

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

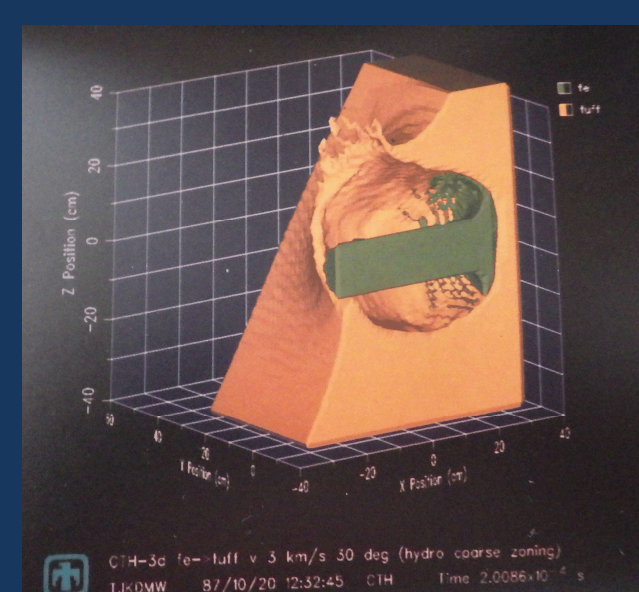
CTH was created to expand Sandia's production shock physics code suite to 3D, which was now feasible with the purchase of the Cray XMP 416.

Developing and Maintaining the 3-D Wavecode CTH[®]
J. Michael McGlaun, 1991

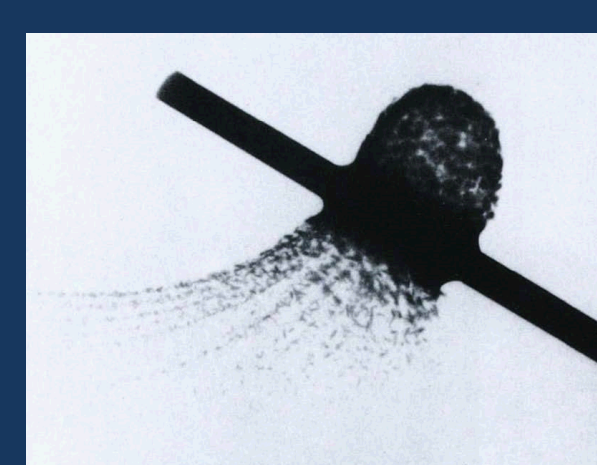
CTH is a code system being developed by S. L. Thompson, F. J. Ziegler and J. M. McGlaun to solve multi-material, strong shock, large deformation problems. In its present form it has one-, two- and three-dimensional capabilities using an Eulerian computational grid. The one- and two-dimensional versions are running on various computers. The three-dimensional version is running on the Cray XMP 416.

CTH was carefully structured to run efficiently on modern supercomputers. At the beginning of the project, a detailed data flow analysis was performed to identify any areas that might not run efficiently on modern hardware. Effectively all of the physics modules were re-written to run efficiently on modern hardware.

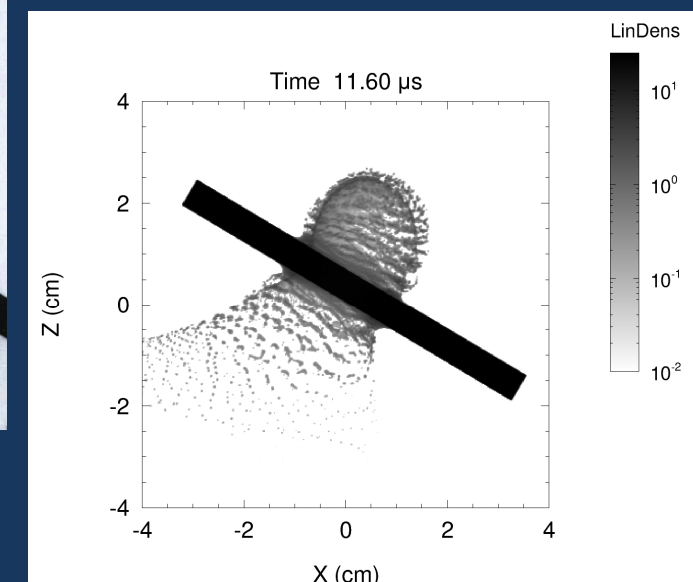
In the first half of the code, I will describe the architecture, database structure and material techniques used in CTH. Only a few two-dimensional plots of data will be shown in one time, as the three dimensional algorithms had to be carefully constructed with this material in mind. In the second half of the code, I will discuss the underlying structure used, the features of the LANL multi-tasking library that added development and debugging, and the speed of the Cray XMP 416. The architecture made multi-tasking of the three-dimensional code easy. Some of the three-dimensional algorithms have not yet been implemented. They have the same general structure as the two-dimensional algorithms so they should implement easily.



