30 Years of CTH

1987-2017

Eric Harstad, Bob Schmitt, Dave Crawford, Kevin Ruggirello and Dave Hensinger

CTH is a multi-material Eulerian shock physics code that is capable of modeling the hydrodynamic response of explosives, liquids, gases, and solids. Materials are represented by complex analytic and/or tabular equations-of-state and advanced strength and failure models.

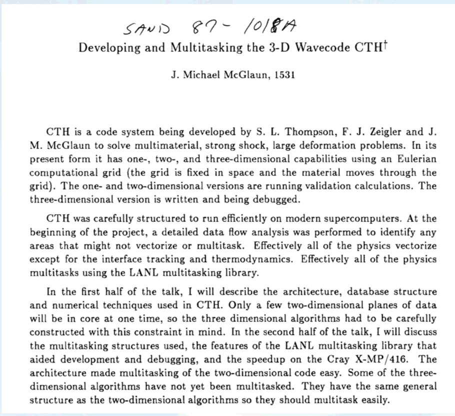
Origins

CHART D = Radiation-Diffusion Hydrodynamic Code (1-D) – created in 1969 by Sam Thompson

CSQ = (CHART D)^2 (2-D) – 1975 by Sam Thompson

CTH = CSQ$^{3/2}$ (3-D) – 1987

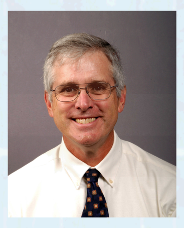
CTH was created to expand Sandia's production shock physics code suite to 3D, which was now feasible with the purchase of the Cray XMP 416.



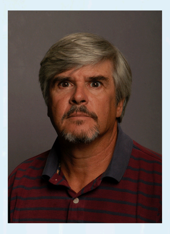
Key Leadership

Samuel Thompson
Architect of CHARTD, CSQ, & CTH Codes

Michael McGlaun
Code Creator & Leader
1986-1990



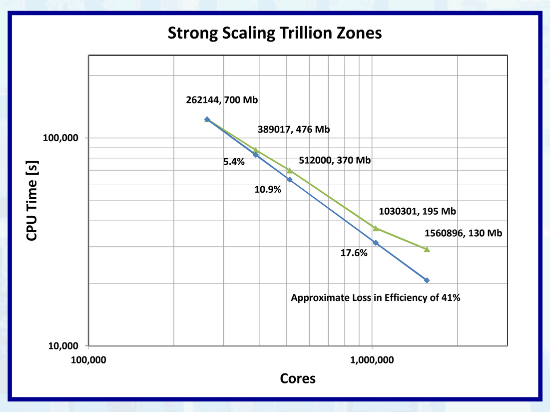
Eugene Hertel Jr.
Code Lead, Steward
1990-1999, 1995-2008



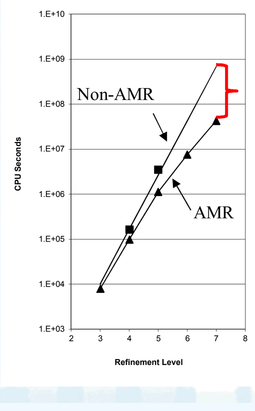
David Crawford
Code Leader
2003-2013

Distinguishing Strengths

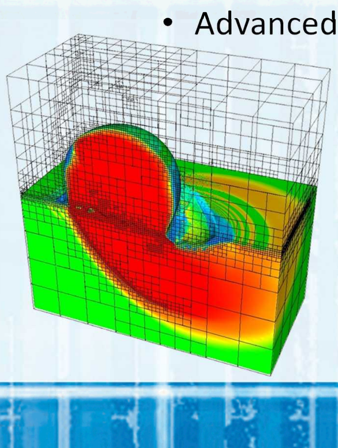
- Exceptional Time-to-Solution
  - DIATOM Geometry Generation
  - Massively Parallel
  - On-the-fly Graphics
  - Extensive Material Libraries
- Scalability shown to 1 million cores
- Adaptive Mesh Refinement (AMR)
  - Non-overlapping Block Based
  - Isotropic 2-to-1 Refinement
  - Indicator Based
- Distributed Source and Executables
  - Unix, Macintosh, & Windows
  - Allows Users to Implement Models/Features
- Complete Analysis Package
  - Inception
  - Characterization
  - Execution
  - Analysis With Graphics
  - Aux utilities TIGER, BCAT, Spyhis, and More
- Large User Base (1000+ Users)
  - Diverse User Community
  - Feedback (cth-help@sandia.gov)
    - Models
    - Feature Requests
    - Bug Reporting
- Training
  - Multiple Classes Per Year
  - Advanced Topics

