

A SOLID MECHANICS TETRAHEDRAL WORKFLOW FOR 100X REDUCTION FROM DESIGN TO ANALYSIS

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MOTIVATION:

Analysis Timeline of a Component

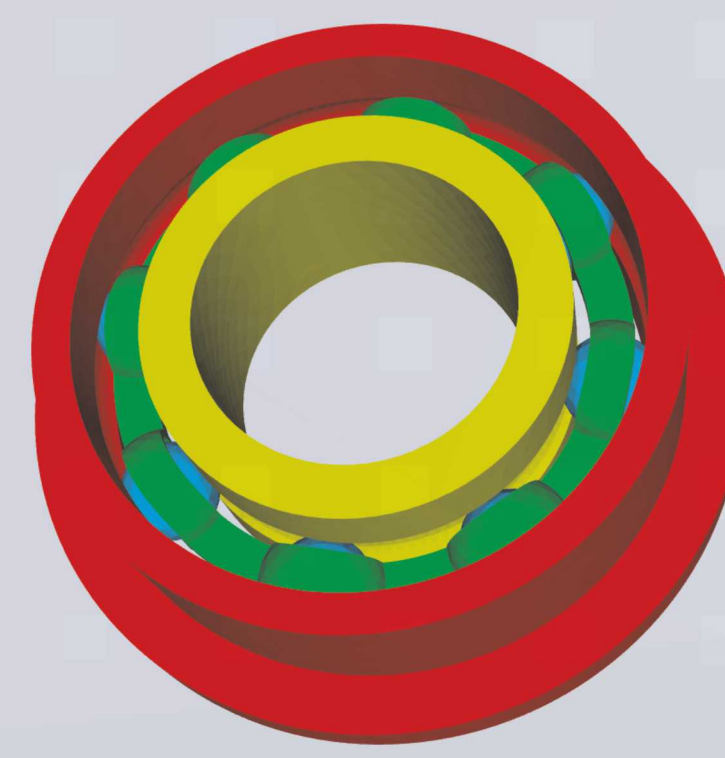
- (2 weeks) CAD geometry cleanup and defeaturing
- (6 months) Creation a hexahedral mesh component
- (2 weeks) Analysis setup
- (1 week) Analysis runtime

Too slow for analysis to impact design iterations

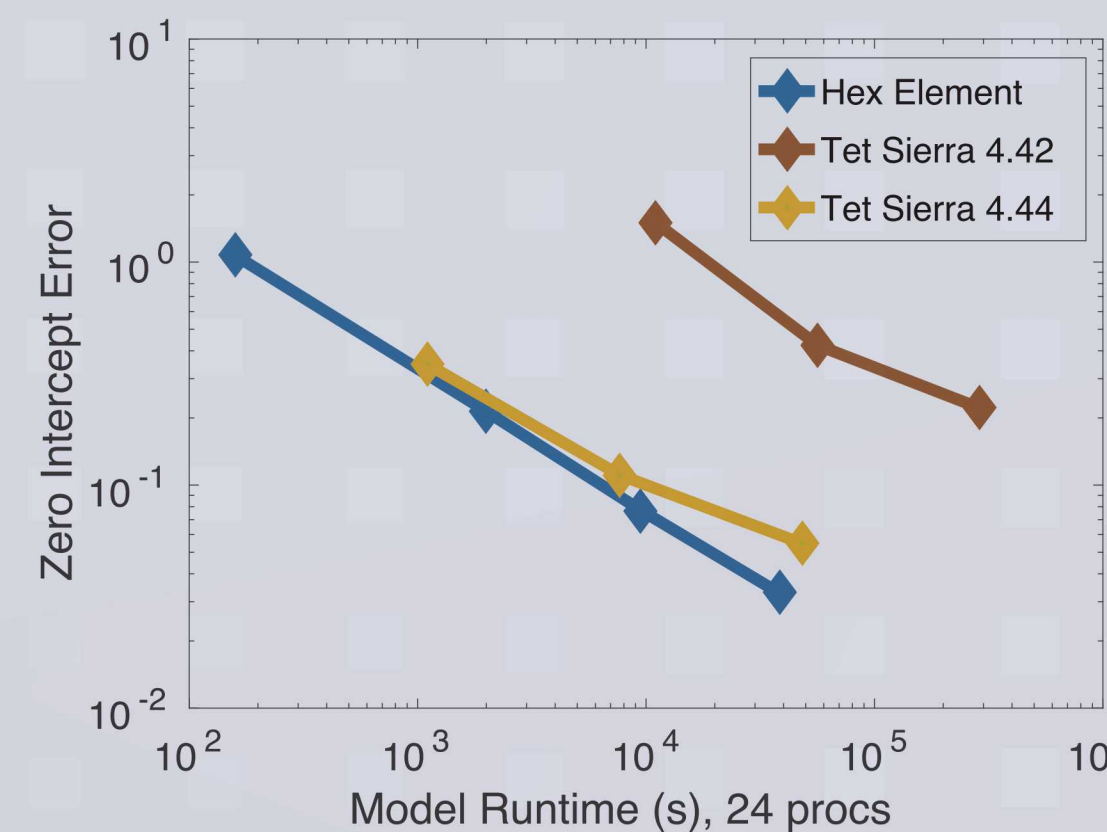
Solution:

