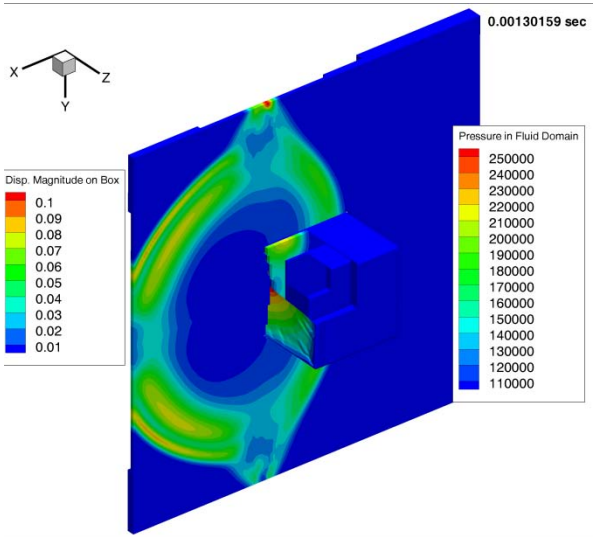
Physics-Based Simulations of Fluid/Structure/Dynamics Interactions in Scenarios Associated with Blast



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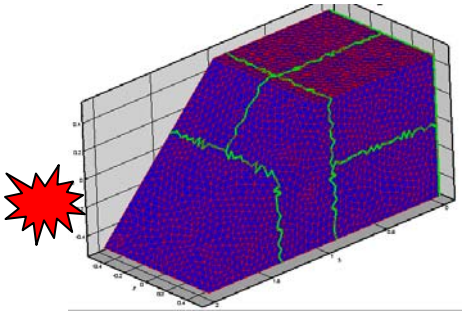
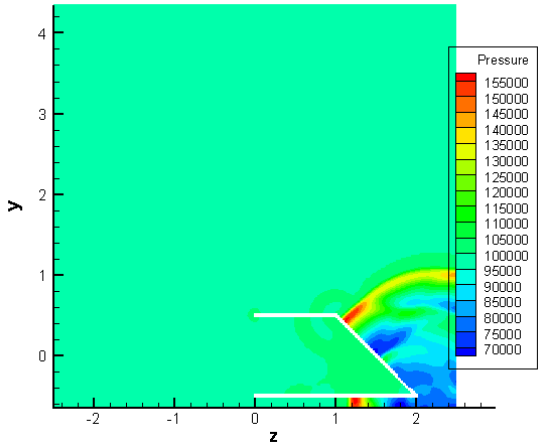
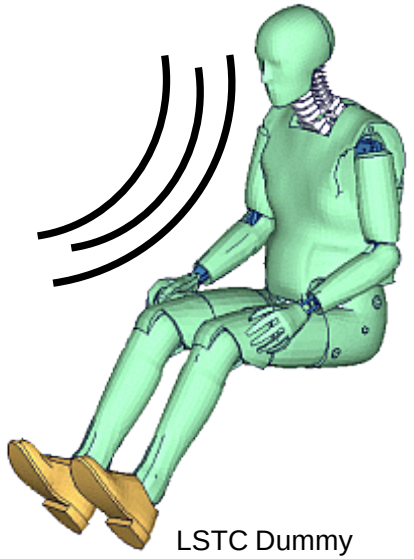
Objectives

- **Develop vehicle occupant blast load simulation**
  - **Fast and accurate - Physics and HPC**
  - **Cost efficient – Open source code**
  - **Flexible and User-friendly**







LSTC Dummy

Outlines

- Background
- Technical Approach
- Results and Discussion
- Summary

IED and TBI

Improvised Explosive Device (IED)

- Over 60% of the blast injury in OEF and OIF in 2009
- Penetration and direct injuries
- Remains weapon of choice and major threats
- Survival rate increased with armor (head, body)

Blast Traumatic Brain Injury (TBI)

- "Signature" injury in OEF and OIF
- Primary blast injury caused by blast induced pressure change
- Battle field and in-theater innovations in treatment lowered killed:wounded ratio
- Simulation to further enhance vehicle occupant survivability

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Fundamental Physics and Simulation

Gas Dynamics - CFD

- Spatial (three-dimensional) and temporal (time accurate)
- High pressure ratio wave of small time scale
- Pressure wave numerical resolution in 3D
- Moving/deforming immersed boundary
- Computationally intensive

Computational Structural Dynamics - CSD

- Spatial (three dimensional) and temporal (time-accurate)
- Materials dynamic behavior
- Large deformation or fragmentation
- Computationally intensive

Motion Dynamics – 6DOF

- Kinematics and dynamics of body motion
- Six degree of freedom (6DOF) motion equations

