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Affordable Solution Verification Enabled by Incremental Hex Mesh Scaling

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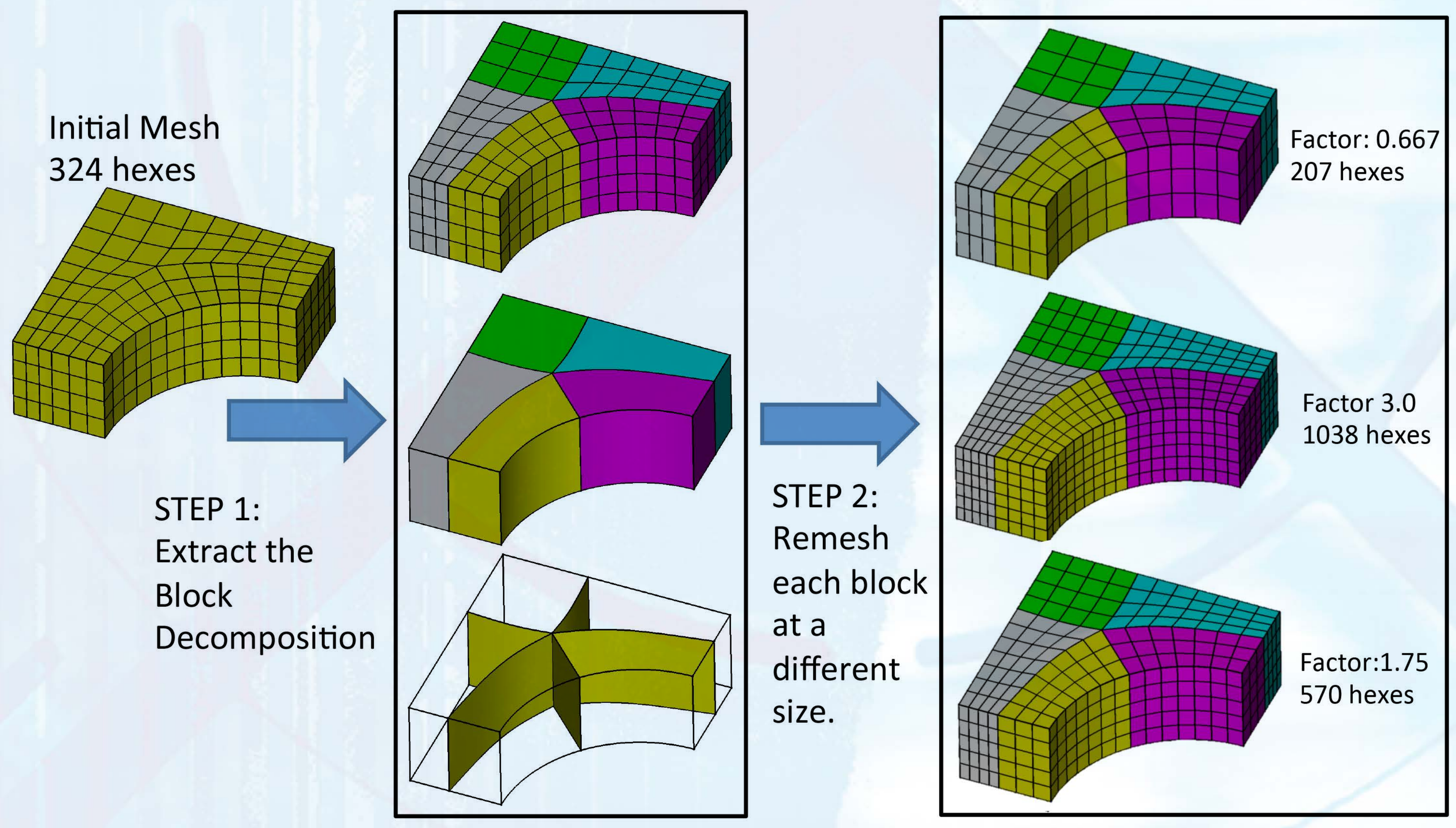
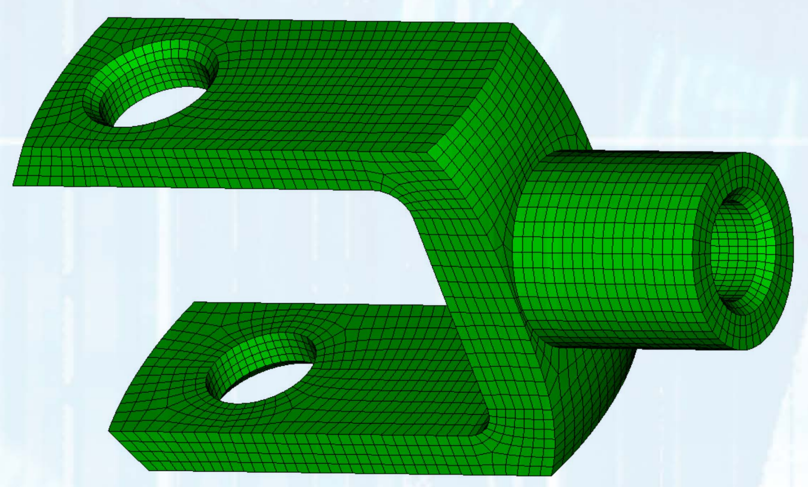
What is Mesh Scaling?