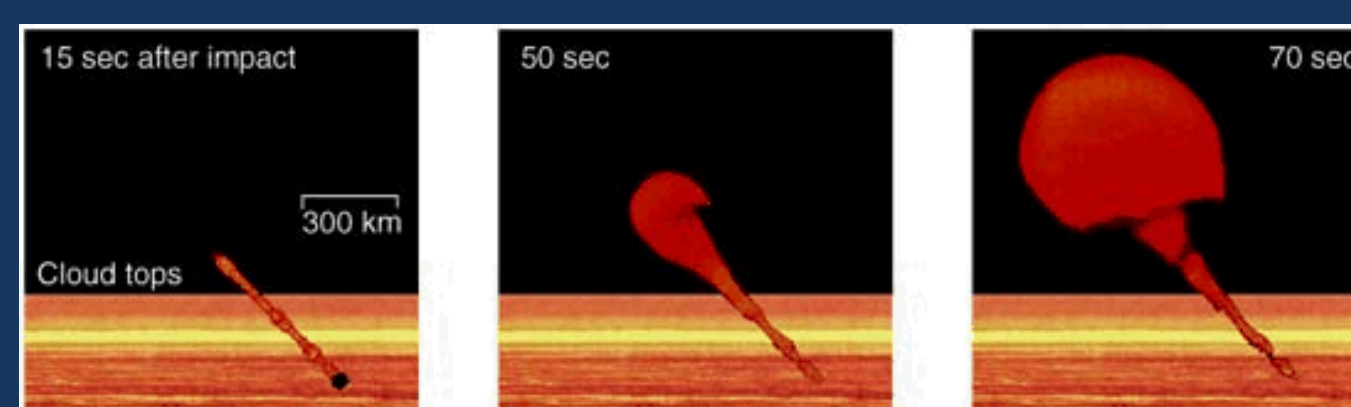
First CTH Analysis/
Prediction of
Experimental
Outcome Oct. 20,
1987 (McGlaun)