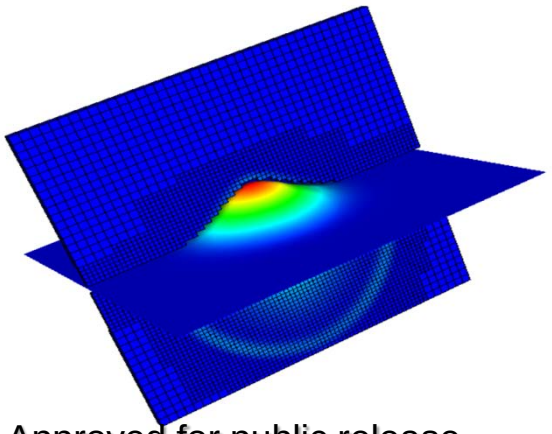
Computationally intensive

Simulation Platform (1)

Fluid Dynamics and Structural Dynamics

Virtual Test Facility (VTF) from Cal Tech

- Developed at Cal Tech's Center for Simulation of Dynamic Response of Materials.
- 3D dynamic response of materials subjected to strong shocks and detonation waves propagate in fluids
- Explicitly coupled Eulerian-Langrangian simulations
- Adaptive mesh refinement for Cartesian finite volume fluid solver
- High order sub-division FE thin-shell structure solves
- Fracture and fragmentation
- Highly parallized CFD and CSD solvers
- Open-source



Simulation Platform (2)

Rigid Body Motion Dynamics

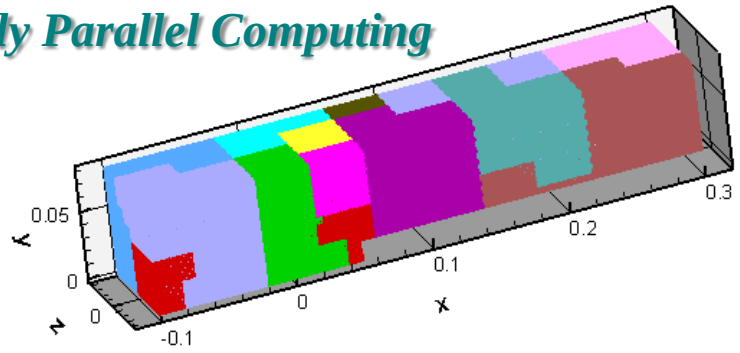
WMU Enhanced Solver

- Geometry flexibility
- Directly coupled to VTF with multiple bodies
- Open-source