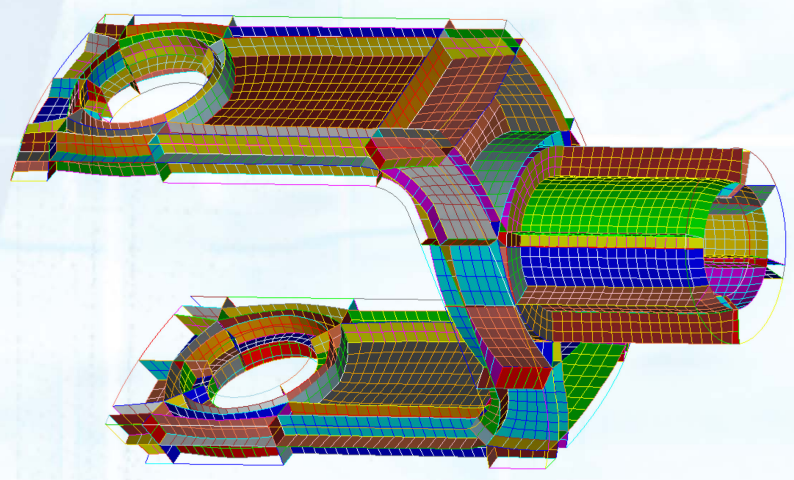
- Mesh scaling is a new method of generating a series of incrementally finer hexahedral meshes for use in solution verification.
- Each mesh maintains the element orientation and relative size gradation from the original mesh.
- Mesh Scaling works by extracting the block decomposition of the input mesh through propagation from the “irregular” nodes and edges in the mesh.
- The resulting 6-sided blocks can each be re-meshed at any mesh size.



