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Title: LANL HOSS Modeling Capabilities General Briefing

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LANL HOSS Modeling Capabilities

General Briefing

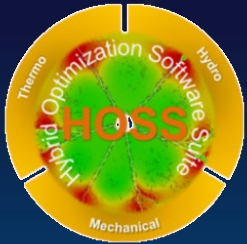
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EES-17 - Modeling & Simulation Team

Los Alamos National Laboratory

7 December 2020

What is HOSS?

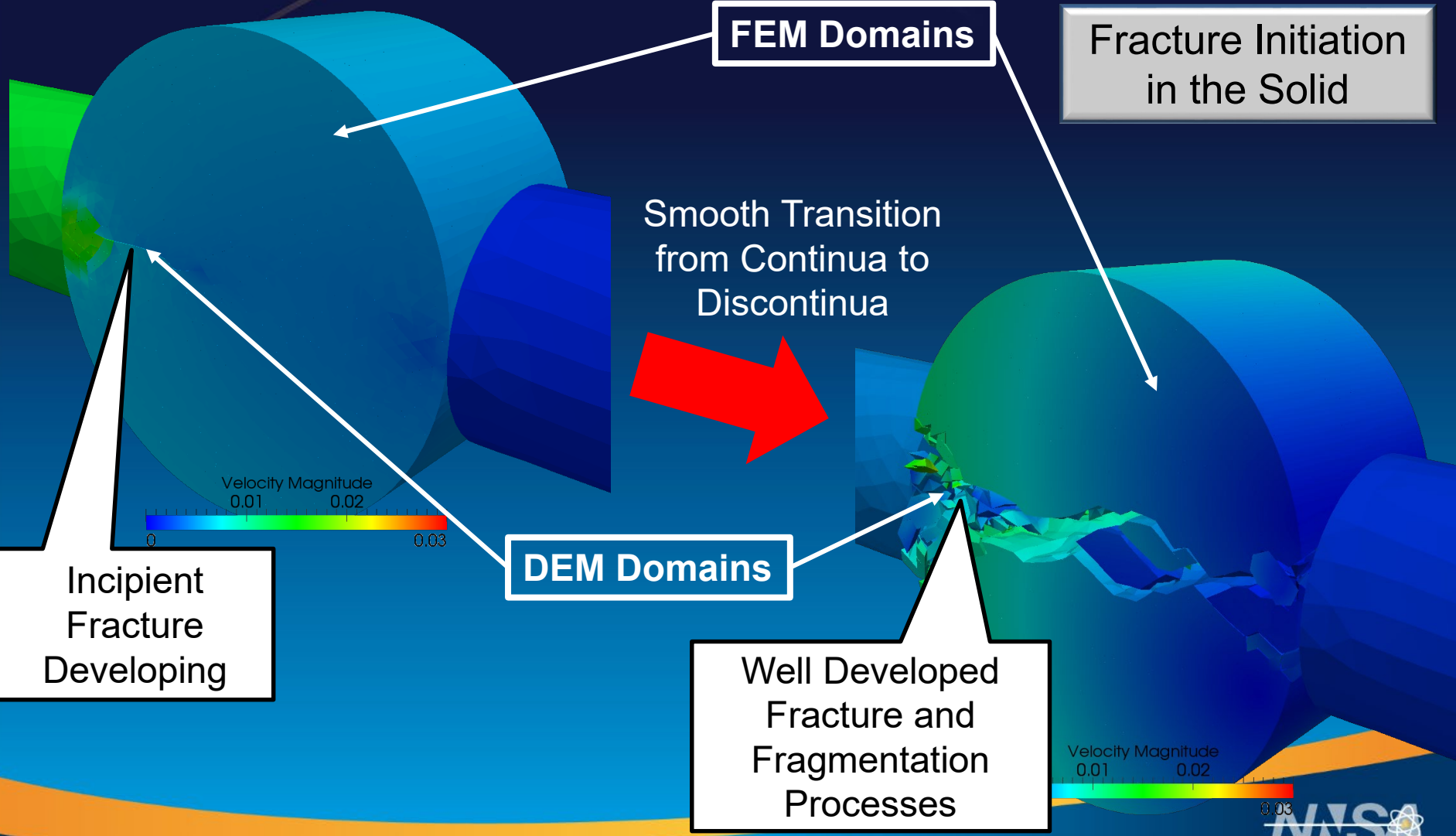


- Hybrid Optimization Software Suite; Multi-physics modeling framework based on Combined Finite-Discrete Element method (FDEM);
- Developed at Los Alamos for 15+ years; Supported by multi-million dollars of funding
- Integrated state-of-the-art theory/algorithms developed in the past 30+ years & summarized in 3 books, 3 patents, 3 copyrights and 100+ papers and it is licensed.



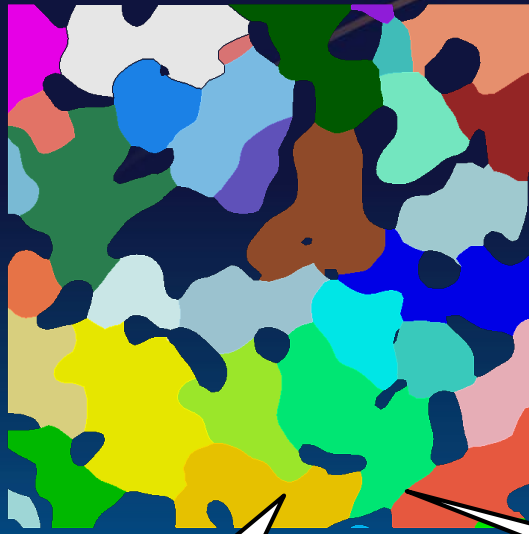
FDEM in a Nutshell

Hybrid Continua-Discontinua



FDEM in a Nutshell

Hybrid Continua-Discontinua

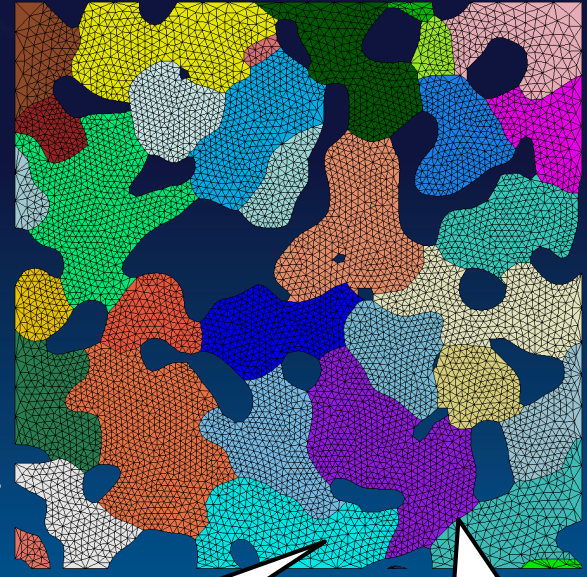


Rigid

Bonding

DEM

- Many particles
- Contact
- Rigid
- Fracture and fragmentation

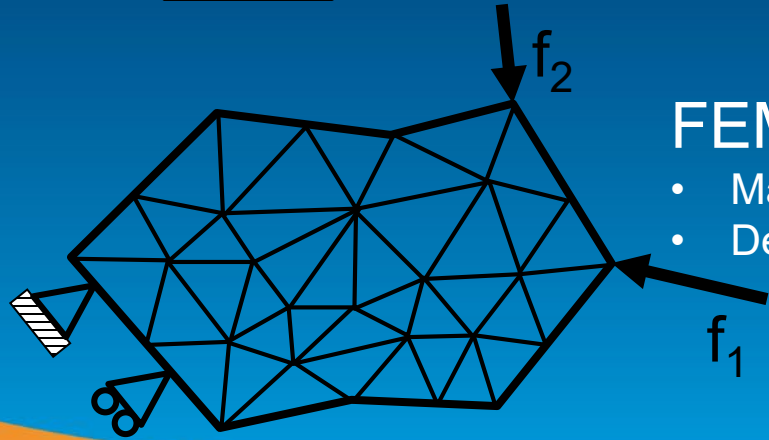


Deformability

Bonding

FDEM

- Many particles
- Many elements
- Deformability
- Contact
- Fracture and fragmentation