- A quality Sierra/SM tetrahedral element to ease meshing
- Cubit enhancements to simplify defeaturing and setup
- Keep analysis runtime manageable

MAKE IT FAST. KEEP THE ACCURACY.



Cylindrical Bearing



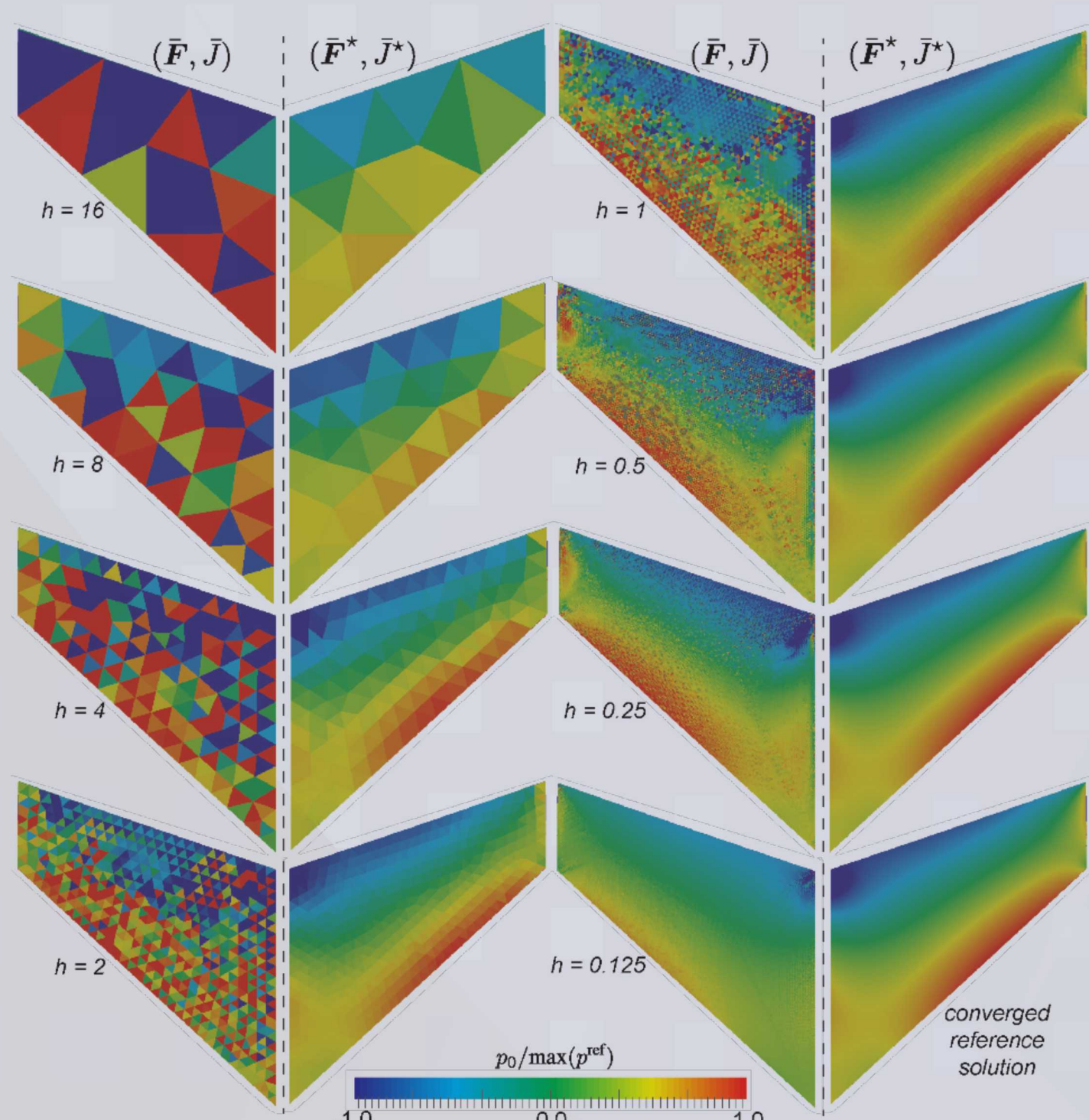
Analyses employed to fit a reduced order cylindrical joint model