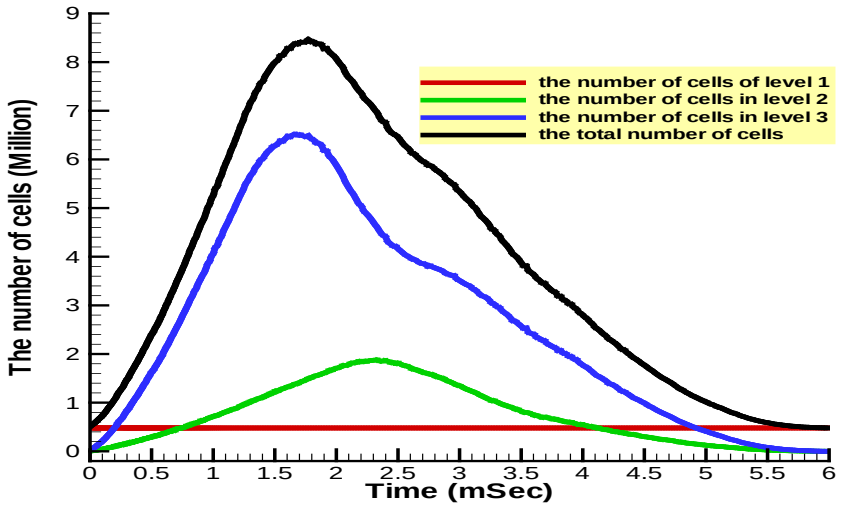
Coupled Fluid/Structure/Dynamics Solver

- Vehicle Occupants Blast Load
- High Performance
- Low Cost

Massively Parallel Computing

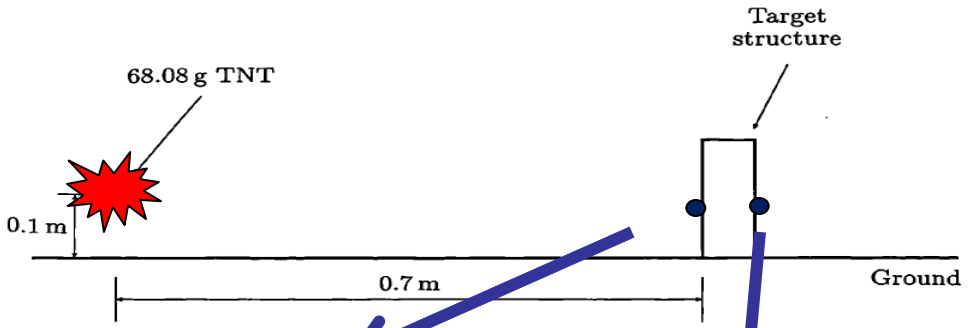


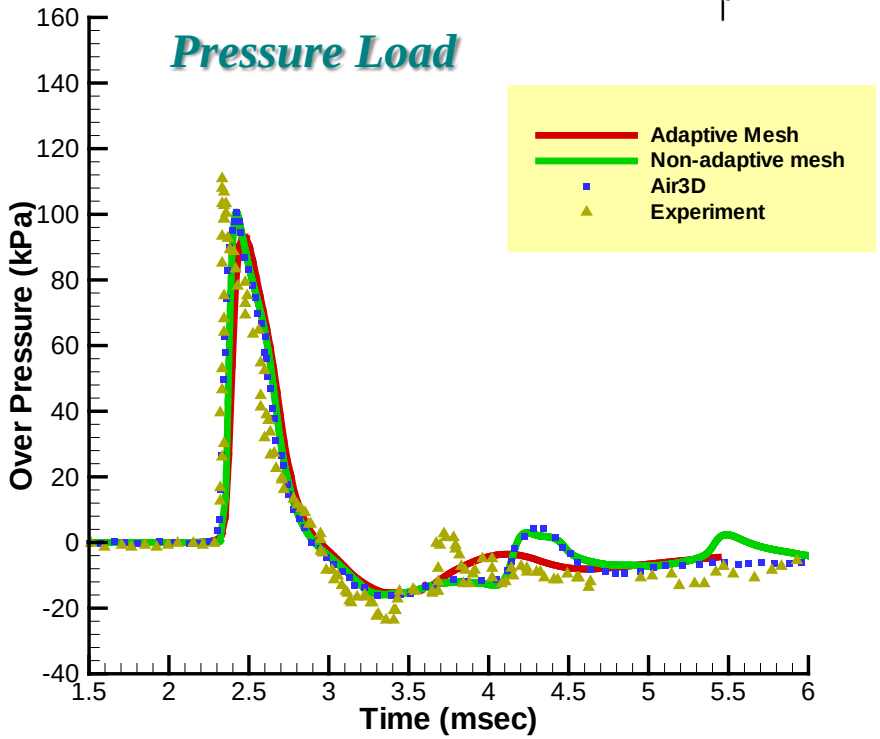
Adaptive Mesh Refinement

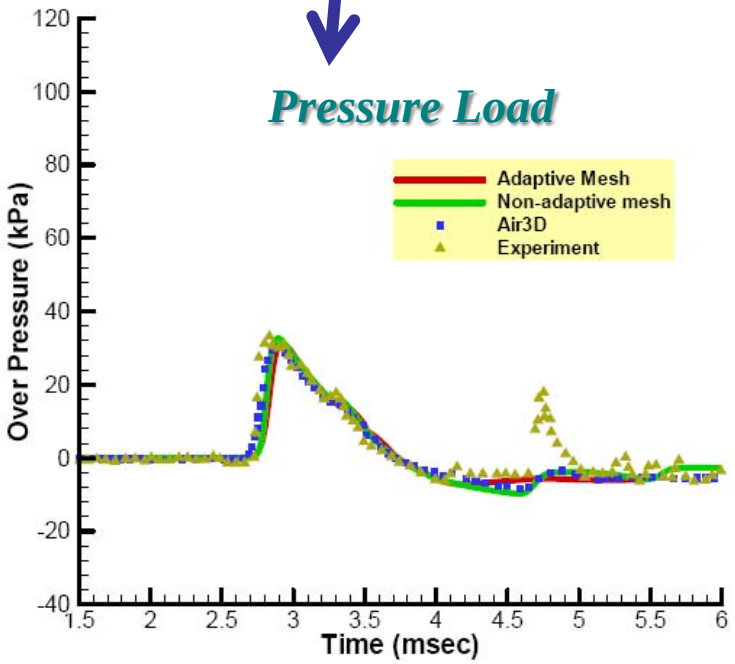


Free Air Blast Wave Propagation

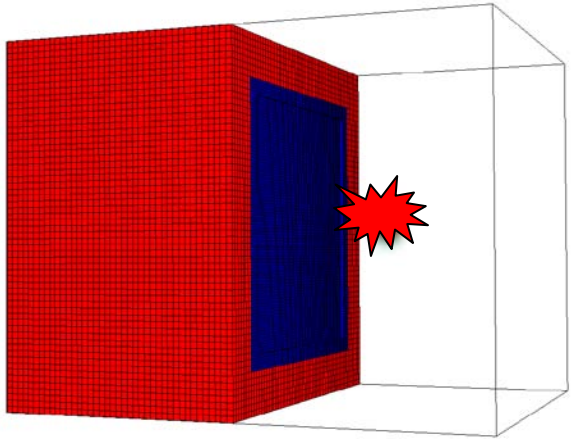
- P_{TNT} = 2.89 GPa
- Base Mesh: 200x150x50
- Two Pressure Loads