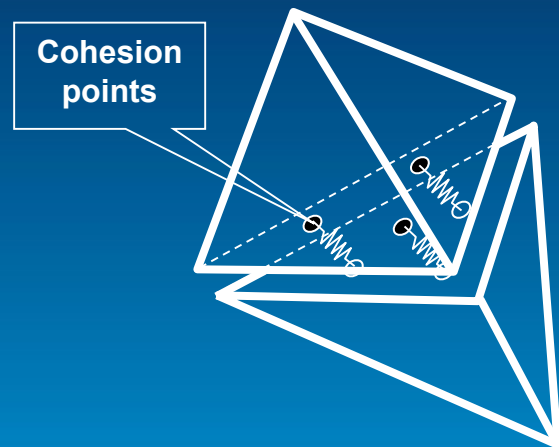
FEM

- Many elements
- Deformability

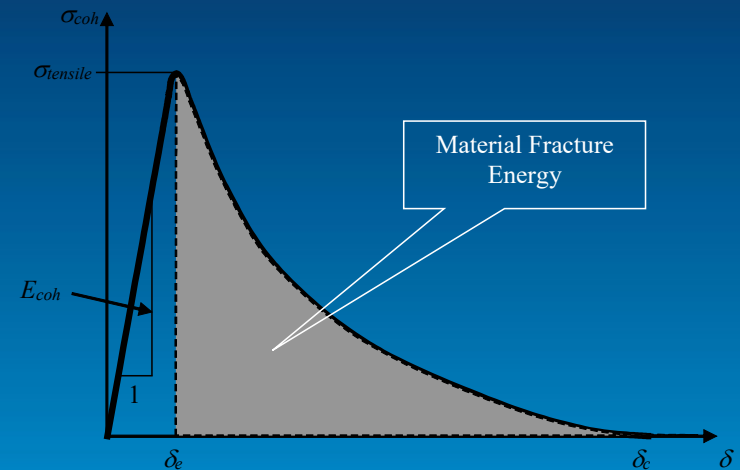
FDEM in a Nutshell

Fracture Model

- A smooth representation of the transitioning of the material from continuum to discontinuum behavior via the incorporation of cohesive models at the interfaces of the finite elements.
- The cohesive model is described as follows:
 - Elastic until the relative displacement (normal or tangentially to the interfaces), δ , reaches the elastic limit, δ_e .
 - When δ is greater than δ_e , the cohesive model enters into the strain softening region. Full breakage occurs when δ is greater than δ_c .
 - Same type of cohesive model is implemented in tension and in shear, but with different parameters.
 - The shaded portion of the curve shown in right figure represents the fracture energy for both tension and shear.

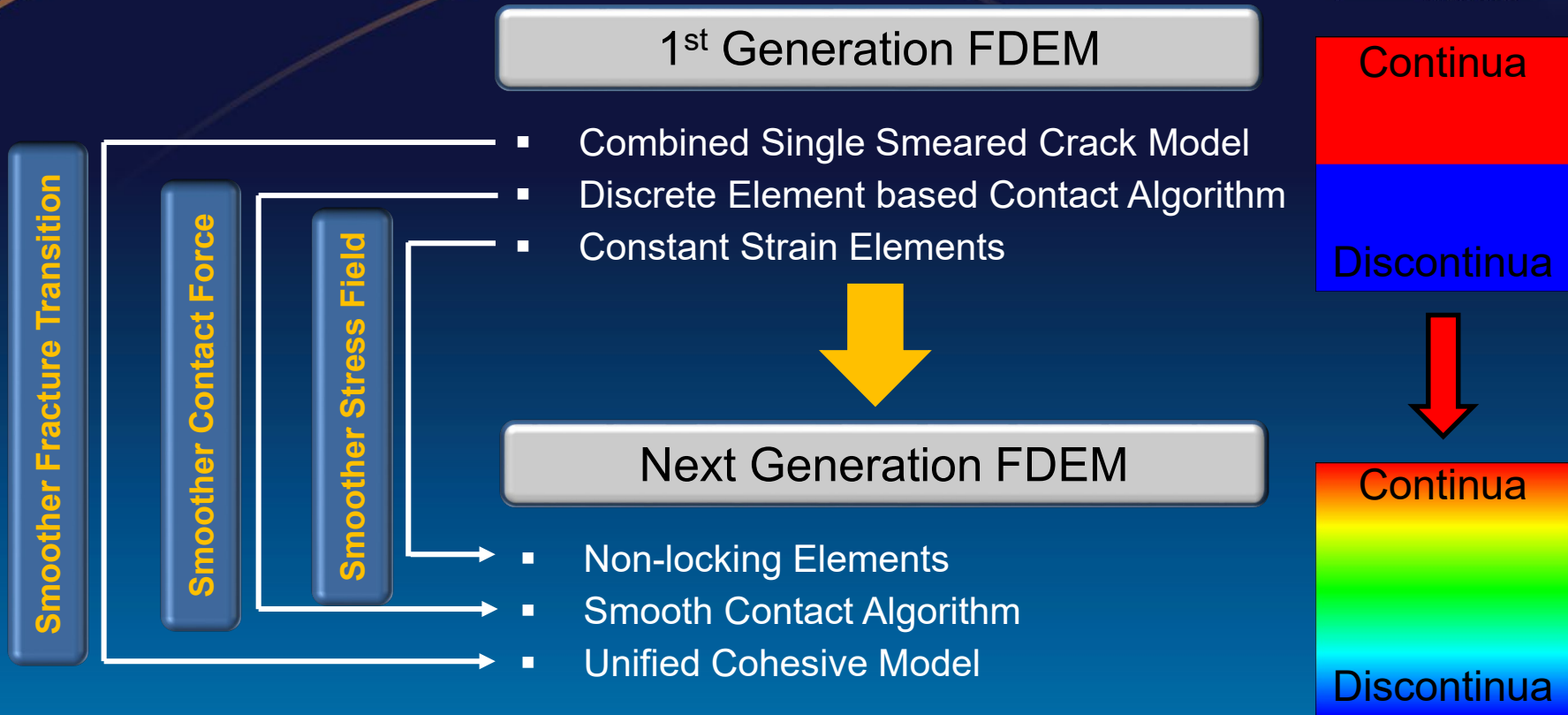


Schematic representation of cohesion points between two tetrahedral cells



Typical strain softening curve for FDEM fracture model. δ_e is the elastic fracture aperture, while δ_c is the maximum fracture aperture

