Overview of Eulerian Methods and Block Adaptive Mesh Refinement Techniques at Sandia

Joint Russian-American Five Lab Conference

Vienna, Austria, 19-23 June 2005

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Shock Physics Eulerian Hydrocodes at Sandia

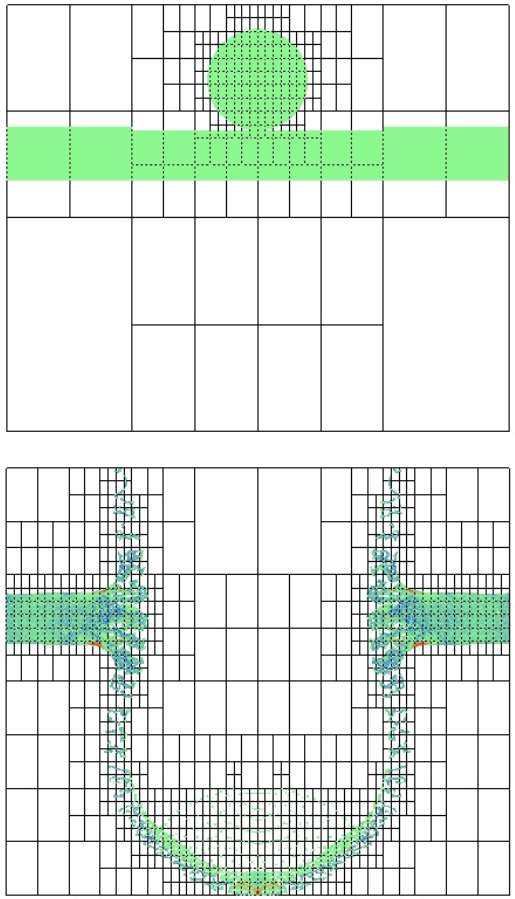
- CTH
  - long development history (predecessors date to 1969)
  - widely used at Sandia and elsewhere
  - fast running, robust and self contained
  - programming languages: Fortran, C
- Curvilinear Multi-Block Structured ALEGRA
  - relatively recent development
  - part of a multi-physics framework
  - provides a component for solutions requiring shock dynamics in conjunction with other physics
  - programming languages: C++, Fortran

CTH: General Information

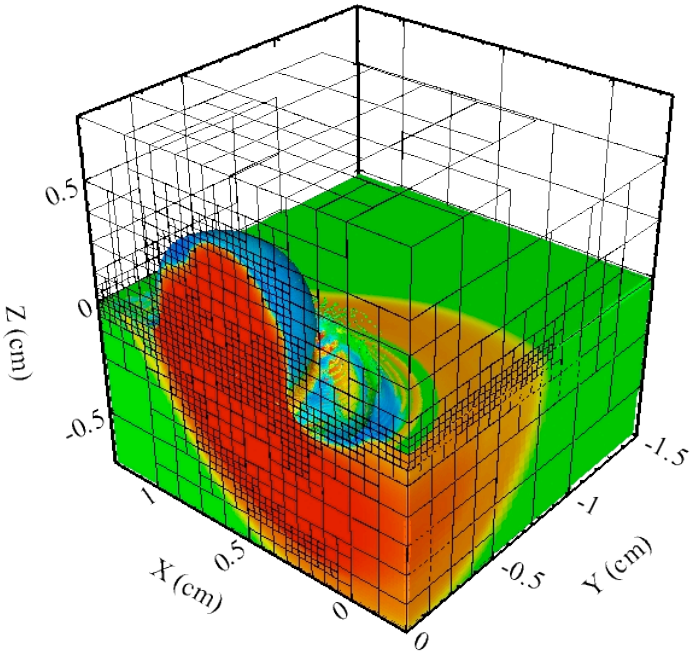
- **Eulerian shock physics code solving conservation equations of mass, momentum, & energy for up to 20 materials**
  - analytic & tabular equation-of-state representations
    - gases, fluids, solids, reactive materials
  - advanced strength & fracture models
  - adaptive mesh refinement (AMR)
- **Easy to use**
  - easy to describe mesh, insertion of geometry, initial conditions
  - built-in parameter tables for commonly used materials
  - easy to use post-processing tools are part of the code package
- **Fast and Robust**
  - Fortran → Fast
  - iteration with a large user base → Robust
  - enables rapid problem solving for the analyst
- **Widely used by ~1,000 users throughout the U.S.**
  - extensively verified and validated