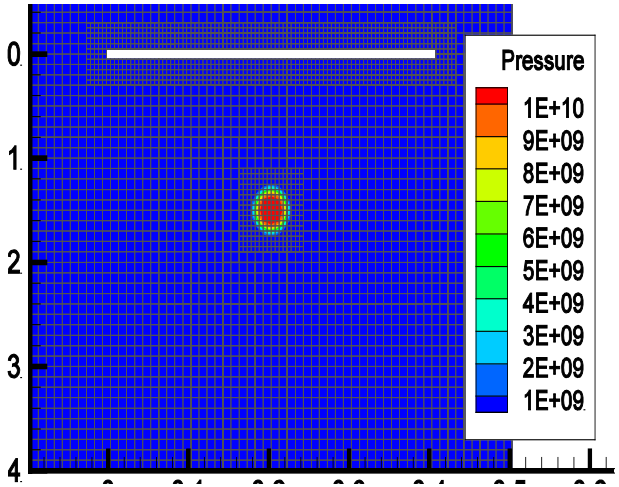


Metal Plate in TNT Blast (1)



- 150 g C4
- Two standoff distances
- AL6XN SS plate thickness 1.9 mm
- 8 Compute Node

Pressure Contours at To



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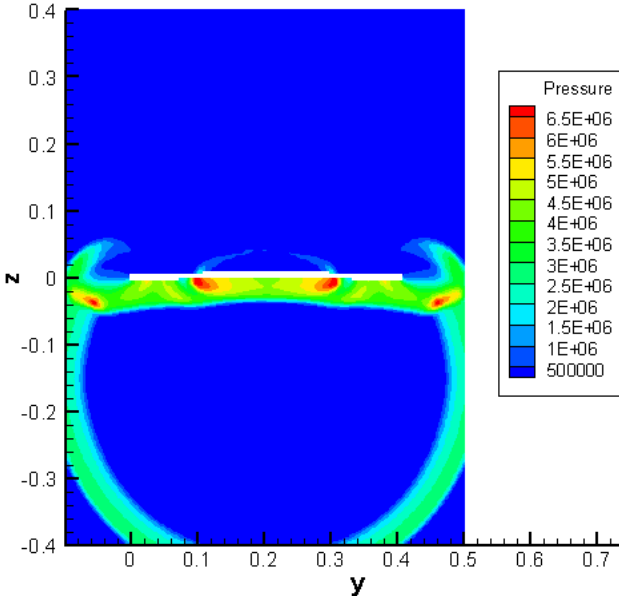

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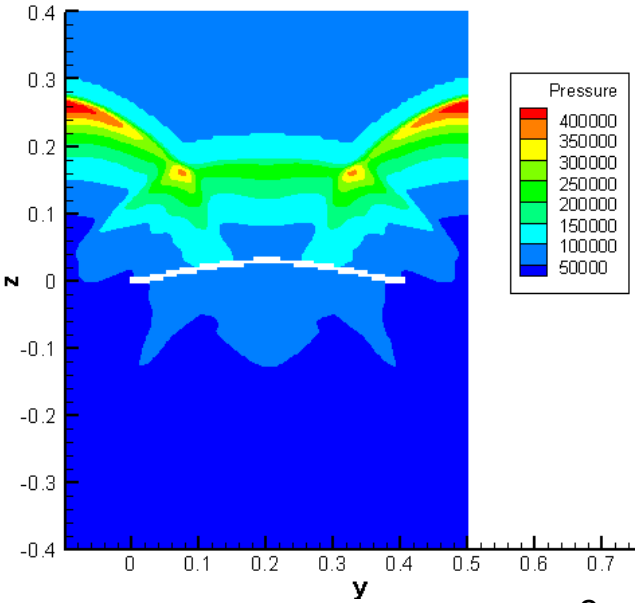
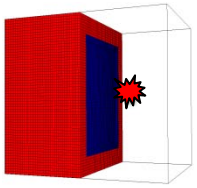
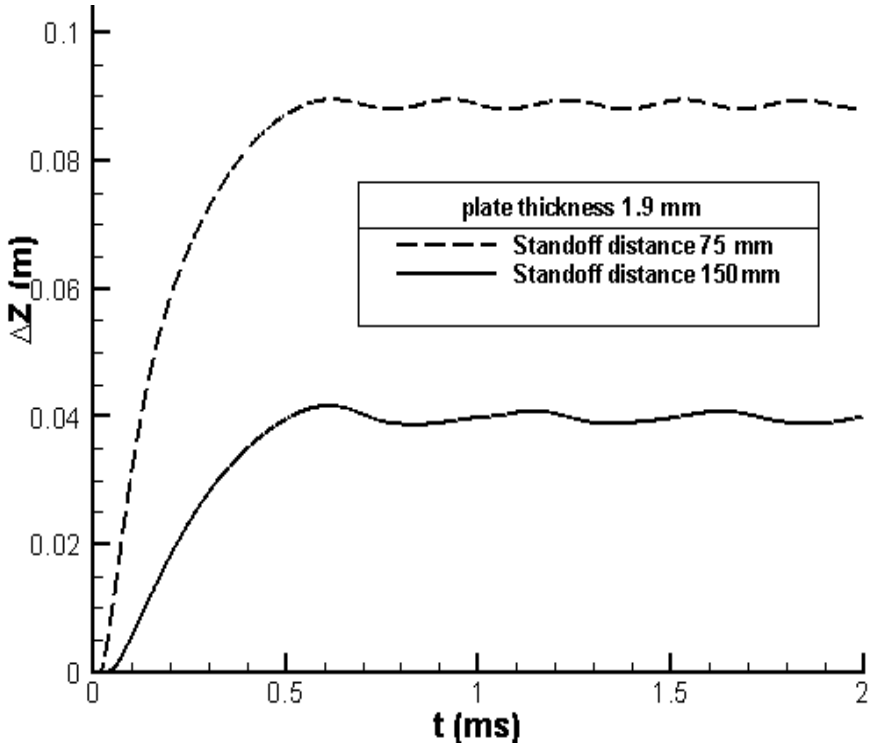