Knuckle Example Model



Initial Mesh

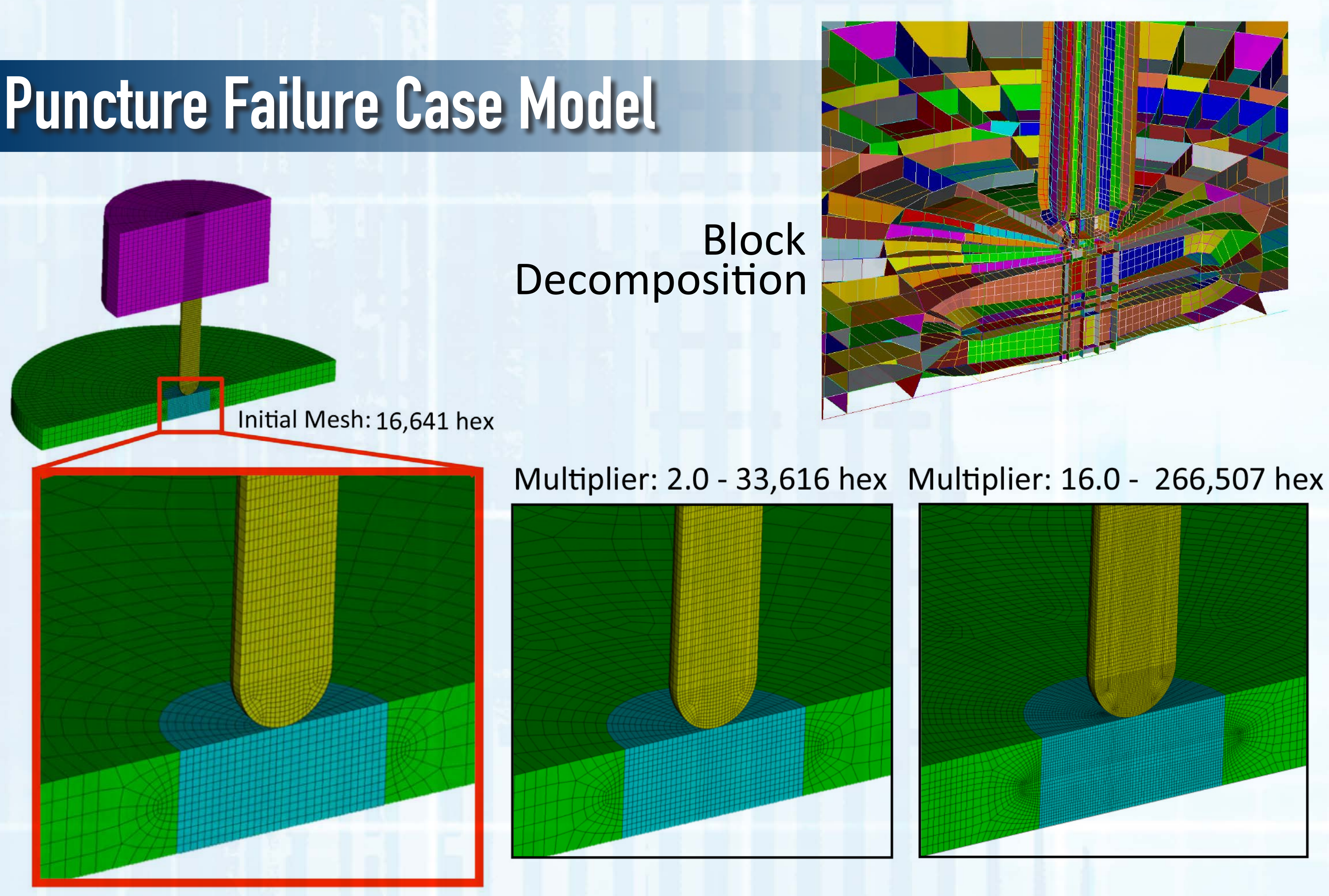


Block Decomposition

Solution Verification Approaches

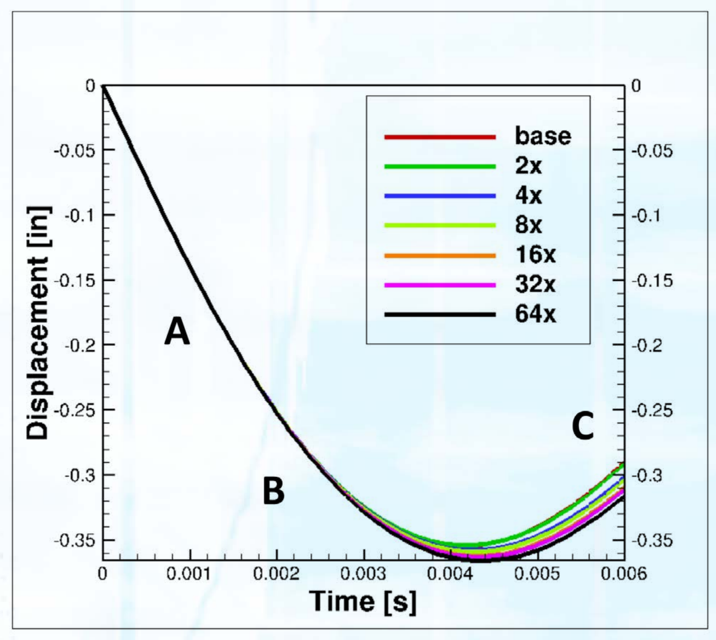
- Uniform mesh refinement studies:
  - Robust, reliable means to estimate numerical error
  - Simplest way is to split elements uniformly
  - Cost of running even 3 meshes > 100x base cost
- Using non-nested mesh sequences should not affect convergence
- For finite element analyses we just need mesh size -> 0
- But extrapolation methods to assess convergence rate and numerical error may not work as well
- Having more fine-grained control of mesh refinement and coarsening should enable faster solution verification!