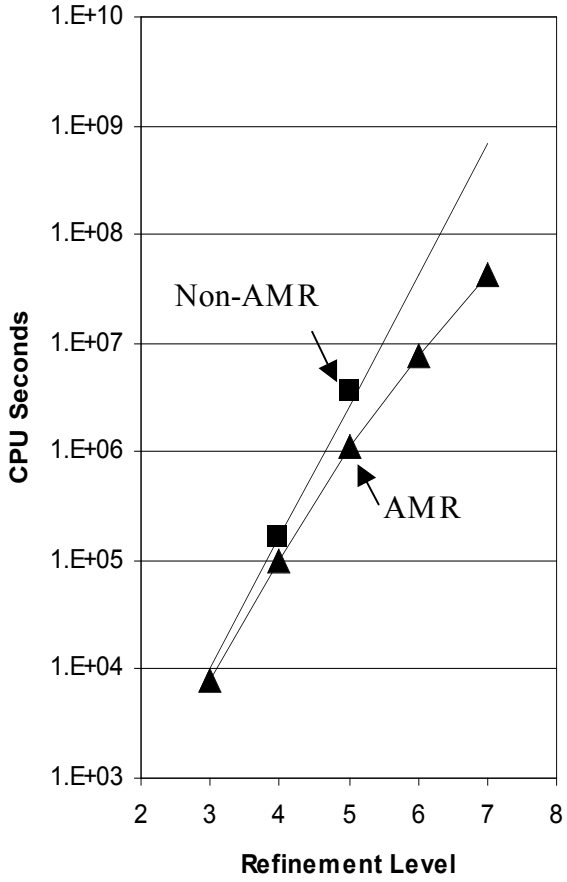
Adaptive Mesh Refinement (AMR) in CTH *(approach)*

- Block-based
- Available in 2-D and 3-D geometries
- Identical logical mesh per block
- Isotropic 2:1 refinement
- Single time-step for all blocks
- Load balance on per-block basis
- User-definable refinement indicators
- Problem initialized via iterative refinement/load balance step



Adaptive Mesh Refinement (AMR) in CTH *(problem scaling)*





- AMR often leads to substantial improvements in performance
- AMR in CTH is being widely used, especially as performance advantages become apparent

Each increment in refinement level is a factor of 1/8th cell volume

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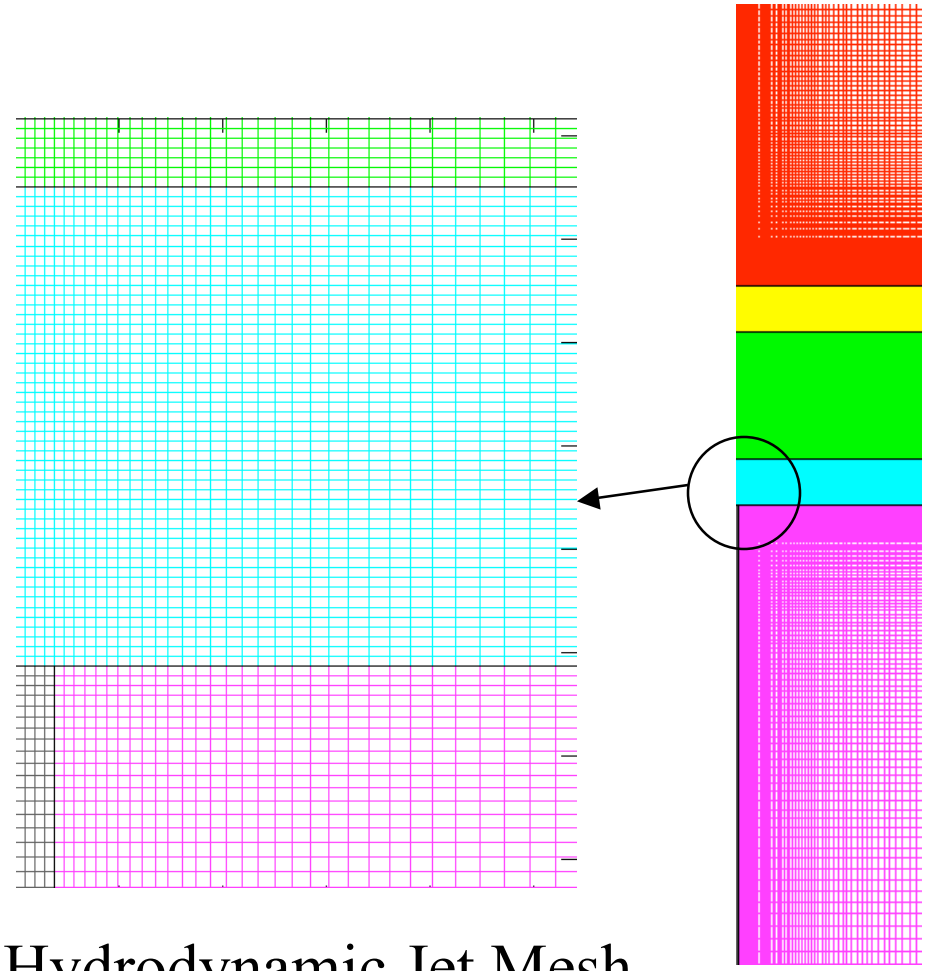
Curvilinear Multi-Block Structured ALEGRA