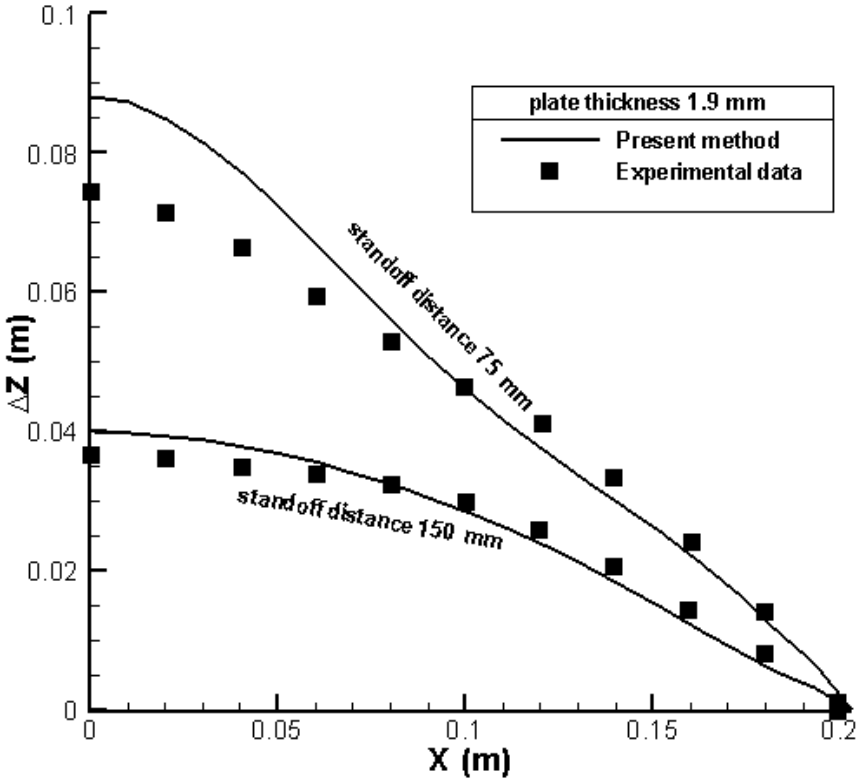
Metal Plate in TNT Blast (2)



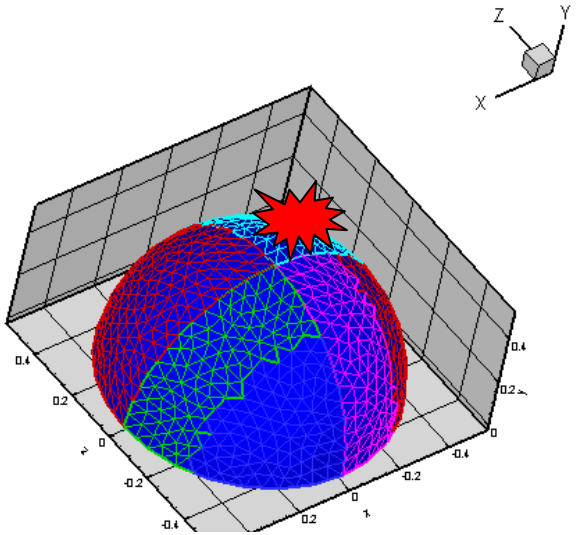
SS Plate Centerpoint Deformation History



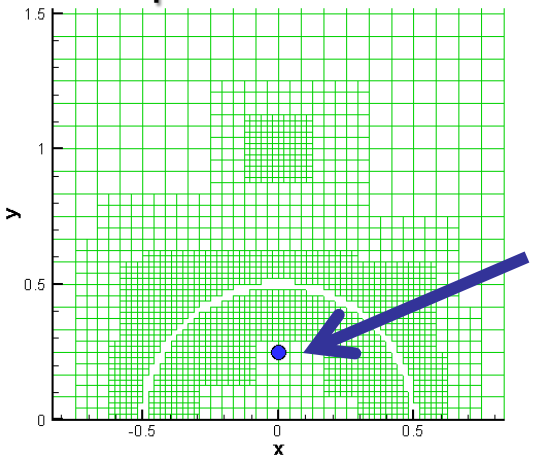
SS Plate Deformation Contours



Blast Over Hemisphere Dome (1)