FDEM Evolution in Time

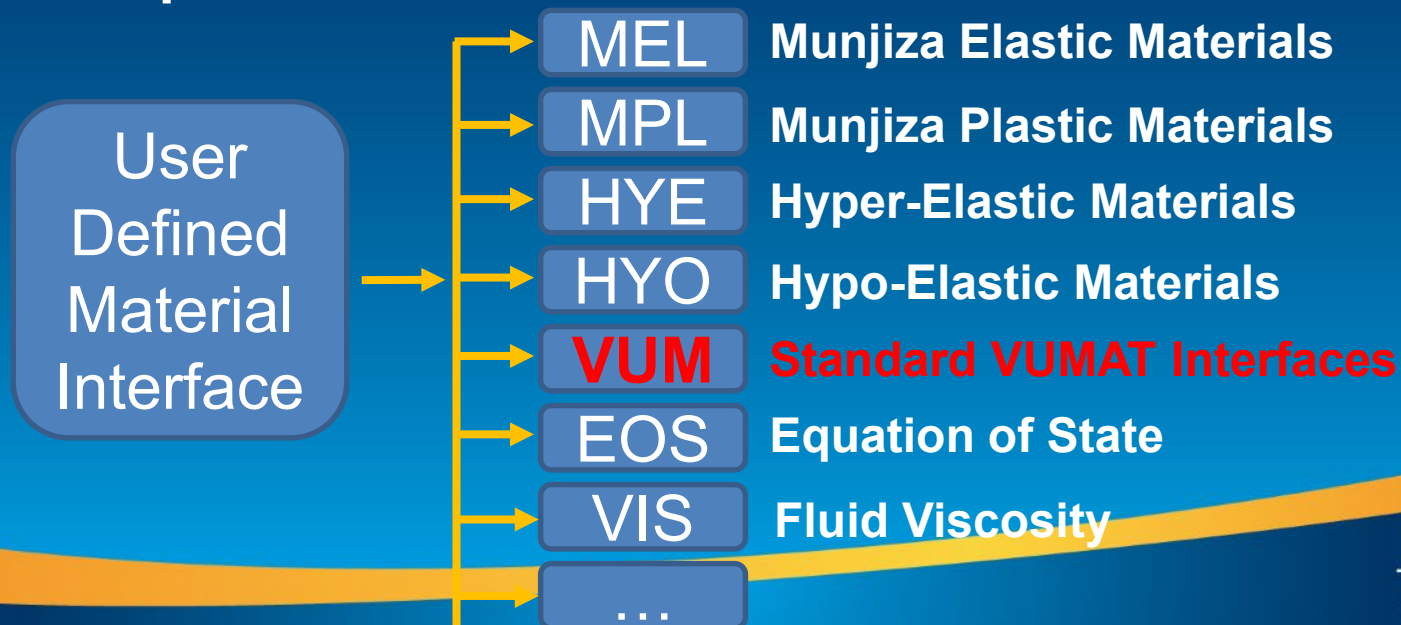


- Other FDEM tools are based on 1st generation algorithms
- Other FDEM tools can only handle limited size of problems (e.g. # of elements < 0.5 M)

Advanced Developments under HOSS

User Defined Material Interfaces

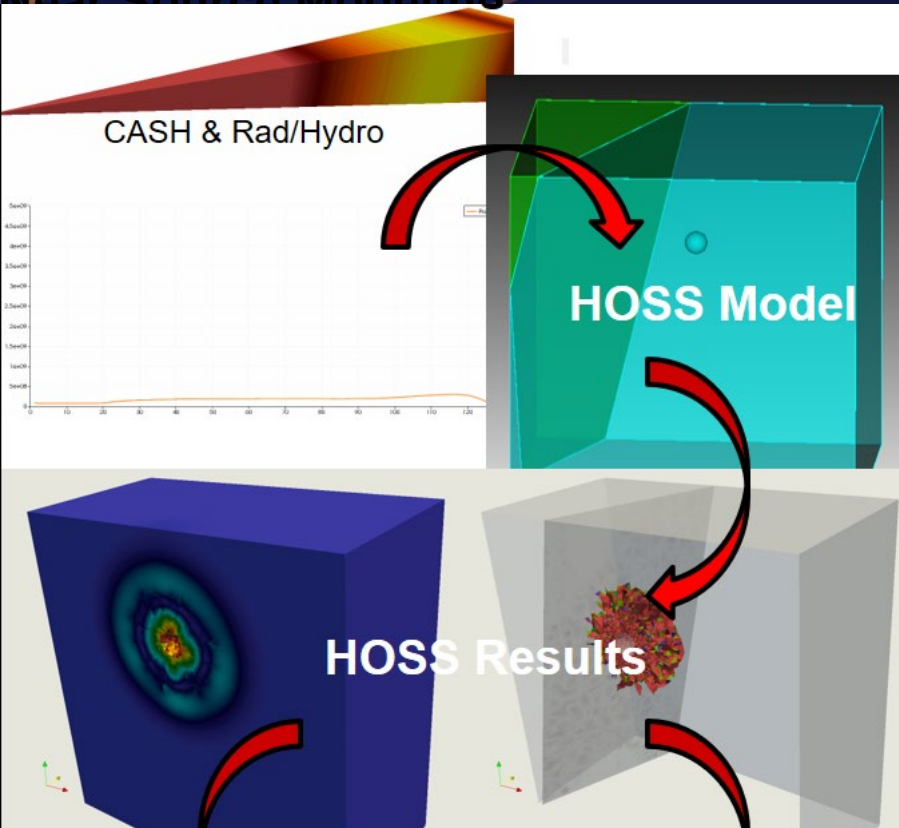
- HOSS provides several types of interfaces for user-defined material models
- The interfaces were designed to be user-friendly and can easily be extended as needed
- **The VUM interface is compatible with ABAQUS' VUMAT; therefore, any user-generated VUMAT material model can be easily incorporated into HOSS**



Why HOSS at LANL

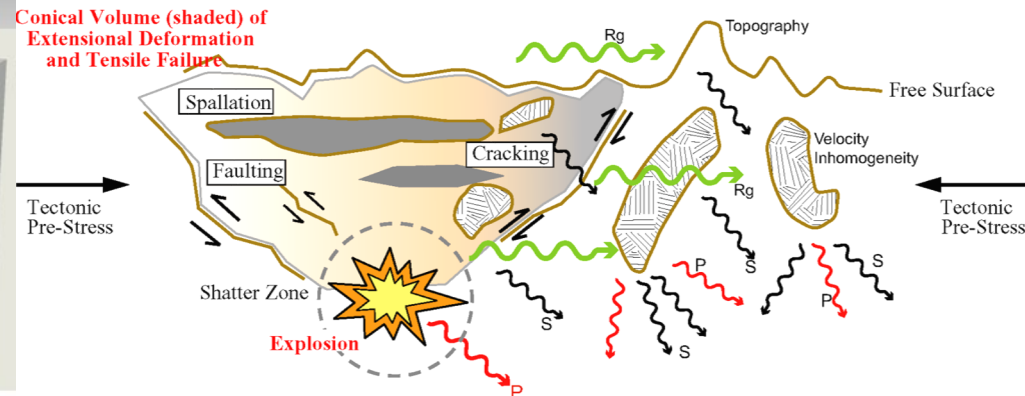
Near-Source Modeling

LANL's EES-17 developed HOSS to provide 1st principle physics-based source region damage and surface spallation effects for gas migration and seismic analysis efforts

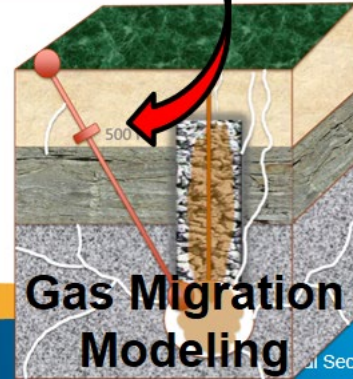


Near-Source Phenomenology

Cross-section of Explosion Source Region
(within 10 - 20 km of the explosion; not to scale)



