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

**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

## Tuesday

<table>
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<tr>
<th>Time</th>
<th>Session</th>
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<tbody>
<tr>
<td>8:00</td>
<td><strong>Class 1</strong>: Let’s Get It Started! An in-depth kick-off to the FEA with Autodesk Nastran Power Track</td>
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<tr>
<td></td>
<td>- Sualp Ozel</td>
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<tr>
<td>9:00</td>
<td><strong>Beyond Linear and Static: What all the other buttons in In-CAD are used for</strong></td>
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<tr>
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<td>- Bart McPheeters</td>
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<tr>
<td>10:00</td>
<td><strong>Beyond Linear and Static: What all the other buttons in In-CAD are used for</strong></td>
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<tr>
<td></td>
<td>- Bart McPheeters</td>
</tr>
<tr>
<td>11:00</td>
<td><strong>Class 2</strong>: All meshes aren’t alike! Tips and tricks for getting the best mesh</td>
</tr>
<tr>
<td></td>
<td>- Mitch Muncy</td>
</tr>
<tr>
<td>12:00</td>
<td><strong>Class 3</strong>: Prep School: Prepare Those Crazy Juvenile CAD Models for the Real World of Simulation</td>
</tr>
<tr>
<td></td>
<td>- Tyler Henderson</td>
</tr>
<tr>
<td>2:00</td>
<td><strong>Class 4</strong>: Simulate what you test: Modeling assemblies for more realistic digital prototypes</td>
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<td>- Andrew Sartorelli</td>
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## Wednesday

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<th>Time</th>
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<tbody>
<tr>
<td>8:00</td>
<td><strong>Class 5</strong>: The World is Nonlinear! Seeing and capturing nonlinear in real-world problems</td>
</tr>
<tr>
<td></td>
<td>- Vince Adams &amp; Dave Weinberg</td>
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<tr>
<td>9:00</td>
<td><strong>A Job Weld Done: Getting to the bottom of modeling welds in FEA...</strong></td>
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<tr>
<td></td>
<td>- Vince Adams</td>
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<tr>
<td>10:00</td>
<td><strong>Innovation Forum</strong></td>
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<td><strong>Class 6</strong>: Goal Driven Design - Using Simulation and Optimization in the Design Process</td>
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<tr>
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<td>- Mike Smell</td>
</tr>
<tr>
<td>11:00</td>
<td><strong>Innovation Forum</strong></td>
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<td></td>
<td><strong>Class 7</strong>: How do the experts see Simulation in the Future of Making Things? - Expert Panel – Angie Schrader, facilitator</td>
</tr>
<tr>
<td>12:00</td>
<td><strong>Class 8</strong>: If your products make an impact, let me introduce you to Explicit Dynamics</td>
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<tr>
<td></td>
<td>- Lee Taylor</td>
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<tr>
<td>1:00</td>
<td><strong>Class 9</strong>: Shaking All Over - Using simulation to understand vibrating products</td>
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<td></td>
<td>- Allen Fowkes</td>
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<tr>
<td>2:00</td>
<td><strong>Class 10</strong>: What do my answers mean? All about results in FEA...</td>
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<td>- Jim Byrne</td>
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## Thursday

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<tbody>
<tr>
<td>8:00</td>
<td><strong>Class 11</strong>: Innovation Forum <strong>Class 12</strong>: A Job Weld Done: Getting to the bottom of modeling welds in FEA...</td>
</tr>
<tr>
<td>9:00</td>
<td><strong>Class 13</strong>: Beyond Linear and Static: What all the other buttons in In-CAD are used for</td>
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<tr>
<td></td>
<td>- Bart McPheeters</td>
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<tr>
<td>10:00</td>
<td><strong>Class 14</strong>: Beyond Linear and Static: What all the other buttons in In-CAD are used for</td>
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<tr>
<td></td>
<td>- Bart McPheeters</td>
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<tr>
<td>11:00</td>
<td><strong>Class 15</strong>: All meshes aren’t alike! Tips and tricks for getting the best mesh</td>
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<td>- Mitch Muncy</td>
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<tr>
<td>12:00</td>
<td><strong>Class 16</strong>: Class 3: Prep School: Prepare Those Crazy Juvenile CAD Models for the Real World of Simulation</td>
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<tr>
<td></td>
<td>- Tyler Henderson</td>
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<tr>
<td>2:00</td>
<td><strong>Class 17</strong>: Simulate what you test: Modeling assemblies for more realistic digital prototypes</td>
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<td></td>
<td>- Andrew Sartorelli</td>
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<tr>
<td>3:00</td>
<td><strong>Class 18</strong>: Class 4: Simulate what you test: Modeling assemblies for more realistic digital prototypes</td>
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<td>- Andrew Sartorelli</td>
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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.
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.