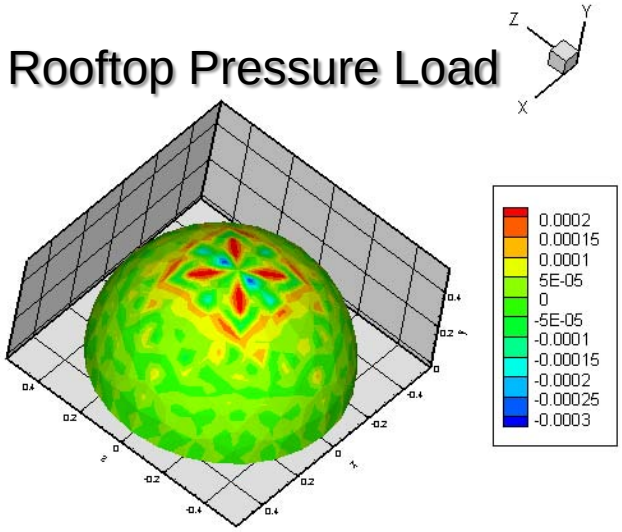


Adaptive CFD Mesh

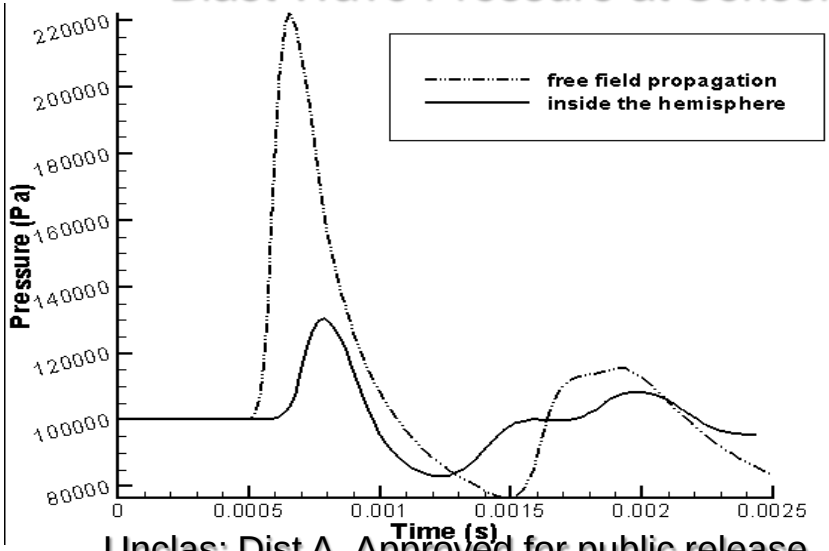


pressure sensor

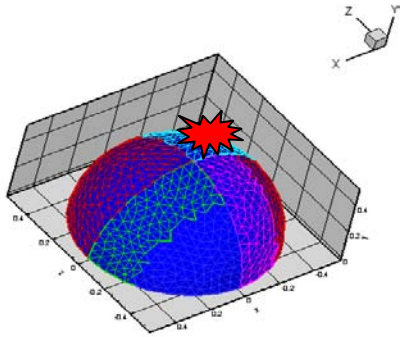
Rooftop Pressure Load



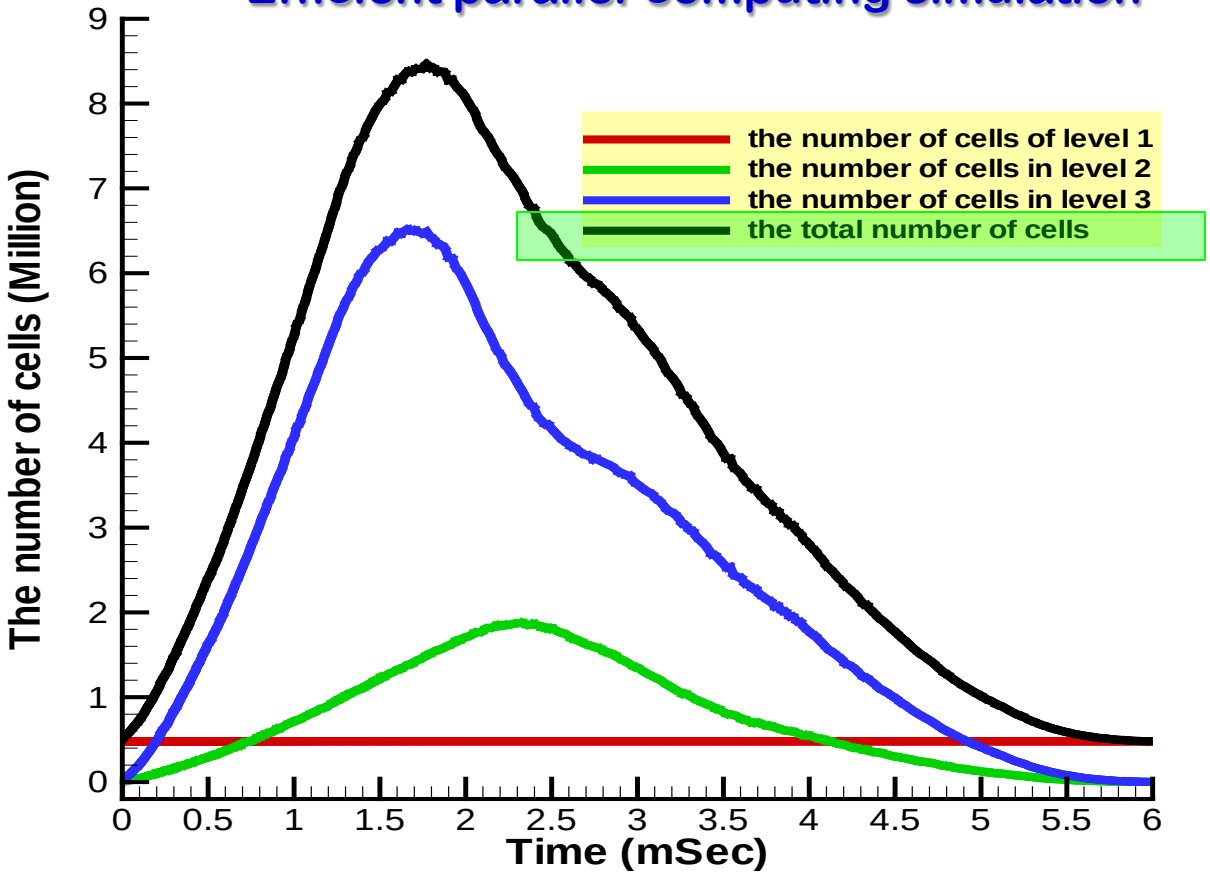
Blast Wave Pressure at Sensor