Physical Signatures

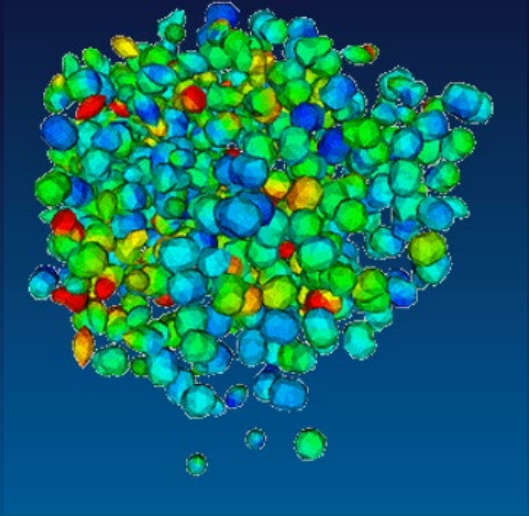


Gas Migration Modeling

HOSS (Hybrid Optimization Software Suite): A fracture mechanics code that properly conserves mass, energy and momentum. Est. 2004.

HOSS Simulation Examples

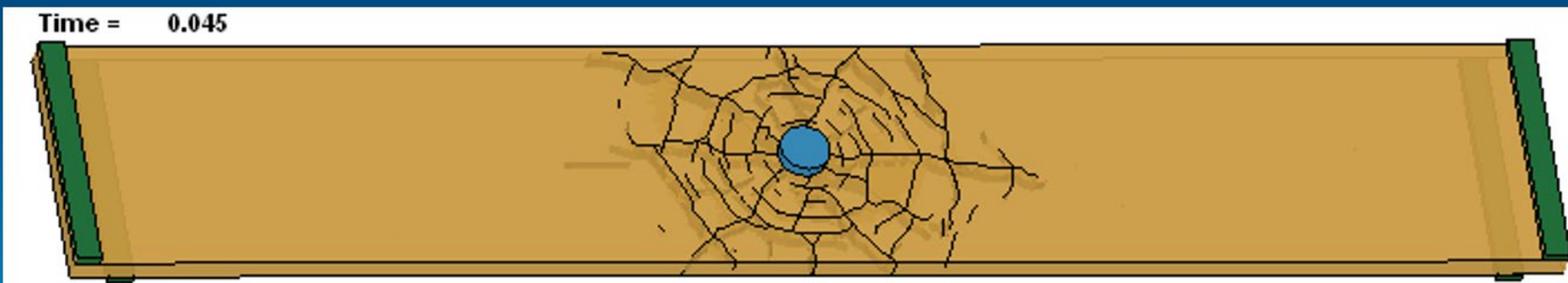
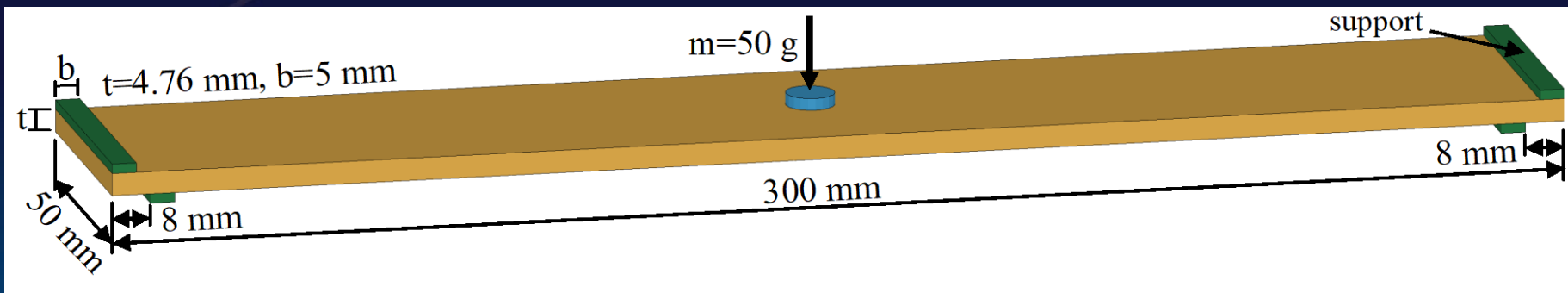
DEM-Based Modeling



The raster is centered with respect to the spherical container. Each particle is given an initial velocity pointing to the center of the sphere. The system is left to relax, thus, a random pattern of collisions take place between the particles

- Features state-of-the-art contact detection and contact interaction algorithms which guarantee high efficiency and accuracy
- Compatible with traditional DEM-based modeling which captures more physics:
 - Millions of deformable particles with irregular shapes
 - Fracture and fragmentation in particles via physics-based fracture model
 - Contact between the newly generated particles
 - Particle-Structure interaction
 - Fluid-Solid interaction