\[ F = -kx \]

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

\[ G \overset{\text{def}}{=} \frac{\tau_{xy}}{\gamma_{xy}} = \frac{F/A}{\Delta x/l} = \frac{F/I}{A\Delta x} \]

\[ \nu = -\frac{\partial \varepsilon_{\text{trans}}}{\partial \varepsilon_{\text{axial}}} = -\frac{\partial \varepsilon_y}{\partial \varepsilon_x} = -\frac{\partial \varepsilon_z}{\partial \varepsilon_x} \]

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

- We are going to apply and leverage modern technology to gain insights into the use cases and capabilities.
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
- Nonlinear
- Thermal / Electrostatic
- Natural Frequency / Modal Analysis
- Vibrations
- Acoustics
- Fatigue Analysis

Focus for this presentation
Linear vs. Nonlinear

Linear
- 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
- 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

Focus for this presentation

Wednesday 8:00 AM
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.
Material Assignment

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

**Mild Steel:**

**Physical**
- Density: $0.284 \text{ lbmass/in}^3$

**Linear Structural**
- Young’s Modulus: $3,193 \text{ ksi}$
- Poisson’s Ratio: $0.275$

**FOS**
- Yield Strength: $30 \text{ ksi}$
- Ultimate Tensile Strength: $50 \text{ ksi}$

**Thermal**
- Thermal Conductivity: $1,259 \text{ Btu in/(ft}^2 \text{ h} \cdot \text{F})$
- Linear Expansion: $21.6 \times 10^{-6} \text{ in/(in} \cdot \text{F})$
- Specific Heat: $0.356 \text{ btu/(lbmass} \cdot \text{F})$

![Material Assignment Diagram](Image)
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.
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:

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

where \( S_x, S_y, \) and \( S_z \) are the axial stresses in the global directions, and \( S_{xy}, S_{yz}, \) and \( S_{xz} \) are the shear stresses.

In terms of the principal stresses \( S_1, S_2 \) and \( S_3 \):

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

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.
Walkthrough

1\textsuperscript{st} 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. 2\textsuperscript{nd}
3:00 – 4:00 PM
Murano 3203 Level 3

Participate in an Open Lab
Thursday, Dec. 3\textsuperscript{rd}
10:00 – 10:30
Level 2 Artist Foyer
### Resources – SimHub

**[simhub.autodesk.com](http://simhub.autodesk.com)**

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<td>Forum and Idea Station</td>
<td>Ask questions, share your knowledge and ideas</td>
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→ 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.

- **Build Your NASTRAN in CAD:** Nathan In CAD leverages the advanced Autodesk NASTRAN solver within both Autodesk Inventor and Revit to show you how to start using NASTRAN for structural analysis-driven design. Sessions will be hosted by Autodesk from technical experts and cover everything from the theory behind finite element analysis, to setting up your analysis and avoiding common errors.

- **Build Your Robot Simulation:** Join the Autodesk Support team as we help you explore how to leverage Robot 3D to its fullest potential, covering best modeling techniques as well as tips and tricks. We will help you to optimize your workflow and explore the time you need to complete your project.

- **Build Your Simulation Moldflow IQ:** Are you interested in enhancing your Autodesk Moldflow skills? Join the Autodesk Support team for monthly webinars to learn different techniques for various CAD tools you may encounter with your simulations. We will cover best practices, tips, and tricks as well as Q&A throughout the session.

- **Build Your Simulation CFD IQ:** The CFD industry is a complex and growing field for engineers to unite the world and the Autodesk technical support team to see how you can leverage Simulation-CFD to unlock potential, covering best practices, validation models, new product enhancements, and much more. Come and ask all your personal questions and experiences during our open Q&A!

- **Build Your Simulation Mechanical IQ:** Simulation- mechanical is Autodesk’s finite-element analysis package for engineers and analysts, now with advanced simulation solutions from Autodesk and mechanical know-how. Learn about new features and tips and tricks to help boost your Mechanical IQ in this interactive webinar series hosted by Autodesk technical support. Ask questions and get real-time feedback with the software every day.
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- Give instructors feedback in real-time.
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- Handouts

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- Recorded sessions
- Presentations and handouts
- Key learnings

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More Questions? Visit the AU Answer Bar

- Seek answers to all of your technical product questions by visiting the **Answer Bar**.
- Open daily 8am-10am and Noon-6pm and located just outside of Hall C on Level 2.
- Staffed by Autodesk developers, QA, & support engineers ready to help you through your most challenging technical questions.