Analyst requirement: Tet analysis must perform within 2X runtime of hex analysis

Optimization	Speedup	Reason
Correct handling of curved edges	10.0X	Allows solving to same accuracy on a coarser mesh
Correct critical time step computation	3.0X	Achieves same result with less time steps
Code structure and mathematical	3.5X	Make more efficient use of machine hardware to do same computations

These optimizations are multiplicative, net speedup: ~100X!

MOTIVATION:



Initial, qualitative studies comparing wave propagation in hexes and tet10s under uniaxial strain.

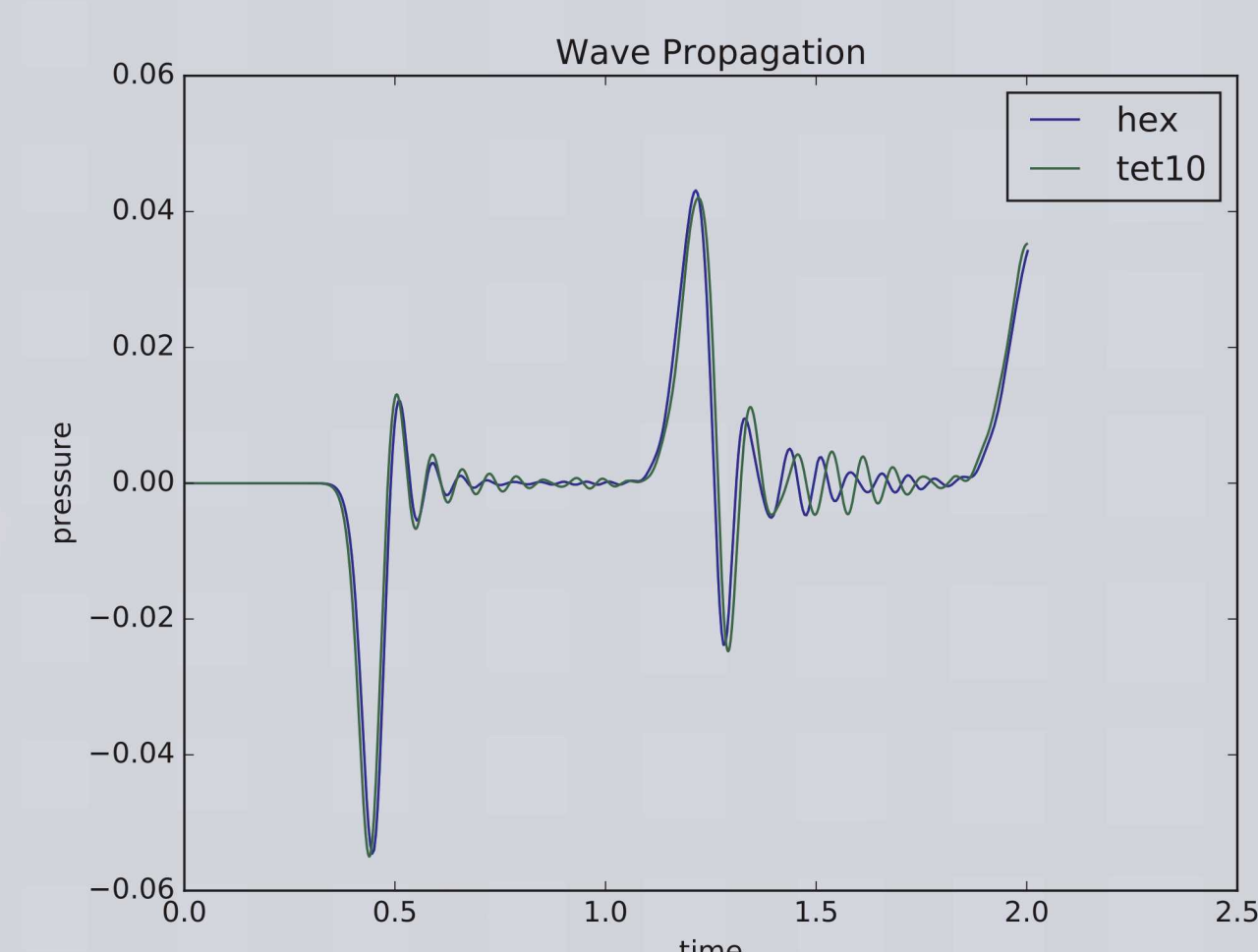
Prior work published in IJNME (2016)