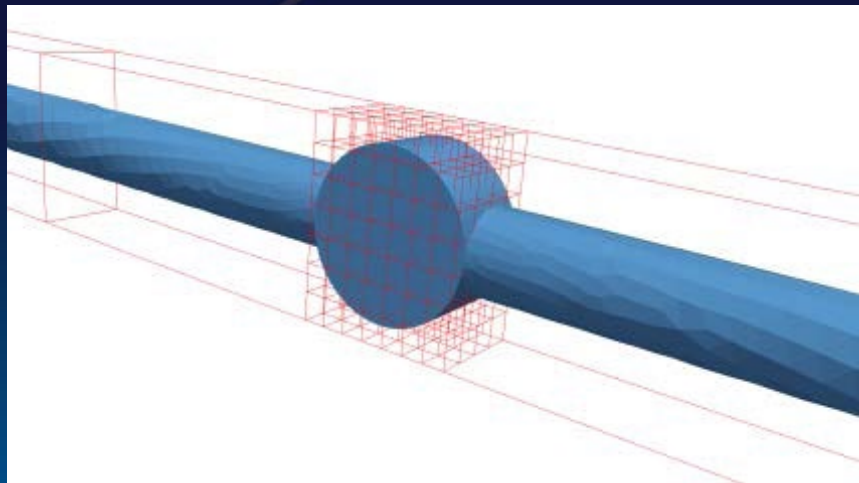
2.5D Impact with Fracture



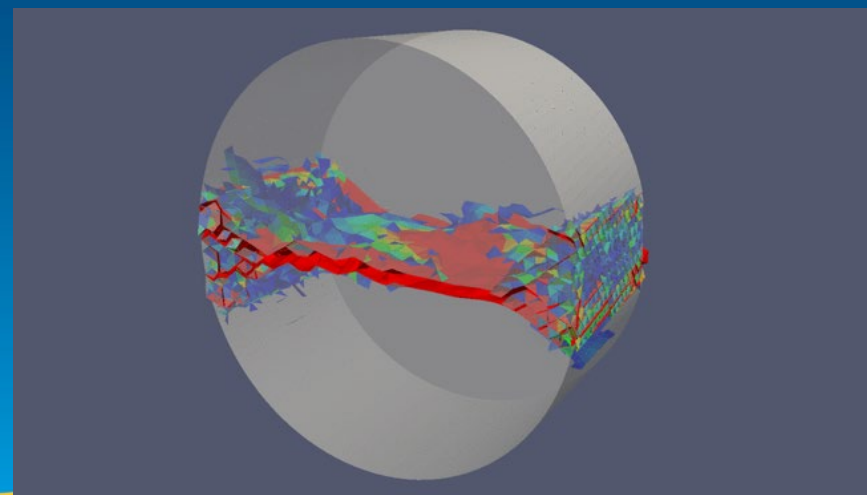
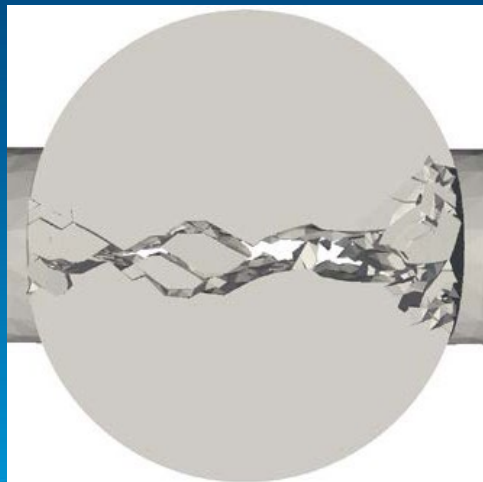
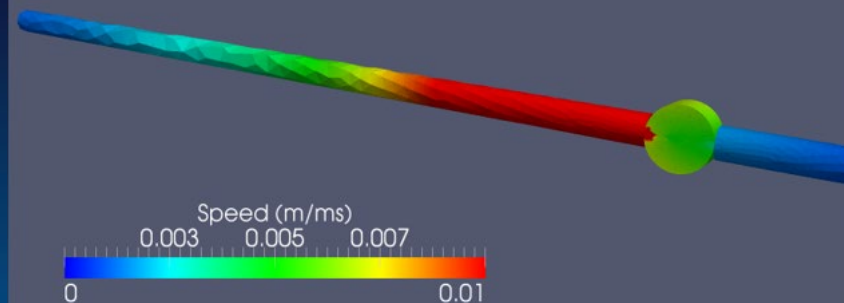
5 m/s, 2 layers solid-like shell elements

3D Fracture – SHPB Experiments

Validation of a three-dimensional finite-discrete element method using experimental results of the Split Hopkinson Pressure Bar test, Int. J. Rock Mech. Mining Sc. 70:101-108

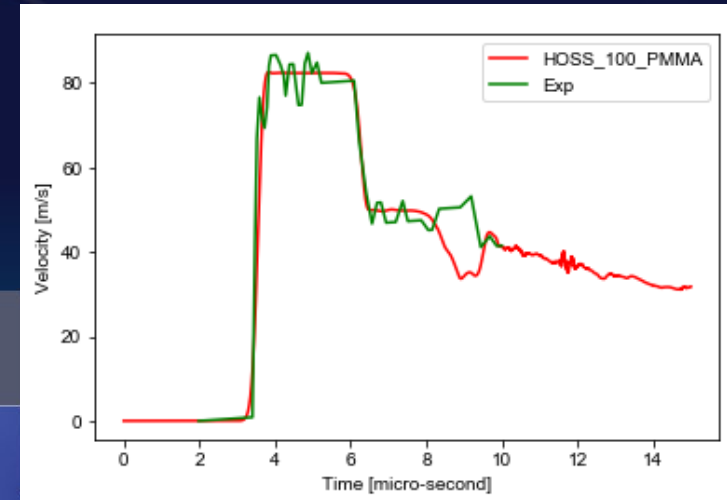


Animation of the Stress Wave



V&V: Geomaterial Flyer Plate Dynamics

Experiment data: Yuan & Prakash 2013, "Plate impact experiments to investigate shock-induced inelasticity in Westerly granite"



Aluminum

Granite

PMMA

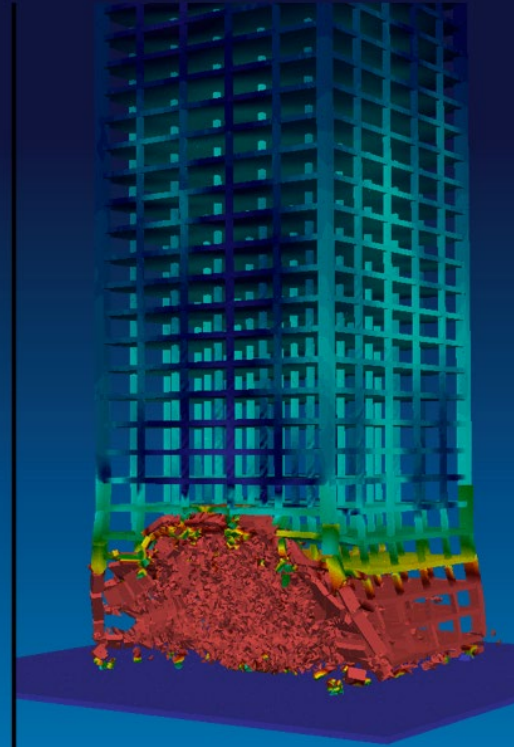
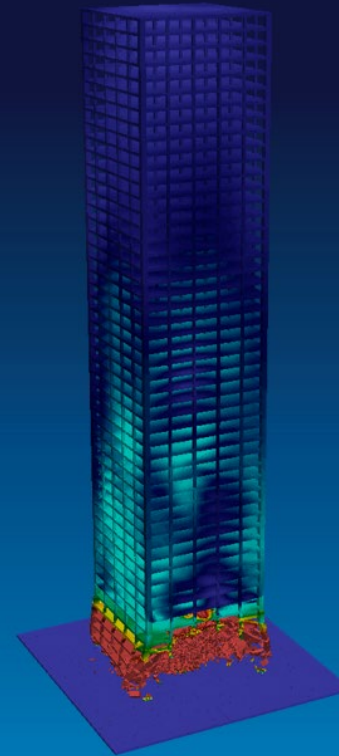
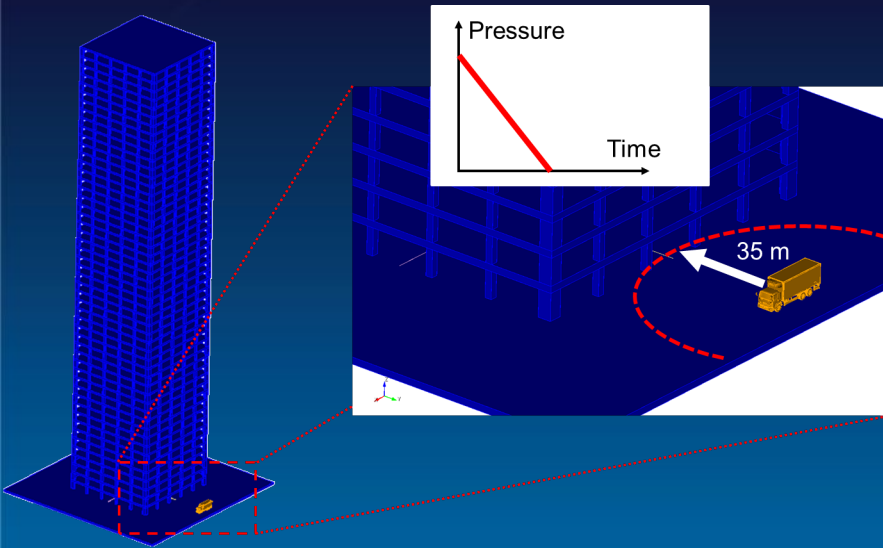
Westerly granite impact spall simulation (Impact Speed: 91.5 m/s)

