Verification & Validation

(V&V)

- This set of slides is a part of a larger and more comprehensive video on Best Practices in Finite Element Analysis coming soon on MechCADemy!
- Stay tuned! Subscribe to **MechCADemy YouTube channel** so you won't miss it!
- Watch the video "Theory of Finite Element Analysis, 8 simple and practical steps (watch before your next FEA)" on MechCADemy

FEA Verification

Did I solve the model right?

- **Mathematical Accuracy**
  Ensures the software solves governing equations correctly (done by FEA developers).

- **Code & Model Checks**
  Your job: test your model using
  ✓ Patch tests
  ✓ Analytical solutions

- **Mesh Convergence**
  Do results stabilize as mesh is refined? If not, something may be wrong!

Solution output!
(important tool for troubleshooting)

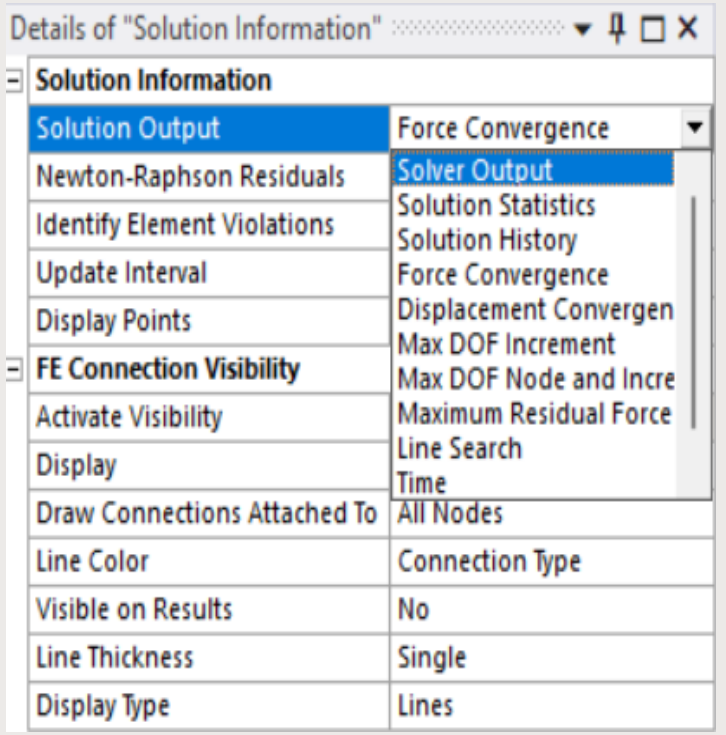
- A diagnostic powerhouse, especially in nonlinear runs.
- Learn to read and understand the messages. It will:

✓builds your modeling intuition
✓speeds up debugging
✓boosts confidence.

- When things go wrong, your first clue is often already there — in the Solution Output.

```
***********************************************
 SUMMARY FOR CONTACT PAIR IDENTIFIED BY REAL CONSTANT SET          14
Max.  Penetration of -6.661338148E-16 has been detected between contact
element 250397 and target element 249498.

Max.  Geometrical gap of 0.996128767 has been detected between contact
element 250135 and target element 249707.
*WARNING*: The geometrical gap may be too large.  Increase pinball if
it is a true geometrical gap.  Decrease pinball if it is a false one.
For total 504 contact elements, there are 492 elements are in contact.
There are 492 elements are in sticking.
Max.  Pinball distance 1.
One of the contact searching regions contains at least 21 target
elements.
***********************************************
```