- Accurate operators & integration
- Formulation for isochoric motions

Extend work to dynamics

- Wave propagation
- Critical time step estimates for shock

Robust element performance for contact



CAPABILITY COMBINATORICS: THE CHALLENGE OF PRODUCTIONIZATION

Verified Working in Composite Tet

- Hypo elastic models
- Hyper elastic models
- Thermal strain
- Artificial strain
- Stiffness damping
- Restart
- Element Death
- Mass scaling
- Mass damping
- Kinematic boundary conditions
- Force/Pressure boundary conditions
- Exotic boundary conditions (shell/solid joint, cylindrical joint, etc.)
- MPCs
- Contact
- User output
- Rigid Bodies
- Mesh rebalance
- Element to node extrapolation for output
- Implicit/Explicit handoff
- Lanczos time step estimate
- Elastic tangent stiffness
- Arpeggio hand off and transfer
- Noe based time step

Not Yet Supported for Composite Tet

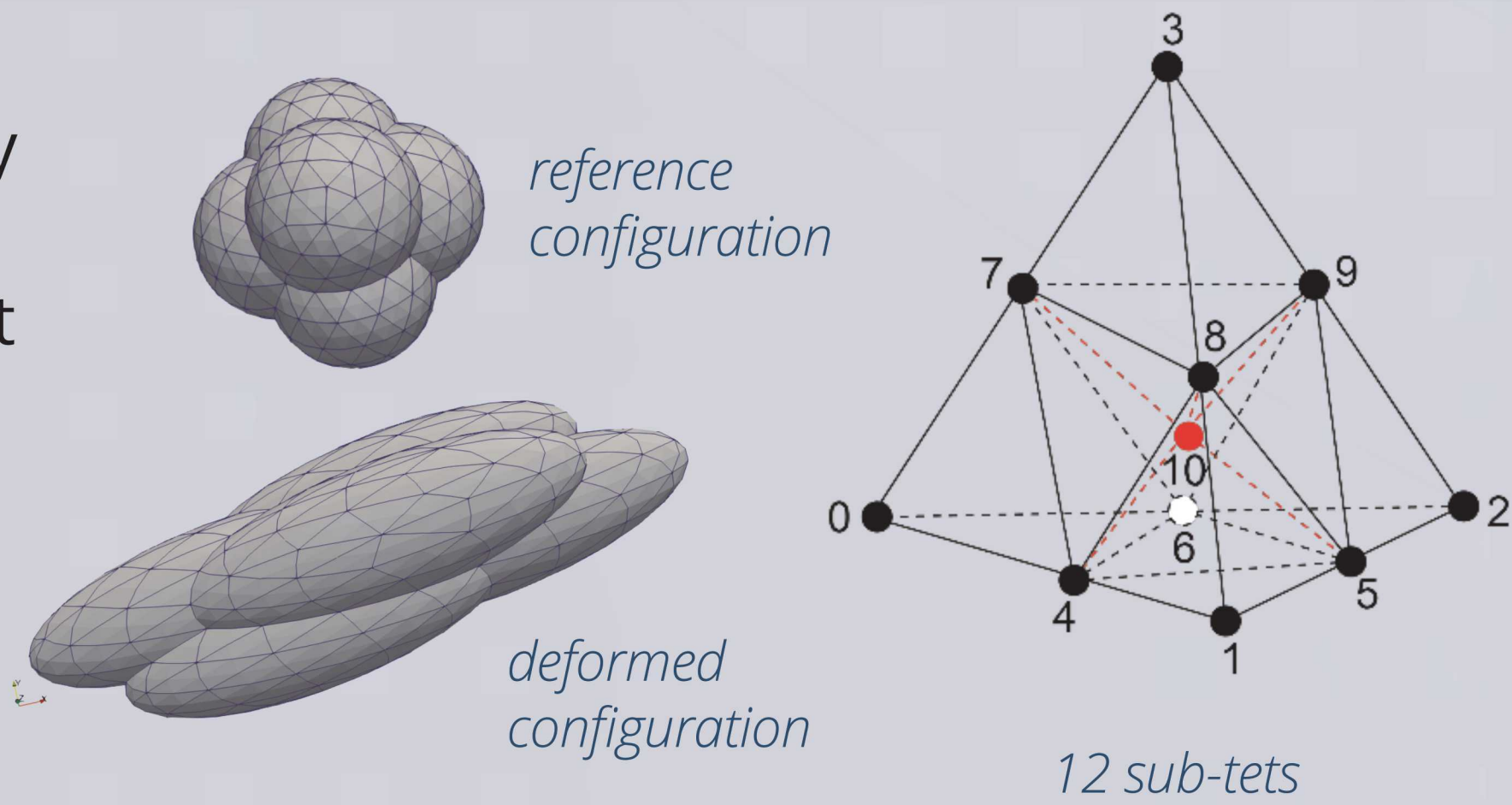
- Equation of State Models
- Salinas hand off
- J-Integral
- Zapotec CTH coupling

For a new element to have true impact it must work robustly in existing complex workflows. An effort often underestimated

- LDRD & friends must
- Support work
 - Aid documentation
 - Aid testing
 - Aid debugging/troubleshooting

COMPOSITE TET ENHANCEMENTS: REFORMULATE FOR CURVED SURFACES

Technology pull: Mid-edge nodes must snap to boundary to increase geometric representation for the contact of bearings and components with curved edges



