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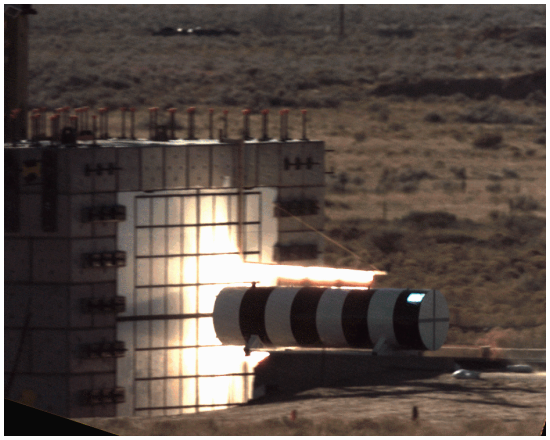
High performance computing challenges for fluid-structure interaction problems



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Supercomputing Conference 2006
Tampa Bay, Florida
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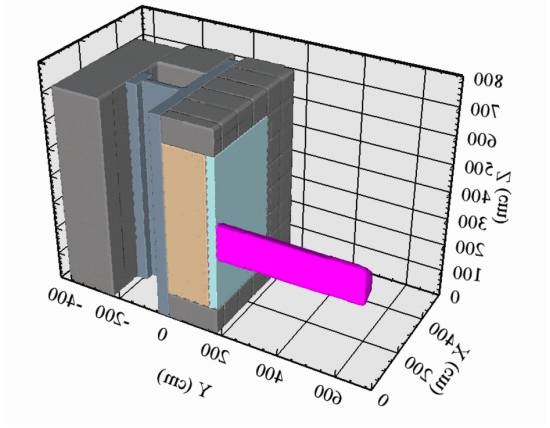

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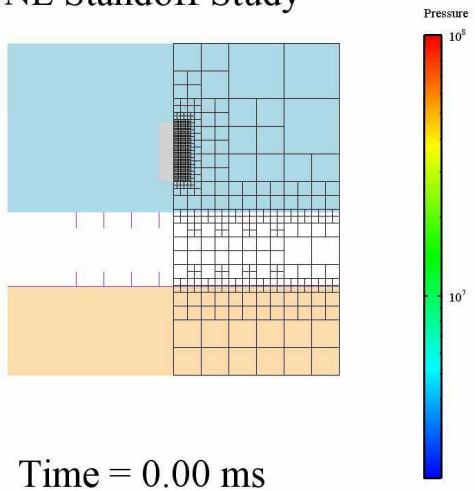
Capability Challenges

Goals:

- Solve blast/structure interaction problems modeling the physics of ***thin*** geometry
- Blast pressures penetrate the structure and generate both internal and external structural loading.
- ***No one numerical method can economically model the wide range of length scales typical of a blast against a large thin-walled structure.***

Explosive blast interacting with a thin structure

SNL Standoff Study



Late time weld failure

Fragments and tearing

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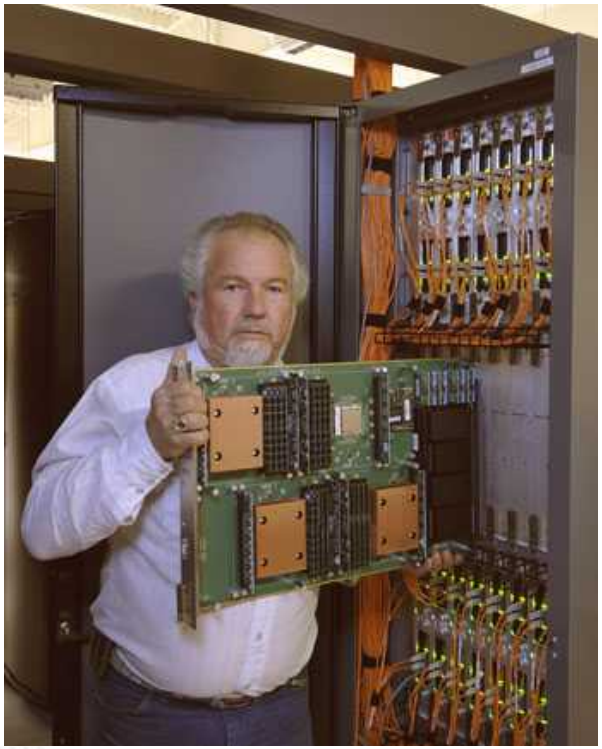
Necessary Resolution for Representing Phenomena in Eulerian Shock Physics Codes