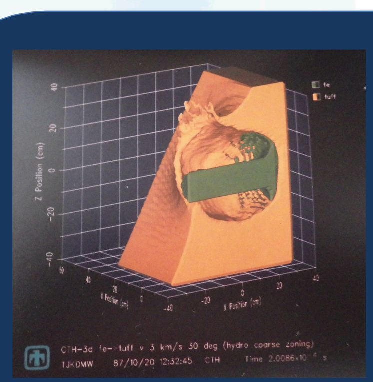


Scaling Study to 1.5 million cores on DOE's Sequoia (LLNL)

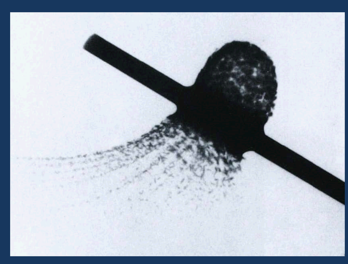


Comparison of AMR and Flat Mesh Performance (2001)

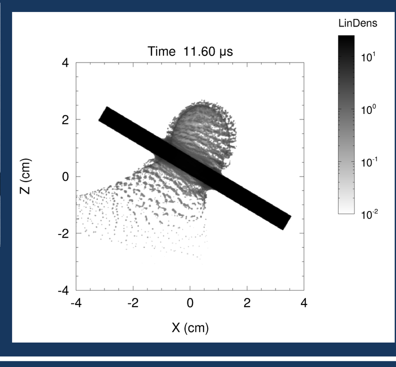




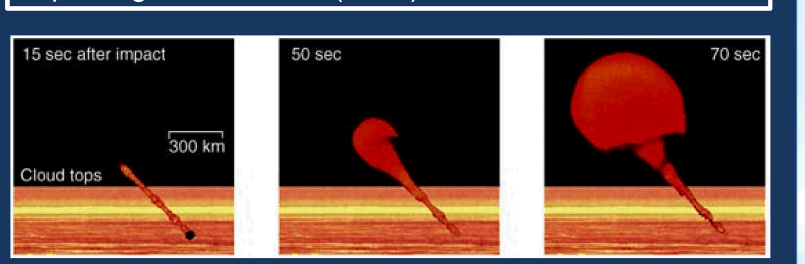
First CTH Analysis/ Prediction of Experimental Outcome Oct. 20, 1987 (McGlaun)