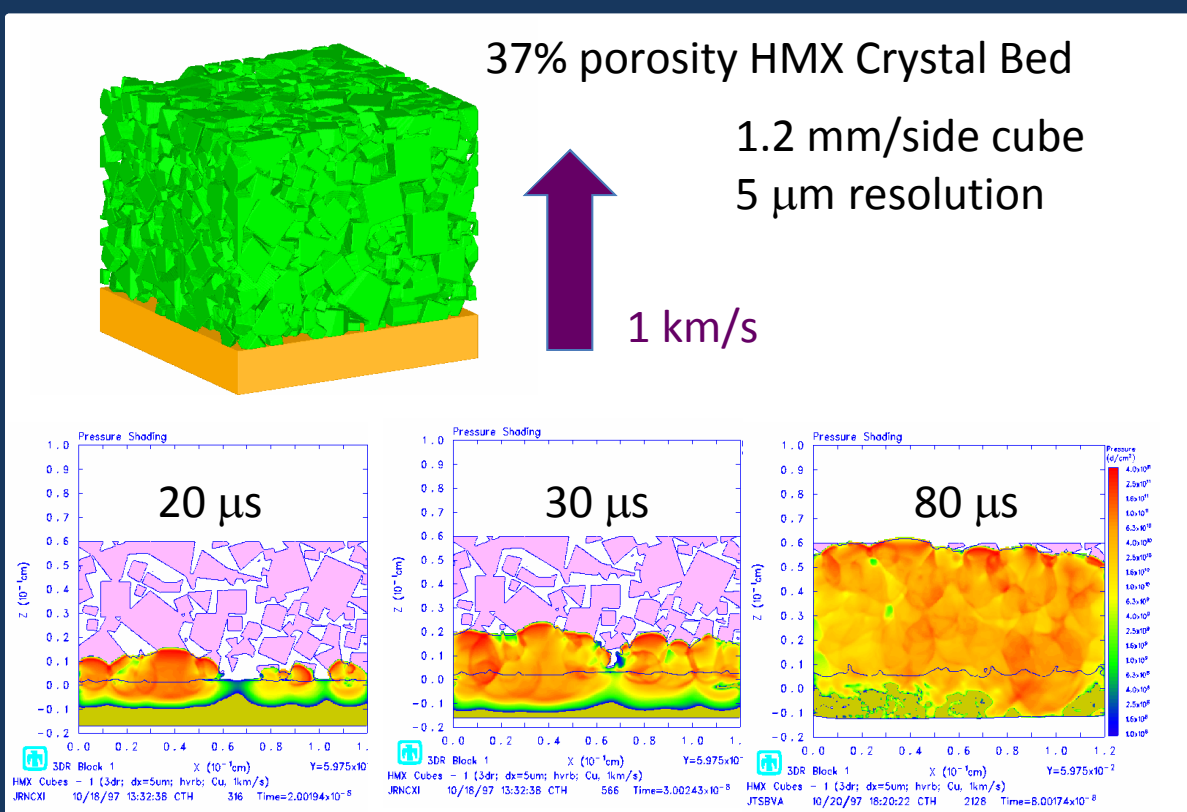
Radiograph From
Experiment



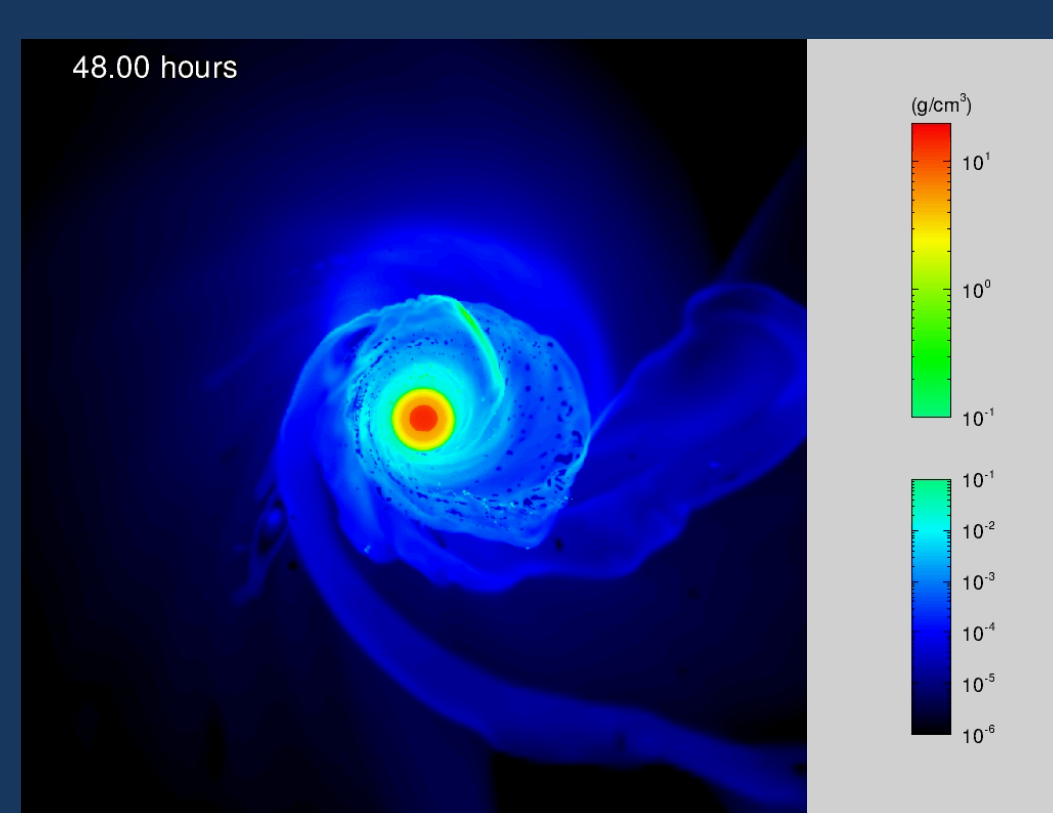
Re-creation of Grady/Kipp Simulation of Copper Sphere
Impacting a Steel Plate (1993)