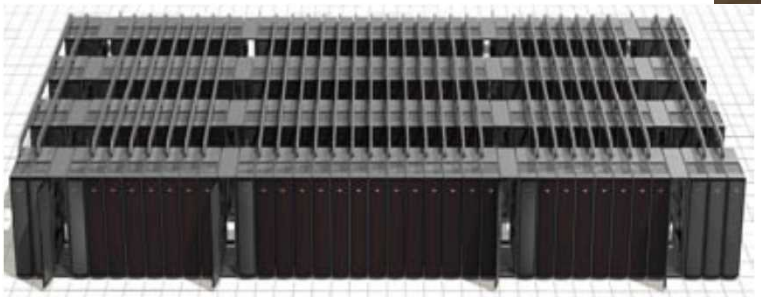
Physics Feature	Resolution			
	Minimum	Low	Medium	High
	1 to 2 cells	3 to 5 cells	5 to 7 cells	7 to 15 cells
Air shock	yes	yes	yes	yes
Blast impulse	some	yes	yes	yes
Through thickness shock	no	some	yes	yes
Fragmentation	no	no	some	yes
Debris tracking	no	no	some	yes
Spall	no	no	some	some
Ductile tearing	no	no	no	some
Bending strength	no	no	some	yes
Welds	no	some	some	yes
Blast pressures inside structure	some	some	yes	yes

- Isotropic material response and representative physics resolution
- Necessary resolution conditions, but not sufficient conditions
- Accurate models for each feature are required to capture necessary physics
- Assumptions should be validated and are problem dependent

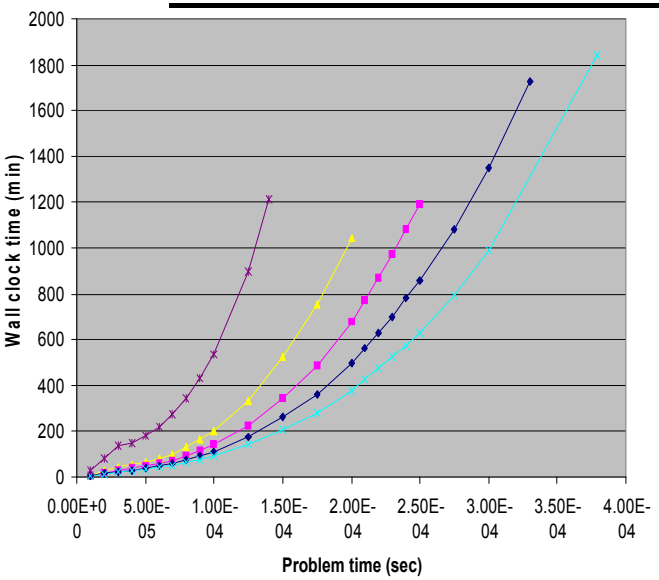
CRAY XT3 (Red Storm)

- MPP supercomputer designed jointly by SNL and Cray
- Linux machine with 10,368 AMD Opteron 2 GHz compute nodes
- Catamount operating software
- #6 on Top500 list for 2005
- Currently undergoing massive hardware/OS upgrade—12,960 AMD Opteron 2.4 GHz Dual Core processors