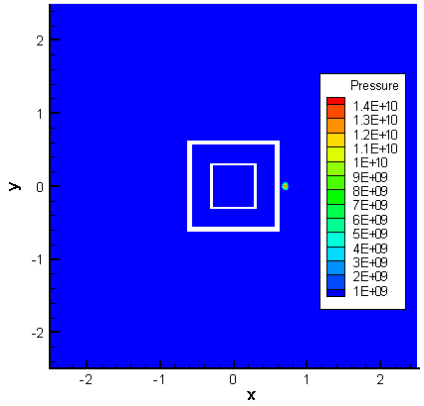
Blast Over Hemisphere Dome (2)



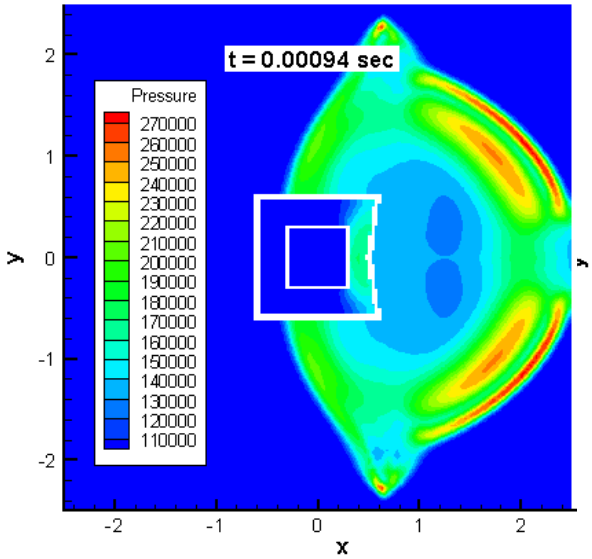
- 3 Level of adaptive mesh refinement
- Total # of cell adapt to accuracy need
- Efficient parallel-computing simulation

