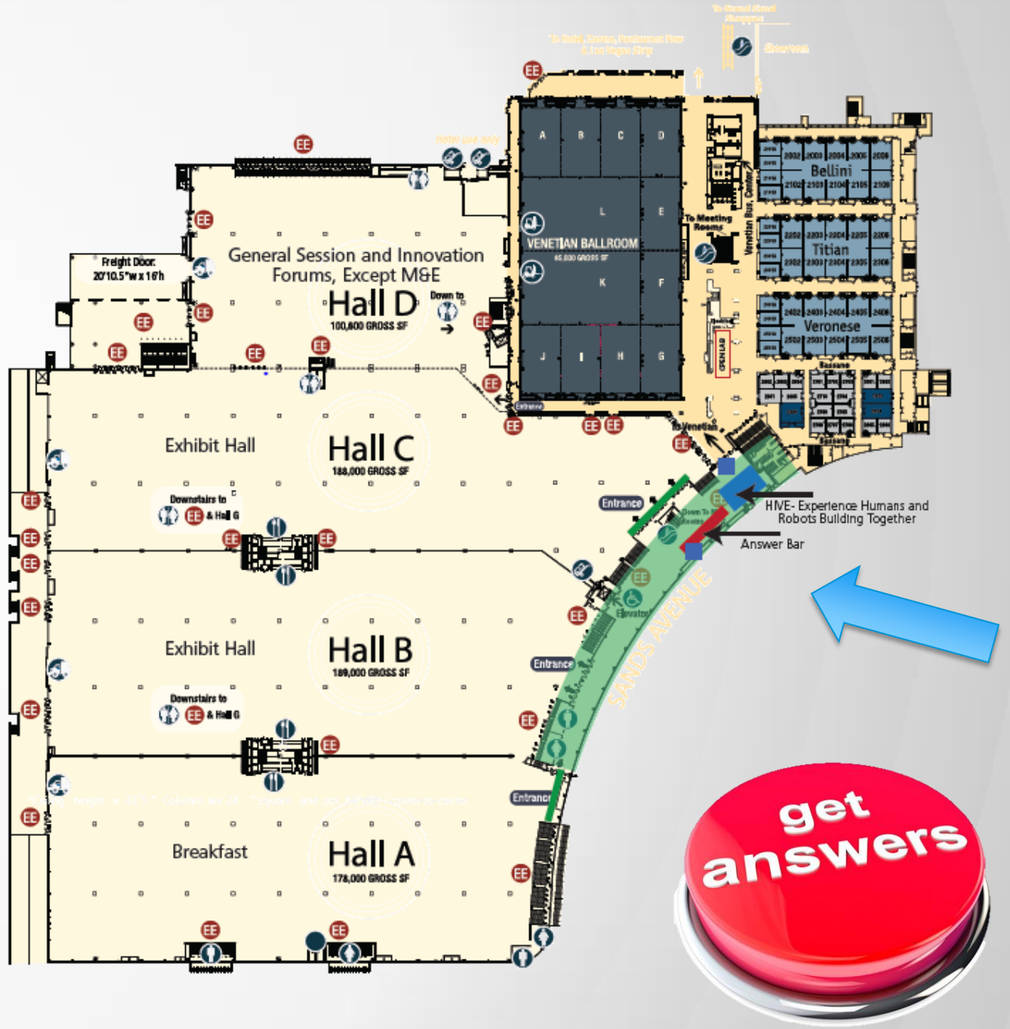

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