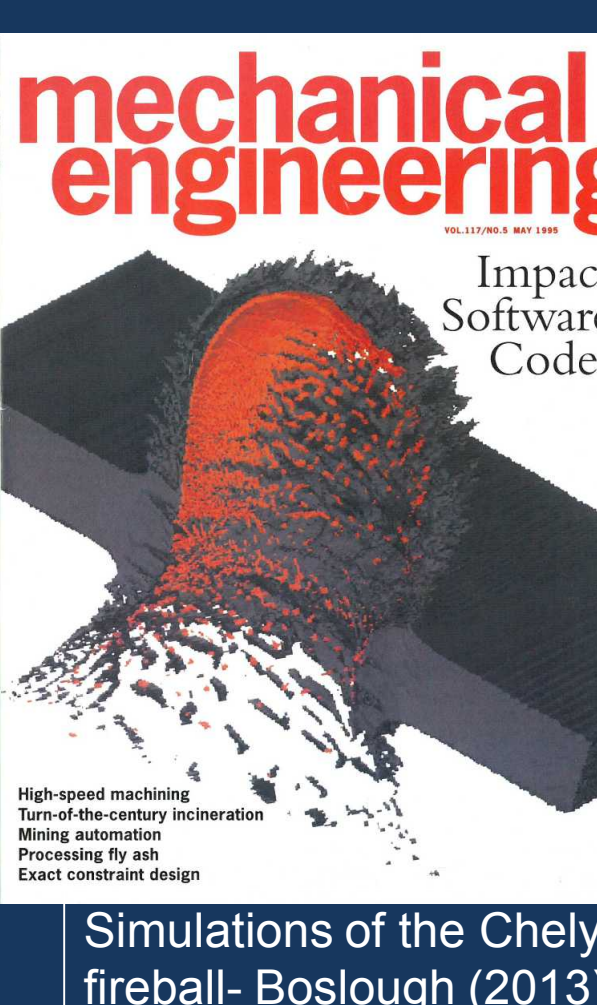
Shoemaker-Levy 9 Comet Impact Simulations
(Crawford, Boslough, & Trucano)
10 million zones calculation on Intel Paragon machine (1993)



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



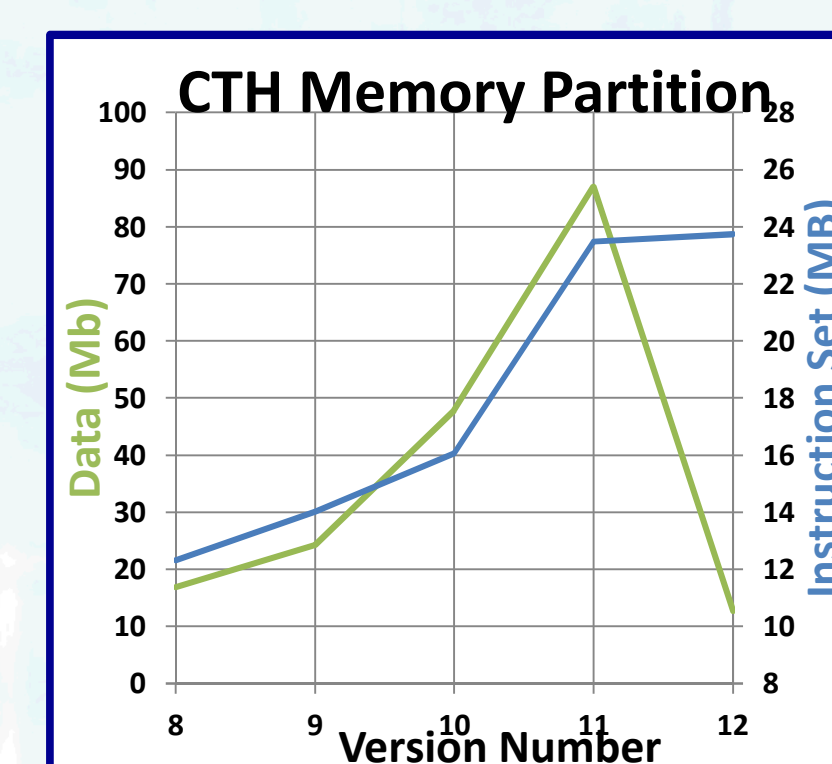
Simulations of the Chelyabinsk
fireball - Boslough (2013)

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(ASCII 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