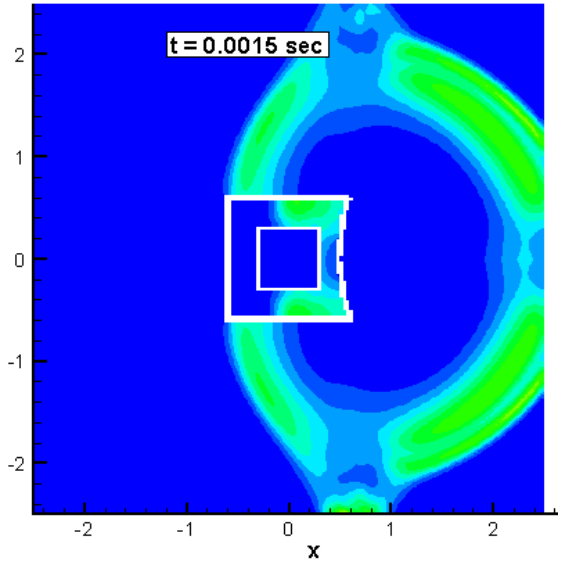


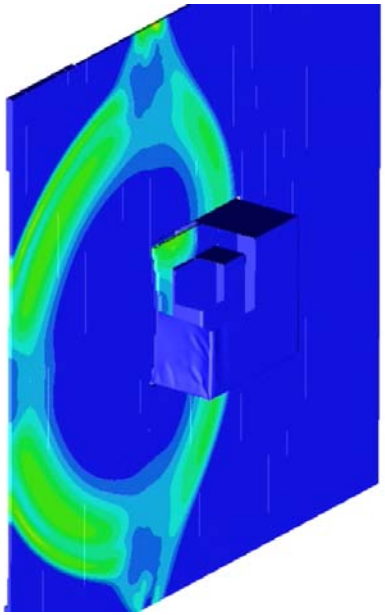
Blast off Boxes (1)



- Two boxes with one centrally located inside the second
- The outer box deforms elastically; the inner box rigid and fixed in space



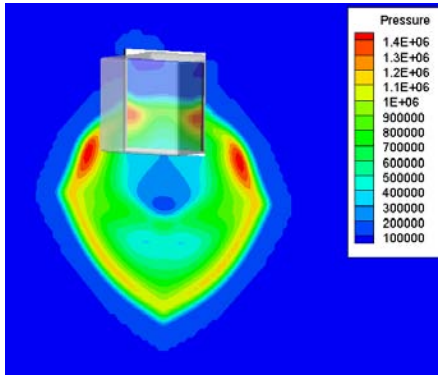


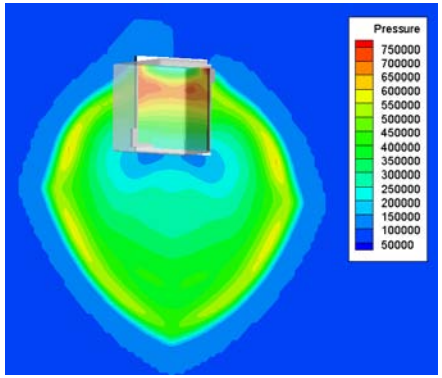


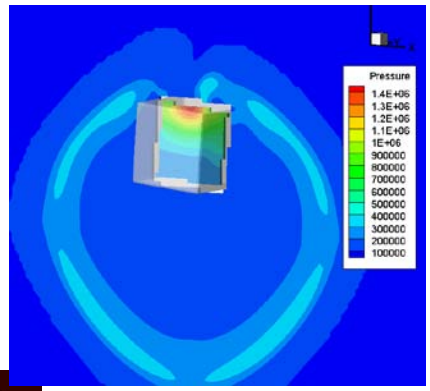
Pressure Contours & Box Deformation

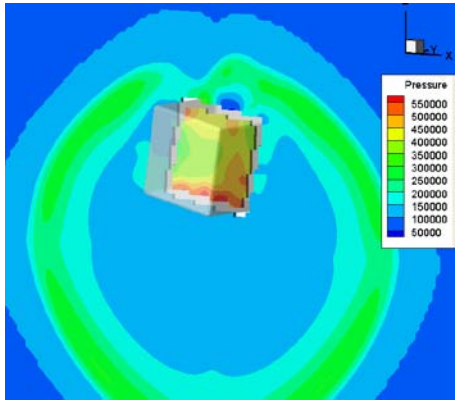
Blast off Boxes (2)

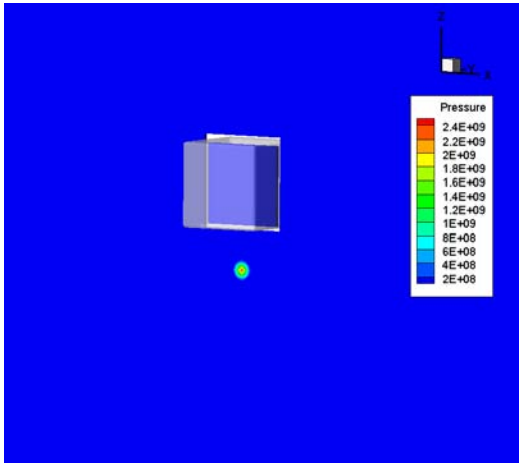
- Blast initiated under a single rigid box
- Unconstrained body motion by 6-DOF











Body 6-DOF Motion & Pressure Contours

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Concluding Remarks

- Developed physics-based computer simulations of the effects of fluid-structure interactions due to blast
  - Open-source software offers accurate and fast simulations
  - CFD in multiply connected domain
  - Generic geometries
- Developed fluid-structure-dynamics interactions mutiphysics solver
  - Vehicle occupant motion and deformation due to direct/indirect exposure to blast wave
- In the future,
  - Apply to realistic dummy model
  - Develop and couple multi-body dynamics capability for human-like dummy model
  - Deliver software for time-accurate vehicle occupant blast wave load simulations to TARDEC