9.1e-02
0.08
0.06
0.04
0.02
0.00e+00

Nodal Velocity Magnitude

For geomaterials the HOSS model also accurately captures the nonlinear effects

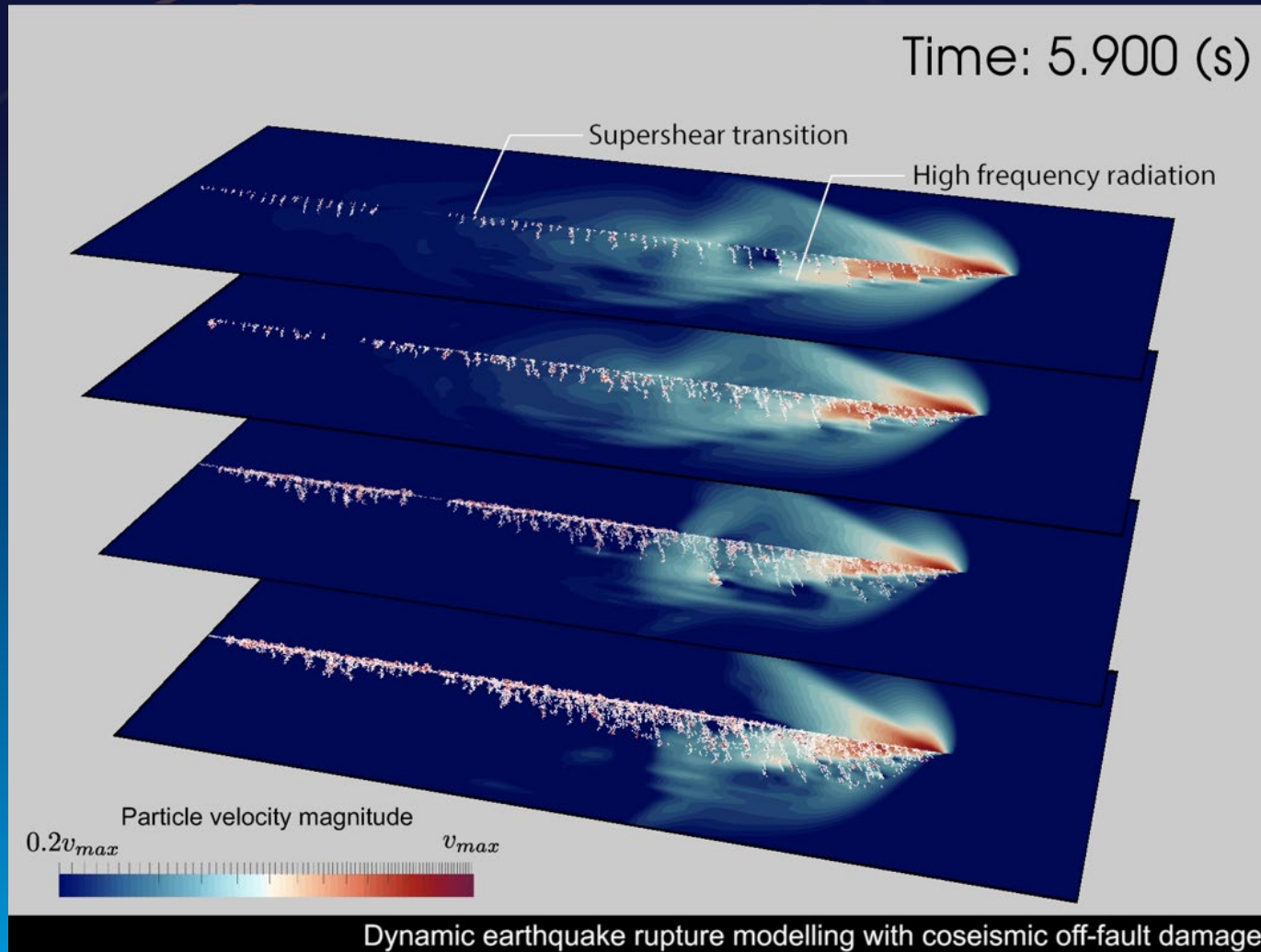
Modern Buildings



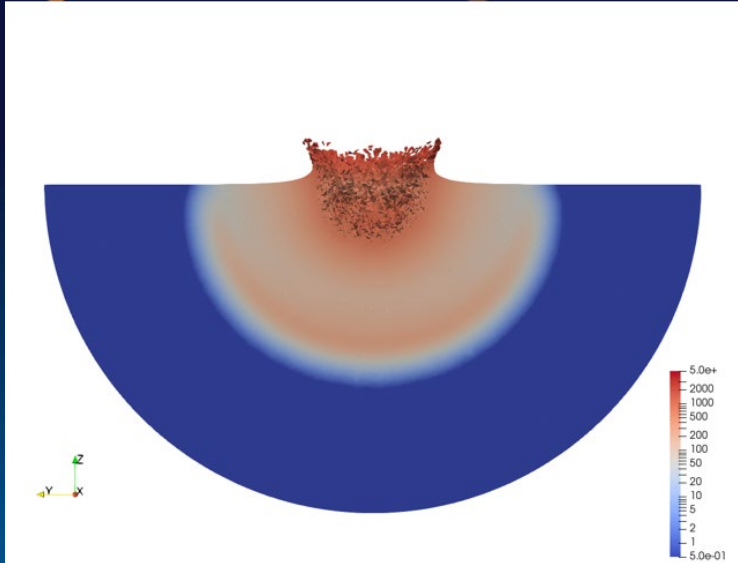
Setup

Animations

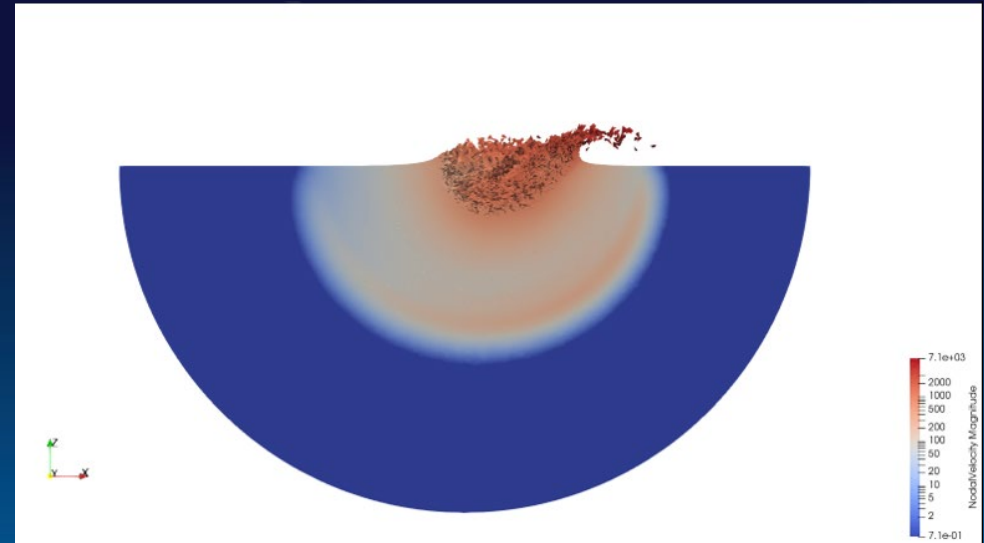
Large Scale Earthquake Modeling



Hypervelocity Impact: Asteroids



Vertical Impact



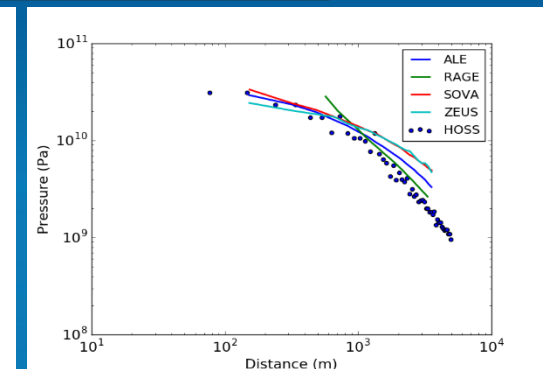