Puncture Failure Case Model

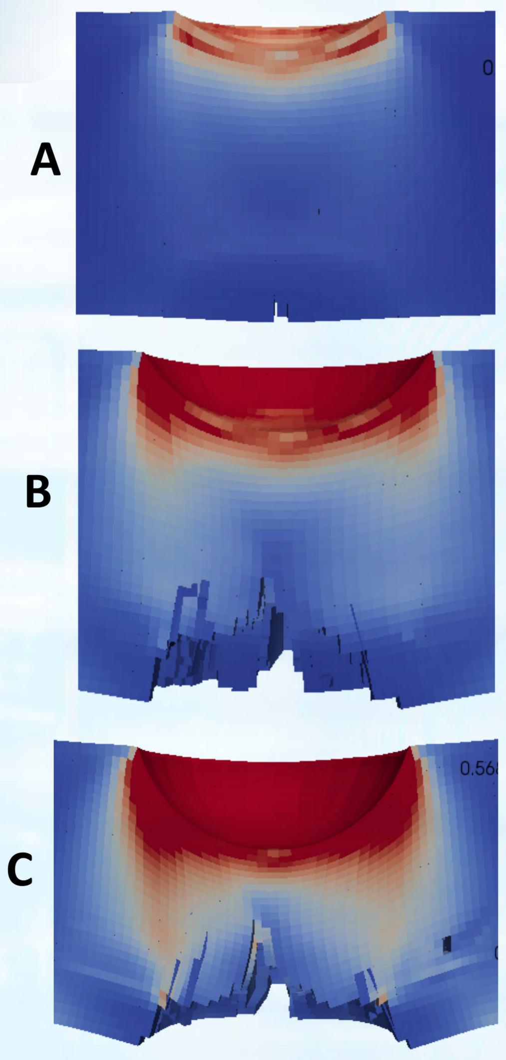


Puncture Failure Case:

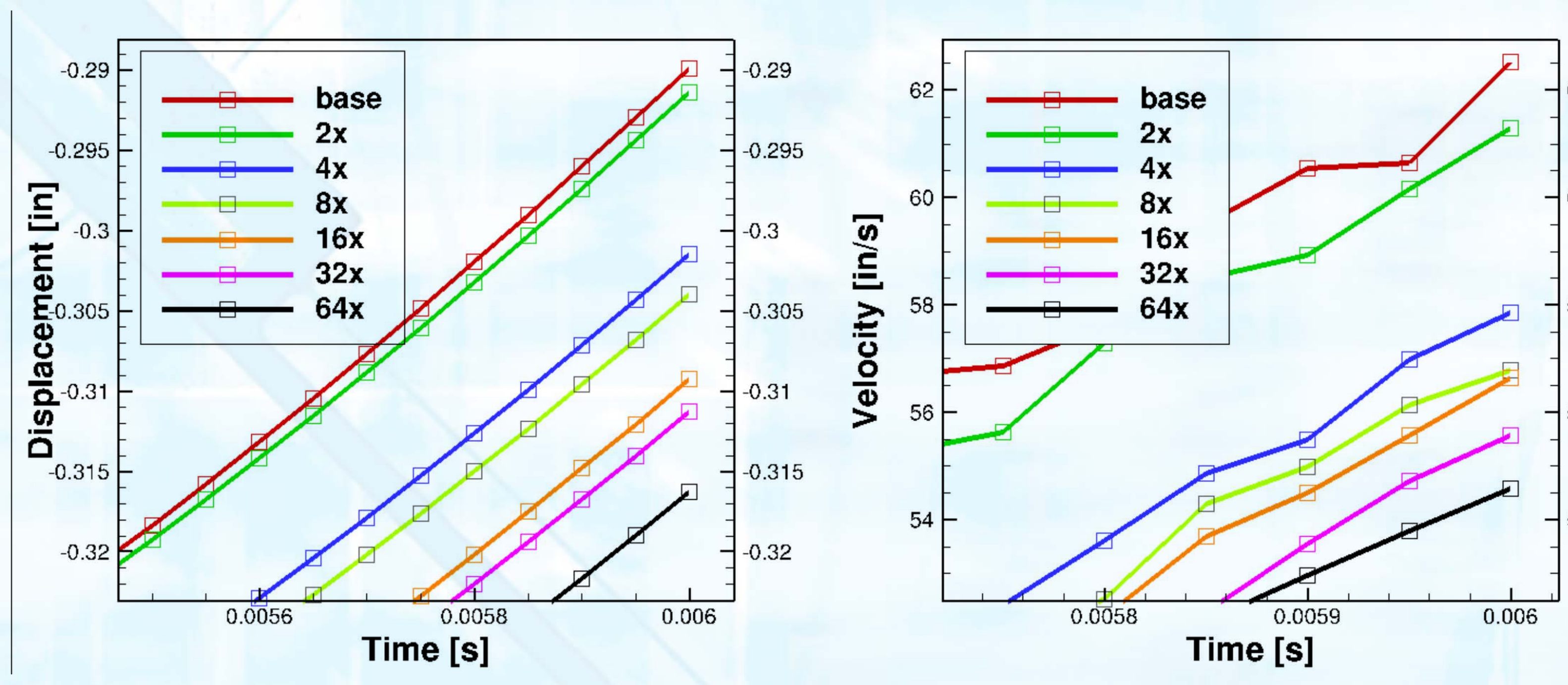
- We are assessing mesh convergence for displacement velocity, and kinetic energy
- These are global scalars computing every time step
- Plots of the solution (displacement, EQPS) with indication of failed elements