- Solid Dynamics and Hydrodynamics
- ALE (Arbitrary Lagrangian Eulerian) Formulation: ALEGRA can run simulations in a continuum from Lagrangian to Eulerian
- Multi-Material with Multiple State: Elements may have any number of materials, each in a unique state
- Single Point Integrated Elements: All element quantities evaluated at the element's centroid, Velocities are carried at an element's nodes
- Time Step Proceeds by Lagrangian step Followed by Remesh/Remap Step
  - Lagrangian Step:
    - Gathers Masses and Forces at Nodes
    - Integrates F=ma forward in time using staggered time step
    - Updates Material States Based on Deformation Rate of Element
  - Remesh/Remap Step:
    - Nodes Moved to Original Coordinates for Eulerian Analysis
    - Element and Material Quantities Remapped based on Element Fluxes
    - Nodal Quantities remapped using Half Interval Shift

Curvilinear Multi-Block Mesh

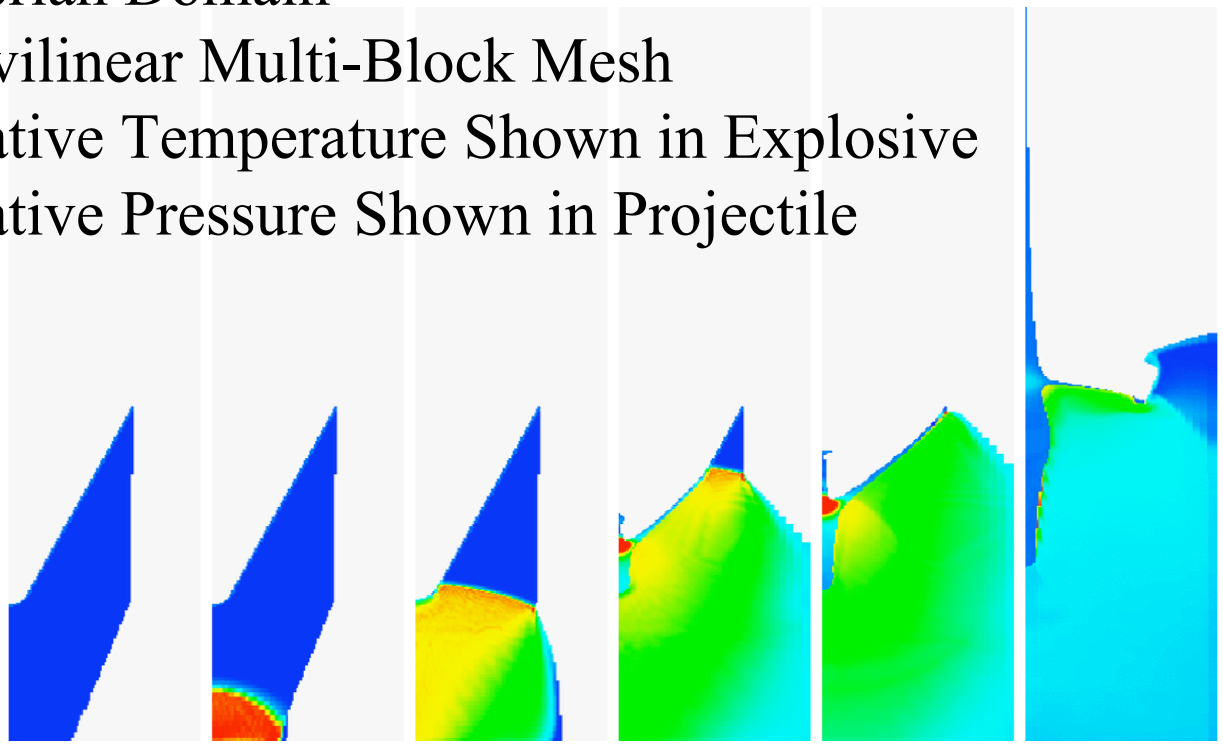
- Allows
  - Arbitrary Node Locations
  - Arbitrary Block to Block Connections
  - Arbitrary Number of Blocks
  - Arbitrary Number of Element in i,j,k Directions for Each Block
- Enables
  - Conformal Geometry
  - Element Budgeting



Hydrodynamic Jet Mesh

Example: Hydrodynamic Jet Mesh Evolution

Explosively Driven
Eulerian Domain
Curvilinear Multi-Block Mesh
Relative Temperature Shown in Explosive
Relative Pressure Shown in Projectile



Conclusions

- CTH will continue to be widely used for general purpose shock physics applications because of its ease of use, performance and robustness.
- ALEGRA fulfills a need as a platform to conduct research and development in modern numerical methods for shock physics and coupling techniques with other physics.
- As both CTH and ALEGRA share many material models and solution techniques, so they share a common vision for shock physics solutions at Sandia and share long term strategies for the future.