FEA Validation

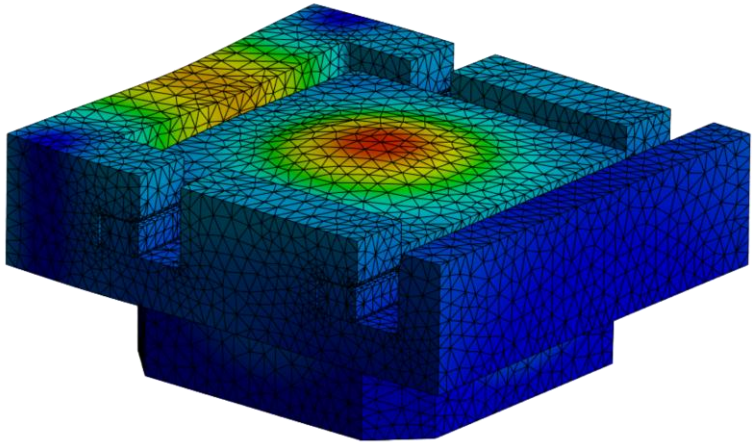
Did I solve the right model?

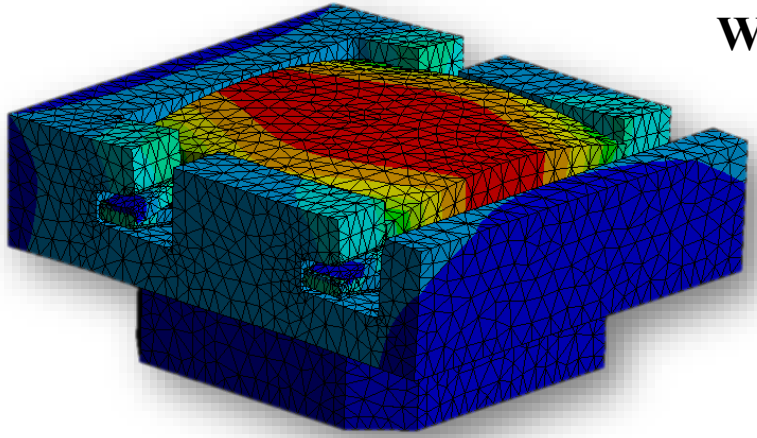
Validation is done entirely by FEA user.

Critical Thinking is a must!

confirming that the **verified** model represents the **real-world** physical problem

CORRECTLY





Which one is correct?!

FEA Validation

Did I solve the right model?

Category I

Model Set-Up & Physics Integrity

? Is the geometry correct? Is the geometry simplified enough?
? Are the units correct and consistent?!
? Are material properties correct?
➢ Isotropic, orthotropic, or fully anisotropic
➢ Linear or non-linear
➢ Mechanical properties
➢ Physical properties
➢ Electrical/magnetic properties
➢ Optical properties,…
? Are the constraints correct?
? Are the loads correct?
? Are all loading scenarios considered?
? If symmetry is used, are the loads updated?
? Are contacts correct?
? Are the right elements?
? Is the right analysis type chosen?
? Are the settings correct for a specific analysis?
? For coupled problems, are the data correctly transferred between the two physics?
? For transient (time dependent) problems, are the initial conditions correct?
? For 1d, 2d, and shell elements, are the cross-section data correct?

FEA Validation

Did I solve the right model?

Category II

Numerical & Global Balance Tests

- ? Is the system in equilibrium?
- ? Do each component and total masses match CAD/BOM?
- ? Do the behavior make sense across the symmetry BC?
- ? For linear models, do outputs scale proportionally with the inputs?

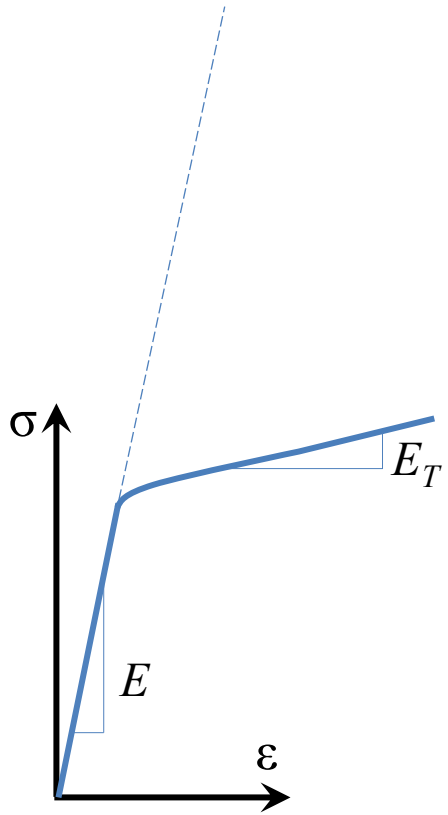
FEA Validation

Did I solve the right model?