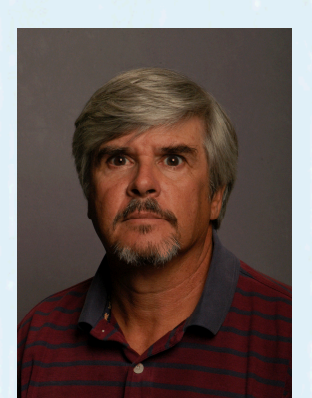


Key Leadership

Samuel Thompson
Architect of CHARTD, CSQ, & CTH Codes



Michael McGlaun
Code Creator & Leader
1986-1990



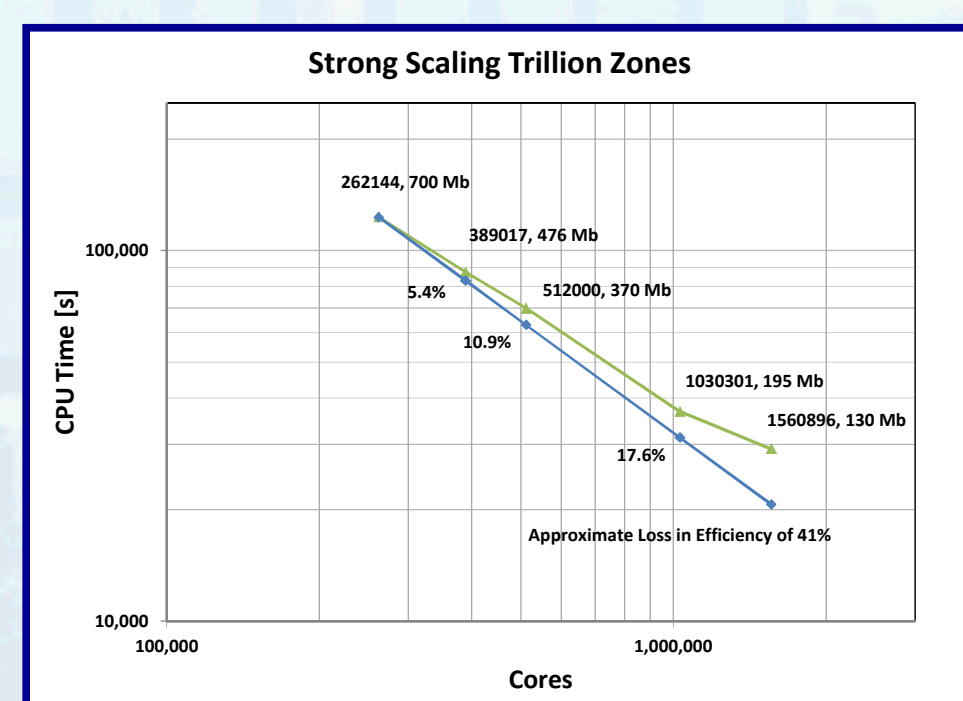
Eugene Hertel Jr.
Code Lead, Steward
1990-1999, 1995-2008