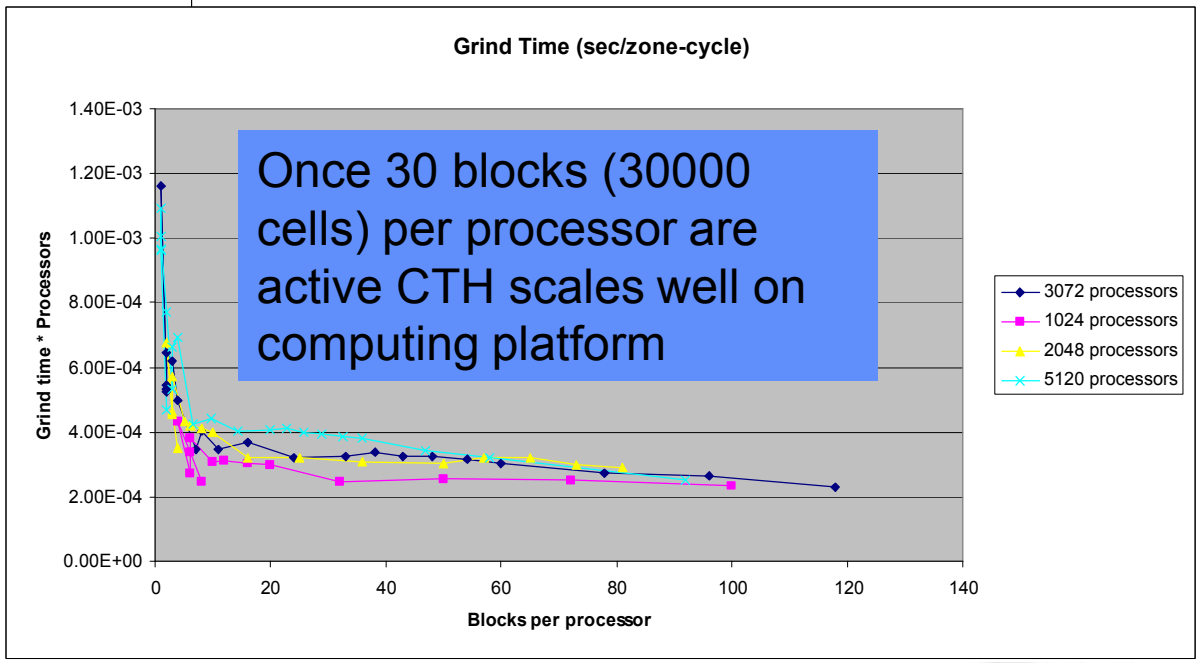




High Performance Computing Platform Scaling



CPU time is not constant
- At start of problem, most cells are inactive
- Parallel computations are inefficient at early times
- At late time, large number of cells are active



AMR Benefits
- At least a factor of three improvement in performance and memory utilization is achievable for many large problems.
- Order-of-magnitude performance improvement is possible for some problems.
- Dynamic load balancing using RCB (or similar) is essential for good parallel performance.

Run Time Estimates

Wall-to-cell thickness ratio	7.0	3.5	1.7	0.9
Cell thickness (cm)	0.027	0.054	0.11	0.22
Blocks	11000000	2750000	500000	64000
Steps	80000	40000	20000	10000
Processors	10000	10000	5000	1000
Blocks/processor	1100	275	100	64
CPU time (days)	**257**	**32**	**6**	**2**
Physics resolution	Air shock, Fracture, through thickness shock, spall, ductile tearing, bending strength	Air shock, Fracture, some bending strength features, some tearing	Air shock, blast impulse	Air shock and impulse dependent on mixed cell numerics, numerical fragemetation by interface tracker

Summary

- SNL High Performance Computing capability (CRAY XT3) used to push state-of-the-art in fluid-structure interaction modeling
- Massively parallel blast-structure interaction simulations were used to validate a variety of fluid structure interaction problems with high resolution