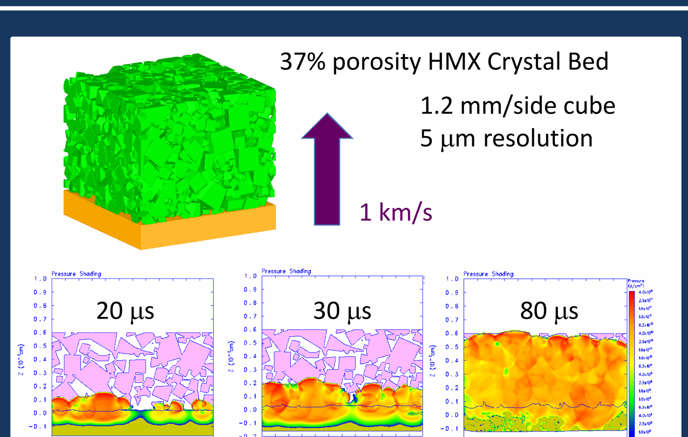
Radiograph From Experiment



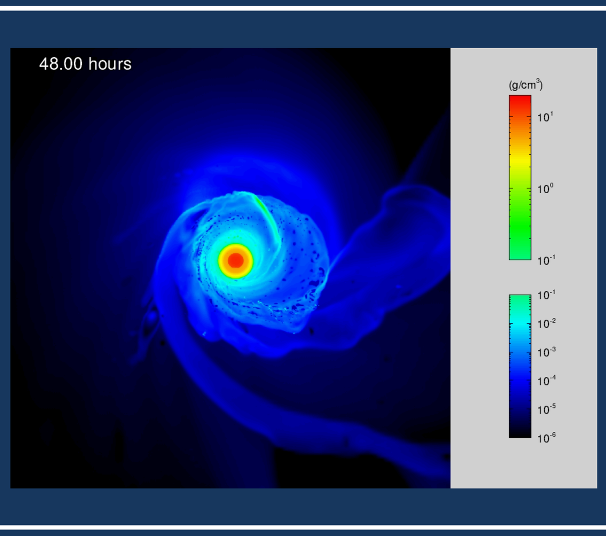
Re-creation of Grady/Kipp Simulation of Copper Sphere Impacting a Steel Plate (1993)



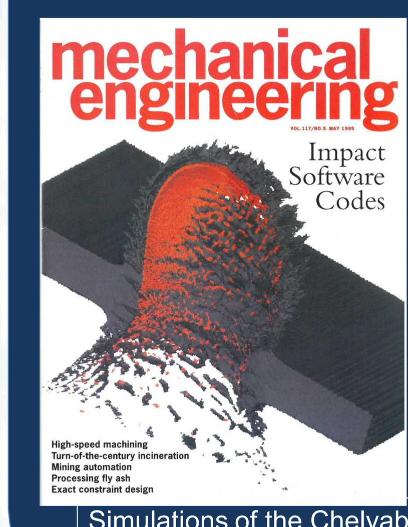
Shoemaker-Levy 9 Comet Impact Simulations (Crawford, Boslough, & Trucano)
10 million zones calculation on Intel Paragon machine (1993)



Copper plate impacting a HMX crystal bed at 1 km/s (Kipp & Baer)
1.2 billion zones flat mesh calculation on ASCI Red



Formation of Moon by Giant Impact (Crawford & Kipp)
54-hour, AMR-CTH simulation with self-gravity, 40 million zones, equivalent to 20 billion zones without AMR (2011)
500x memory gain, 200-300x performance gain



Simulations of the Chelyabinsk fireball- Boslough (2013)

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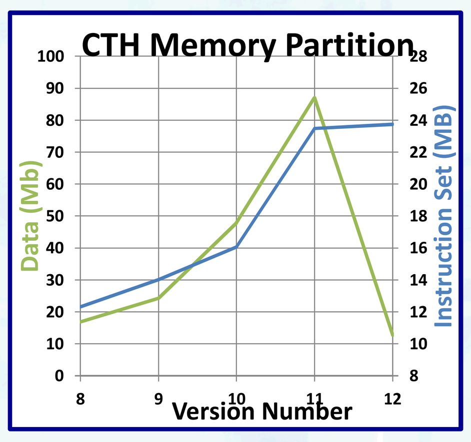
Advancements & Achievements