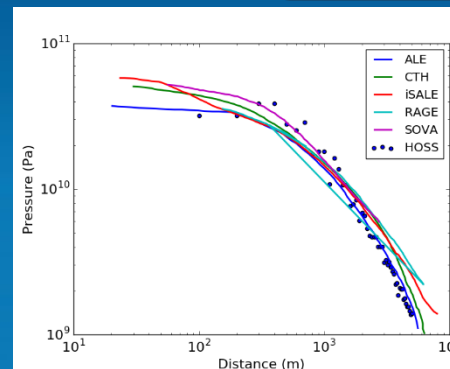
Slanted Impact

Model Size

- 2.4M Finite Elements

Simulation requirements:

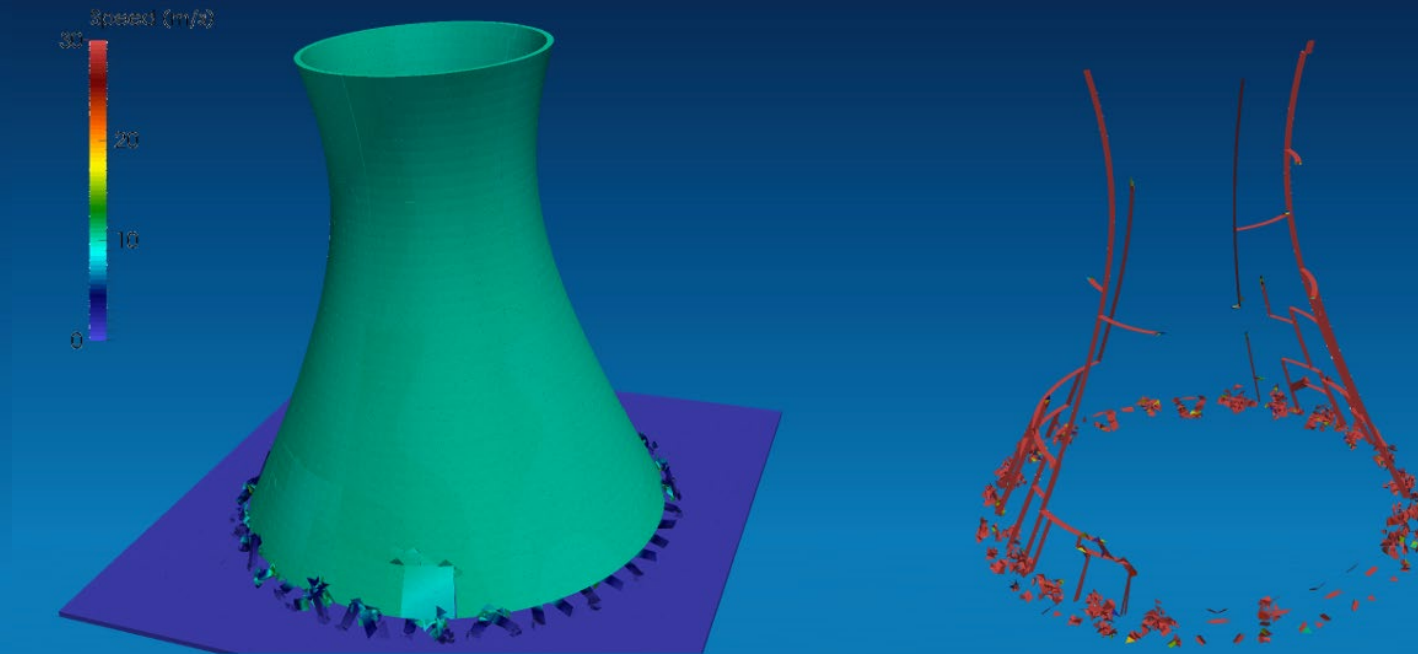
- 3250 processors
- 8:00:00 simulation time



Comparison against other hydrocodes

Natural Phenomena Hazards

- Monitoring, modeling, risk assessment, and hazard mitigation for national and international needs
 - Seismic hazards
 - Engineering seismology: Facilities Safety