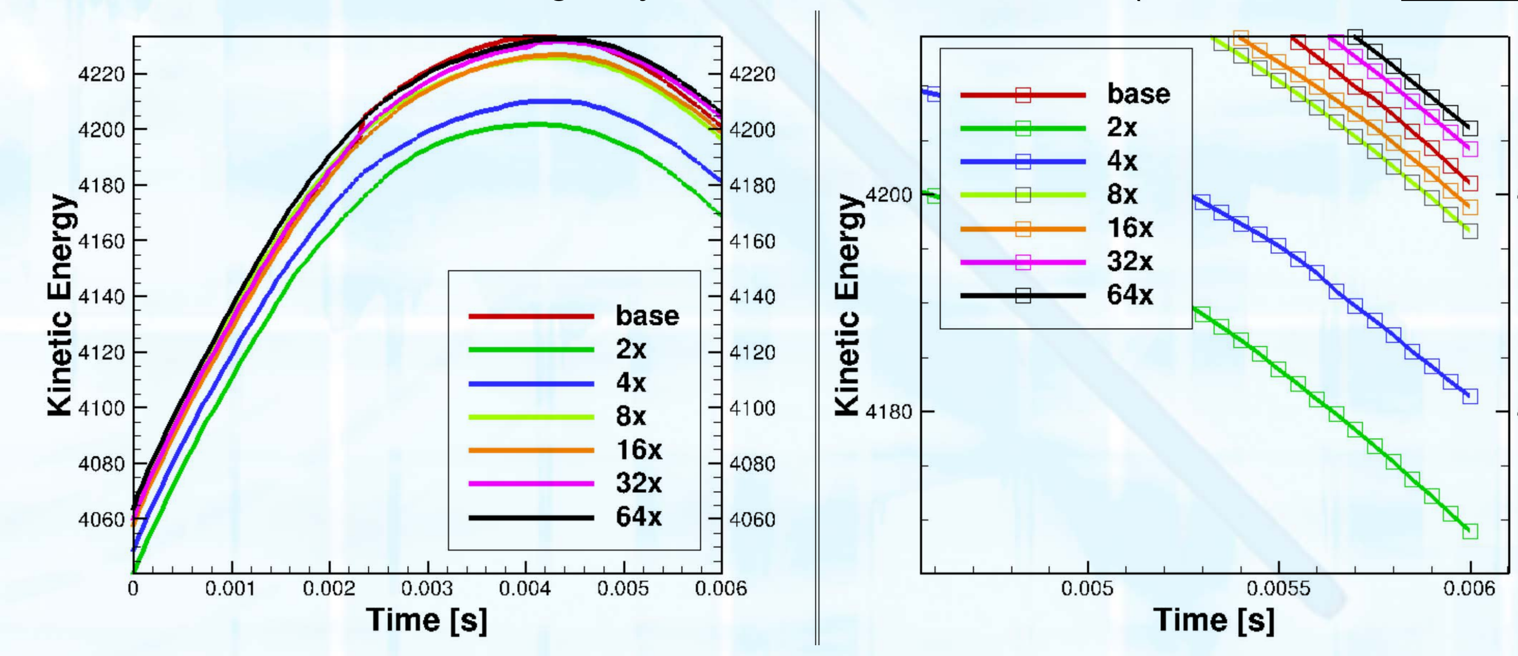
Displacement History
and Equivalent Plastic Strain