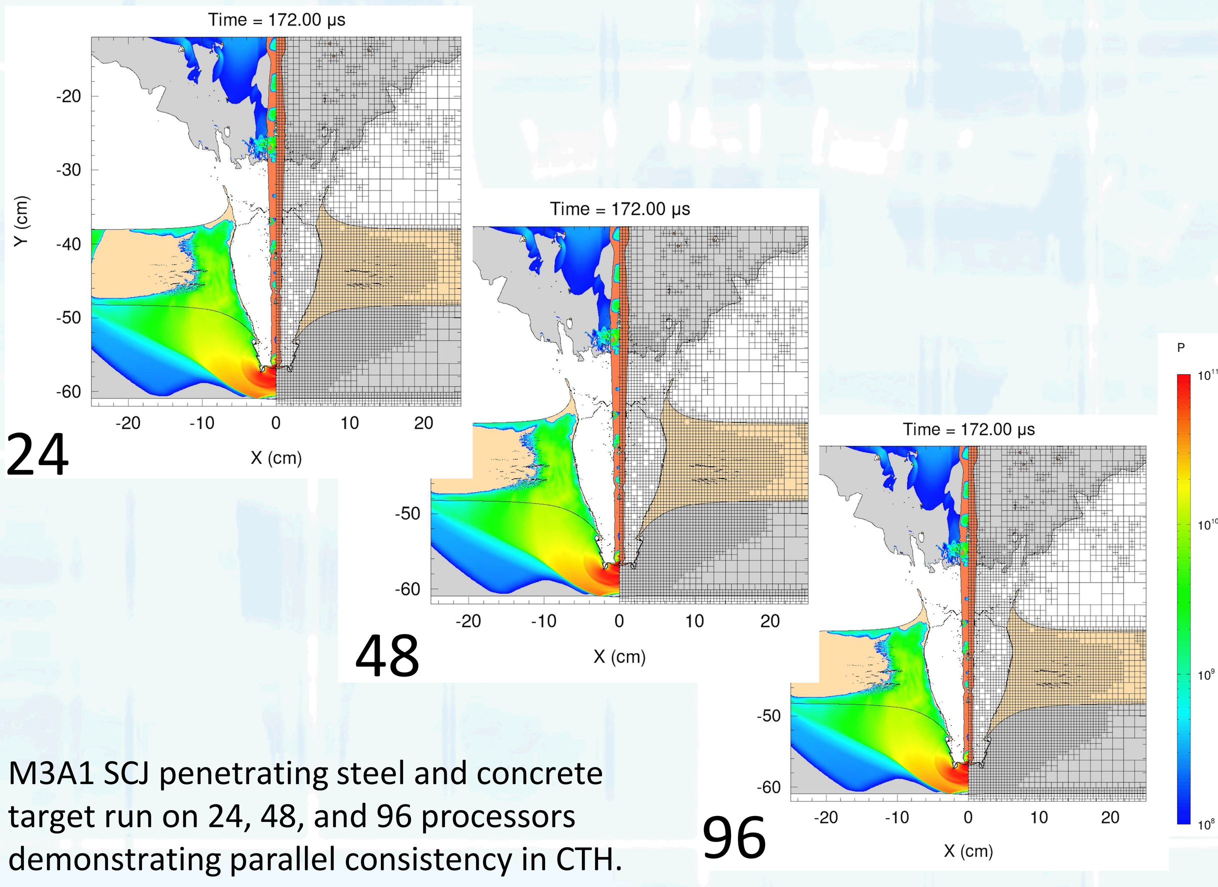
1988 Vectorized for Cray
1989 Shared Data Parallel million cell calculations
1989 USS Iowa Accident Analysis
1990 DARPA Hydrocode Challenge Winner
1992 SMYRA (Sandia Modified Young's Interface Reconstruction)
1994 Shoemaker-Levy 9 Comet Impact on Jupiter
1995 Single Program Multiple Data Parallelization
1997 First Billion Zone Calc(ASCI Red, Kipp)
1998 Spymaster Visualization Tool
2001 Adaptive Mesh Refinement
2003 Columbia Accident Investigation Analysis
2004 Spyhis Visualization Tool
2013 Trillion Zone Calc(Sequoia, Schmitt)
2013 Chelyabinsk Meteor Simulation
2016 Hash Table Diagnostics
2017 Parallel Consistency; # processors regression testing

Current Activities

- Maintain production capabilities
  - Software Quality Assurance Processes
  - Code Development Philosophy
  - Preserve Heritage & Legacy
- Evolving Architectures
  - OpenMP/OpenACC
  - Memory Footprint Reduction
  - Node Shared Memory Storage
- Model Addition/Improvements
  - Reactive Flow
  - EOS Models
  - Constitutive Models
  - Material Library Additions
- Other Development
  - Heuristic Algorithms
  - Thermodynamic Consistency
  - Cost based load balancing



Recent Results



M3A1 SCJ penetrating steel and concrete target run on 24, 48, and 96 processors demonstrating parallel consistency in CTH.

U.S. DEPARTMENT OF ENERGY
NNSA National Nuclear Security Administration
Sandia National Laboratories

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