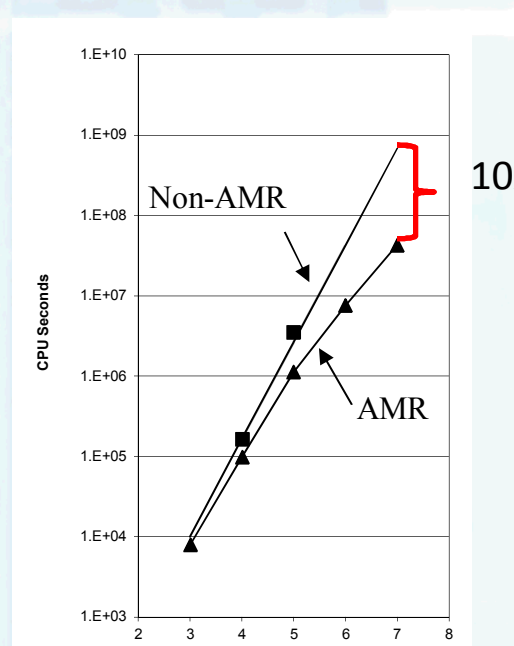
David Crawford
Code Leader
2003-2013

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

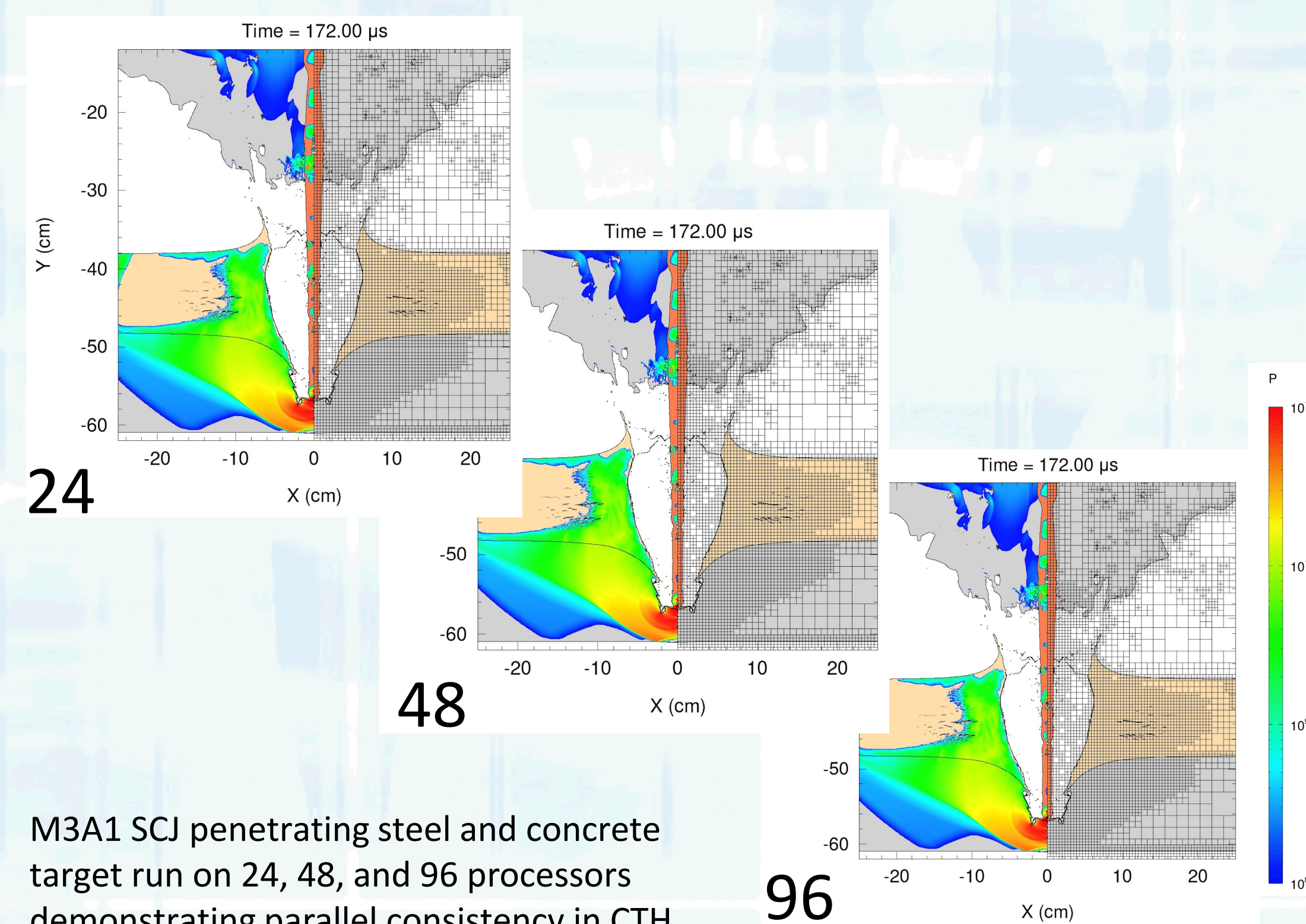


Scaling Study to 1.5
million cores on DOE's
Sequoia (LLNL)

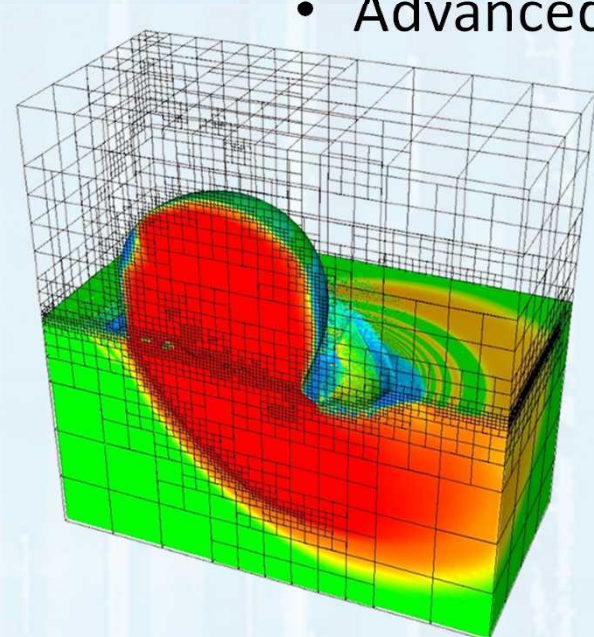


Comparison of AMR
and Flat Mesh
Performance (2001)

Recent Results



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



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