Category III

Physical-Sense / "Smell" Tests

? Does the model deform the way the real part(s) would?
? Do peak displacements/temperature & stresses/heat fluxes make sense?
? Does contact behavior make sense?
? Do load paths make sense?
? Are the stresses bound by stress-strain curve?



FEA Validation

Did I solve the right model?

Category IV

Simplified/ Alternative Analyses

? Are the results in agreement with hand calculations or textbook formula?
? Have you run a modal analysis, especially for large assemblies?
? Have you started with a simpler model?
? Have you considered a benchmark model?!
? Are you evaluating various outputs?
? Are you checking the appropriate stress measure for each material and analysis type?
? Are you first running a linearized version of your nonlinear model?
? Do you need to perform a sensitivity and uncertainty sweep?

FEA Validation

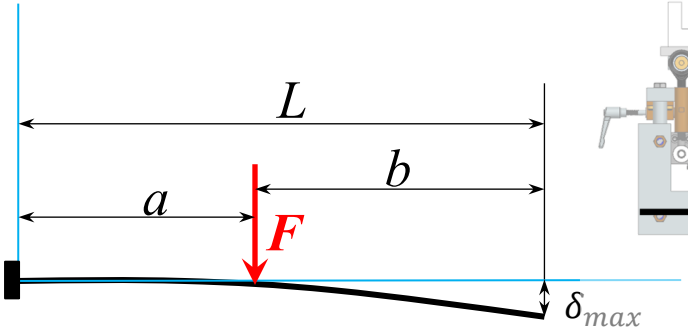
Did I solve the right model?

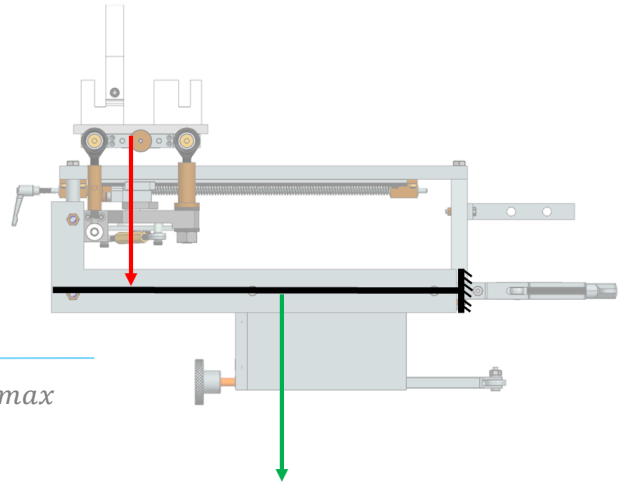
Category IV

Simplified/ Alternative Analyses

Hand calculation

- ❑ Simplify the model as much as possible
- ❑ Remove nonlinearity from the problem
- ❑ Use bonded contacts
- ❑ Use simple BCs and loads
- ❑ Change BCs and loads in the FE model if an easier hand calculation can be done. (don't abuse this method, though!)