Improved composite tet10 formulation

- Gradient operator
- Jacobian (volume)
- Stress projection
- Mass matrix

$$\bar{B}_{a,j}(\xi) = \lambda_{1 \times 4} \left[\sum_{s=0}^{11} J_{\xi}^s \Psi_{4 \times 4}^s \right]^{-1} \sum_{s=0}^{11} L_{a,i}^s [O_{ij}^s]^{-1} J_{\xi}^s \Lambda_{4 \times 4}^s$$

$$J_c(\xi) = \lambda_{1 \times 4} (M_{4 \times 4})^{-1} \sum_{s=0}^{11} \det[O_{ij}^s] \Lambda_{4 \times 4}^s$$

$$\bar{P}_{i,j}(\xi) = \lambda_{1 \times 4} (M_{4 \times 4})^{-1} \int_{\Omega_{\xi}} (\lambda_{1 \times 4})^T P_{i,j}(\xi) J_c(\xi) dV_{\xi}$$

Analytical integrals for kinked edges improve performance in contact

WORK THE WORKFLOW. ITERATE. GET BETTER.

Tetrahedral elements overcome a major meshing hurdle. LDRD worked in close conjunction with analysts to tackle remaining challenges and make single day mesh generation a reality.

Cubit Improvements from LDRD:

- Automated blunt tangency removal
- Detect and repair facet overlap during model creation
- Compute Sierra/SM critical time step during model creation. Automatically optimize mesh to improve.
- Integrated new MeshGems library to enhance tet mesh robustness
- Enhanced Sculpt to provide cleaner, smoother discrete geometry for successful tetmeshing



- clean up model
- cylindrical contact surfaces
- set mesh sizes
- tetmesh body
- stable time step

SIERRA/SM - BATTLE OF THE TET10S