- Displacement/velocity convergence and rates of convergence are uncertain
- We do have more data for assessment (7 meshes instead of just 3)

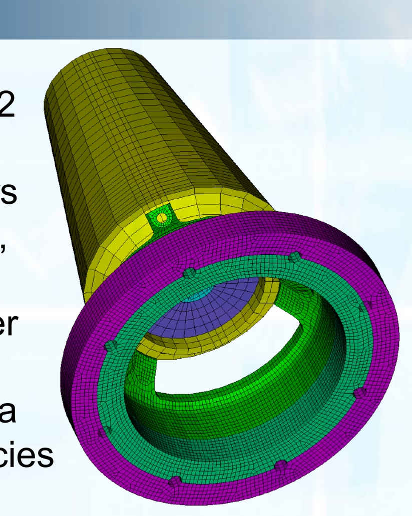


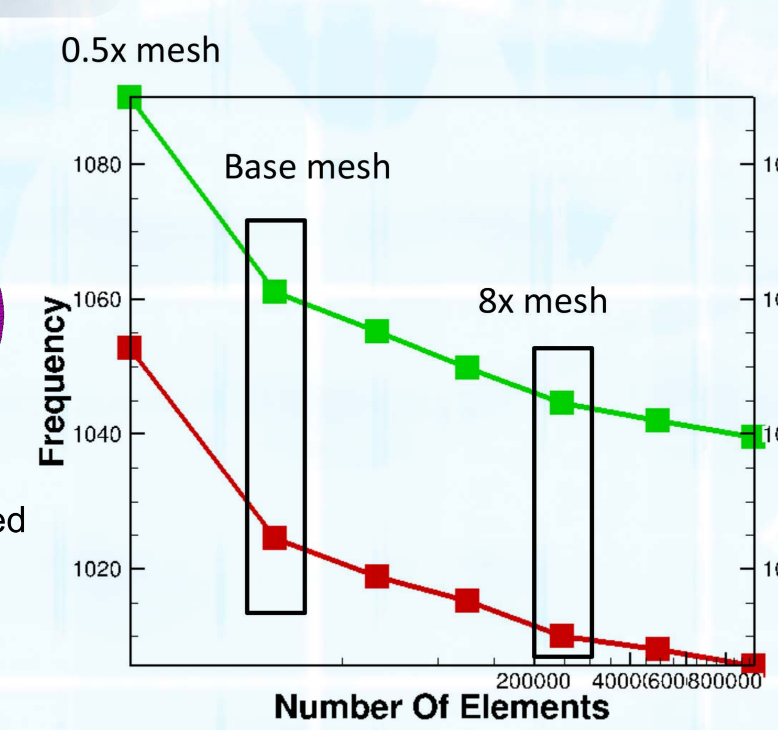
- Integral quantities generally are more well behaved
- We see convergence in kinetic energy (KE) on the finest three meshes (16x/32x/64x)
- This would be missed using only the base/8x/64x meshes (where the KE oscillates).



Cone Model

- Base Mesh: 30,802 hexahedra
- Scaled at multipliers 0.5x, 2x, 4x, 8, 16x, and 32x providing 7 incrementally finer meshes.
- We are computing a number of frequencies and model shapes
- The model contains elastic materials and tied joint models
- Convergence rate assessment may not always be possible
- Data indicates likely convergence of frequencies





PREDICTIVE ENGINEERING SCIENCE PANEL

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NNSA National Nuclear Security Administration

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