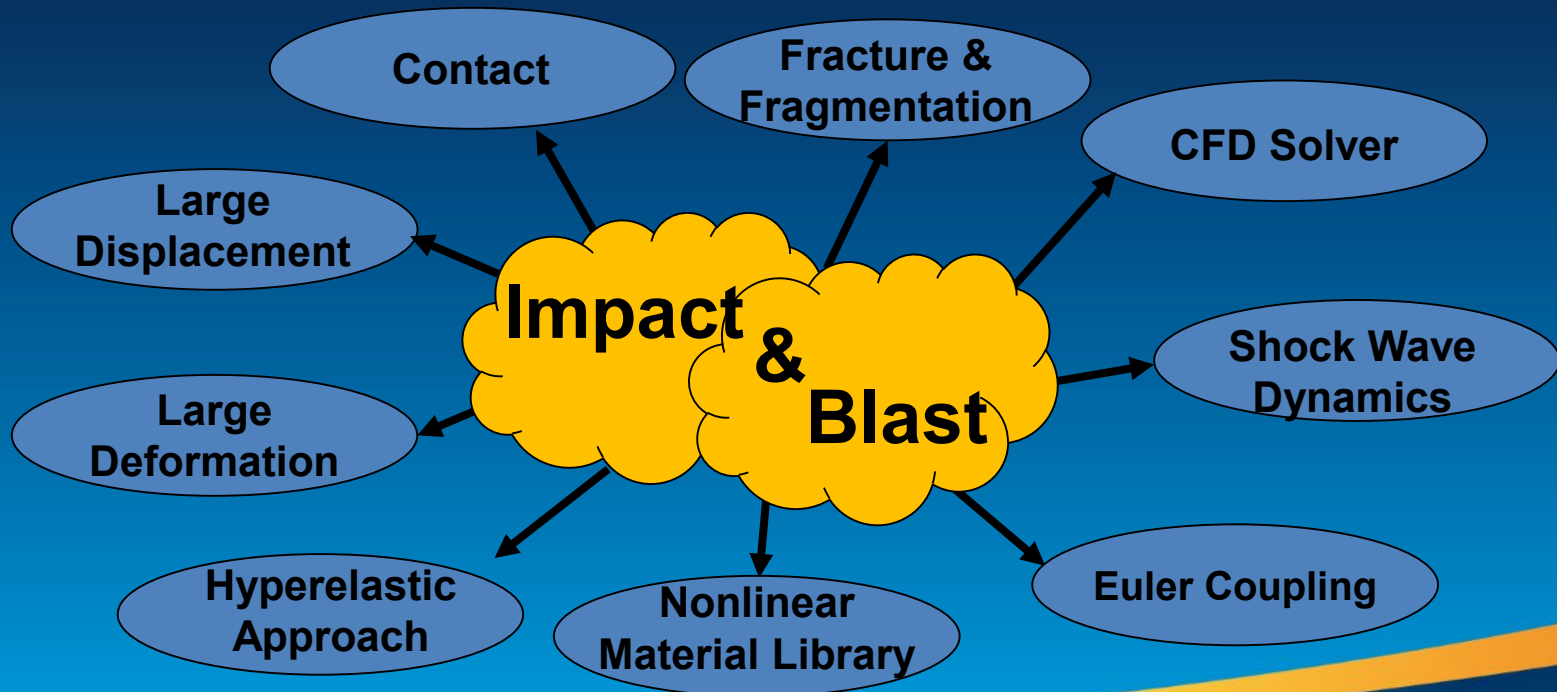


HOSS-FSIS

A Paradigm Shifting Technology

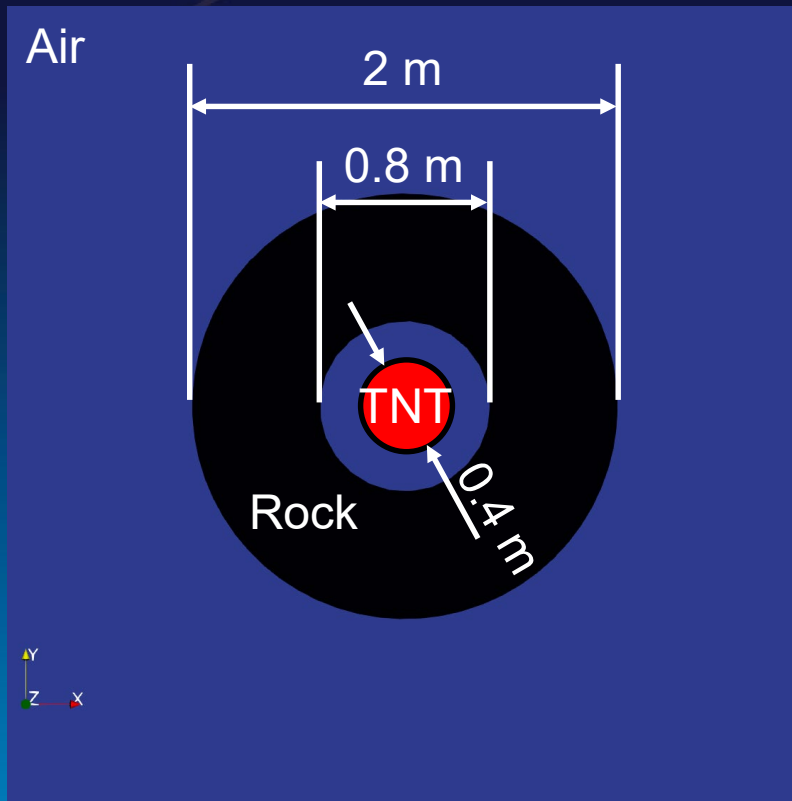
HOSS Fluid-Structure Integration Solver (FSIS):

A hybrid Eulerian – Lagrangian approach, which combines general purpose CFD solvers and start-of-the-art solid solvers, allows explicit representation of material failure (reinforced concrete, steel, rock medium, etc.) due to extreme fluid-induced loading conditions.



Fluid-Solid Interaction Solver (FSIS)

2D Decoupled HE Source



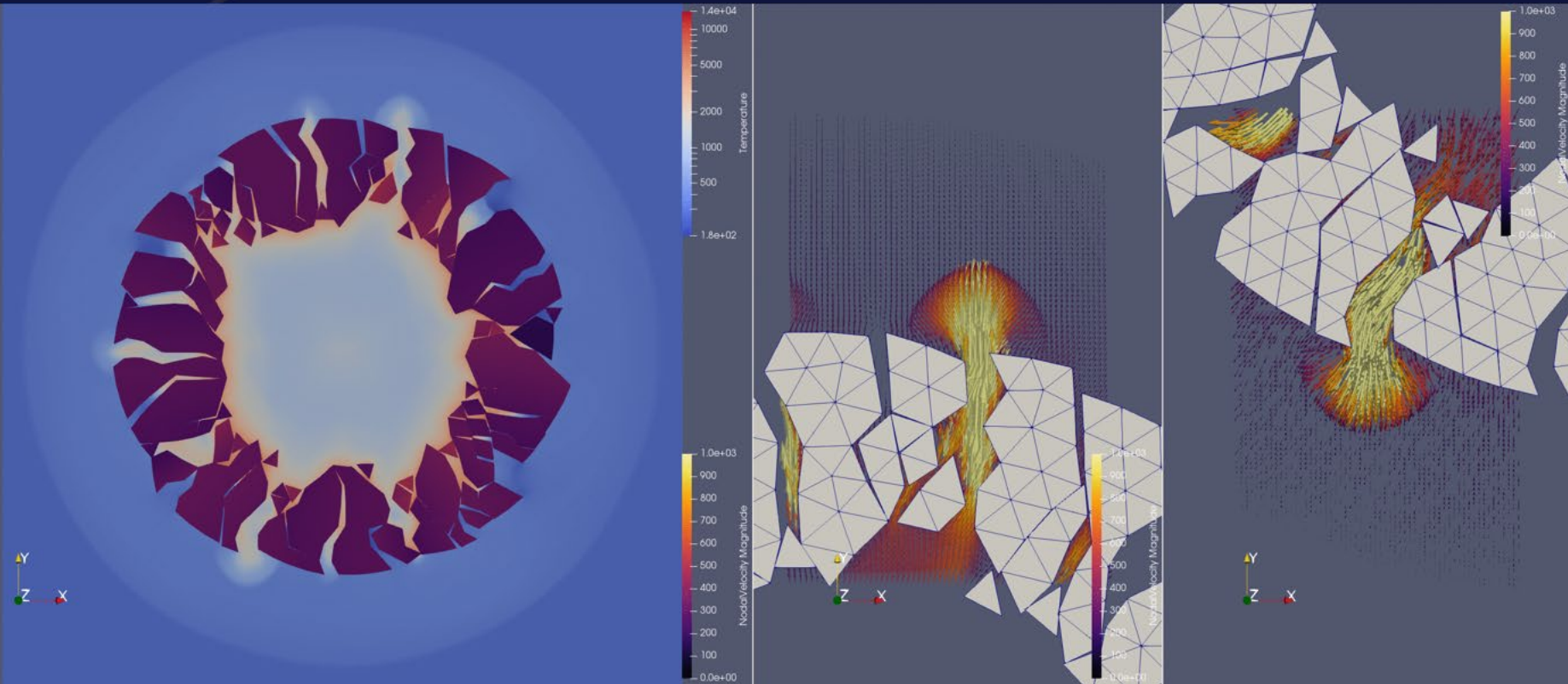
This simulation shows the capability of the newly developed HOSS-FSIS (Fluid-Structure Interaction Solver).

General Setup

- Decoupled source inside of a borehole
- Explosive internal energy similar to TNT
- Detonation done based on amount of work done on the cell

Fluid-Solid Interaction Solver (FSIS)

2D Decoupled HE Source



Temperature

Left panel: fluid temperature – Right Panels: zoom in of gas jetting out of the cavity

Summary

- HOSS is a multi-physics solver that has been applied to a wide range of programs and problems
- We have compiled a Special Issue on the Combined Finite-Discrete Element Method (FDEM) written by seventeen Universities and three government organizations from eight different countries that was recently published in the Computational Particle Mechanics journal:
<https://link.springer.com/journal/40571/volumes-and-issues/7-5>

Thank you for your attention!

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