$$\delta_{max} = \frac{Fa^2}{6EI}(a - 3L)$$

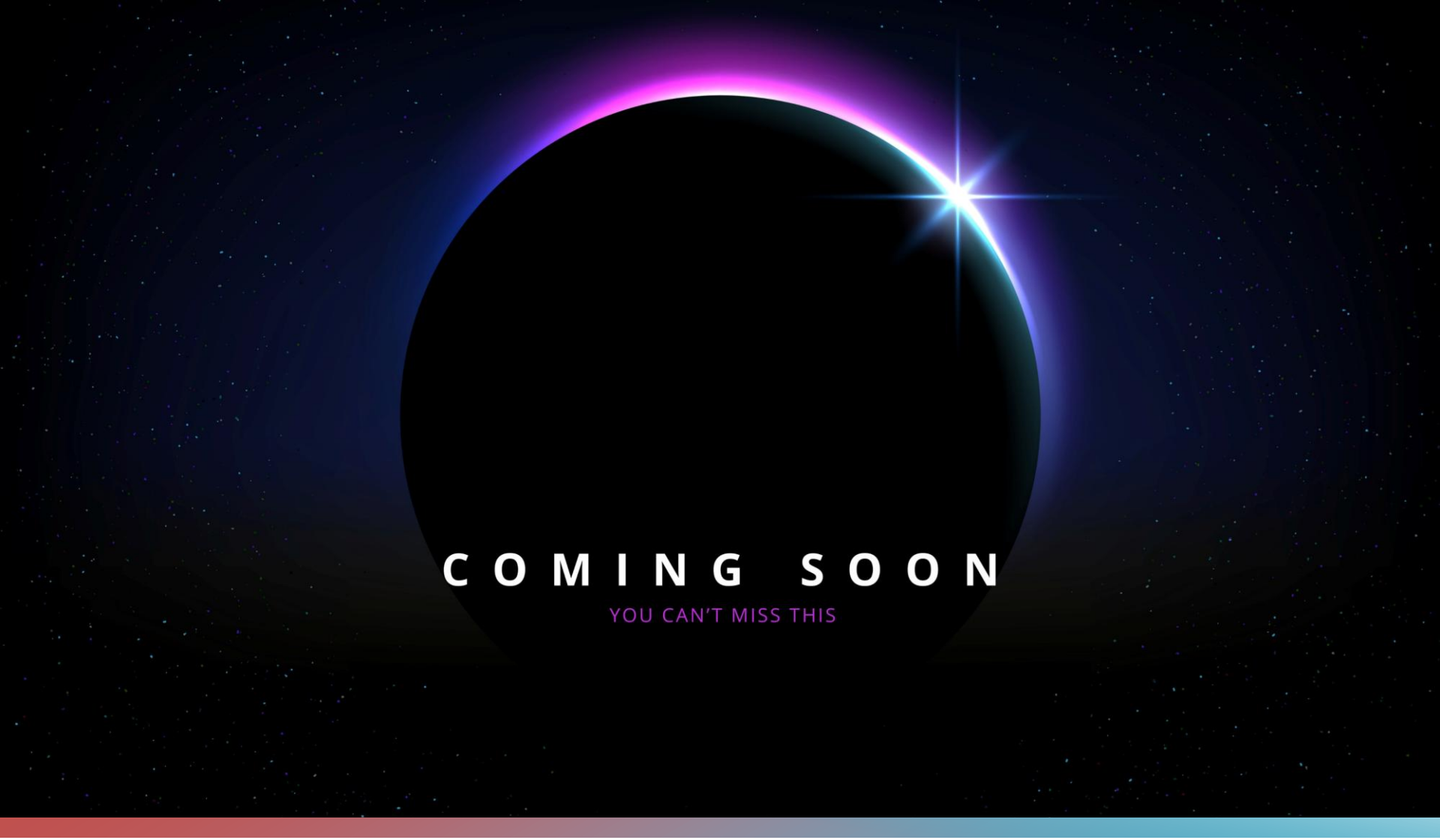
FEA Validation

Did I solve the right model?

Category V

Independent Validation & Peer Review

- ❑ Compare with experiment: strain gauges, thermocouples, dial indicators, accelerometers.
- ❑ Consult domain experts; present assumptions and get push-back.
- ❑ Code-to-code comparison (second solver or analytical plug-in).
- ❑ Document every assumption—future you (or reviewers) will ask “why?”



Best Practices in Finite Element Analysis

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