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Title:	IM Hazards PA Materials Characterization Subgroup Planning for PA Extension
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IM Hazards PA Materials Characterization Subgroup Planning for PA Extension

US/UK Project Agreement Review Meeting

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This presentation outlines proposed plans that the US side of the Materials Subgroup of the US/UK IM Hazards Project Agreement (PA) wants to pursue for the time remaining in the original agreement and during a subsequent possible extension. Deficiencies in our current understanding of the important physics questions are highlighted and proposed experimental and theoretical solutions are presented for discussion.

IM Hazards PA
Materials Characterization Subgroup
Planning for PA Extension

Oct. 5-6, 2011

Sandia National Laboratories

Simple, two-dimensional test geometry

Fragment impact – FSP, Bullet, Sphere

ABVR

Penetration of the cover plate

Role of the bond layer

Fragment state after penetration event

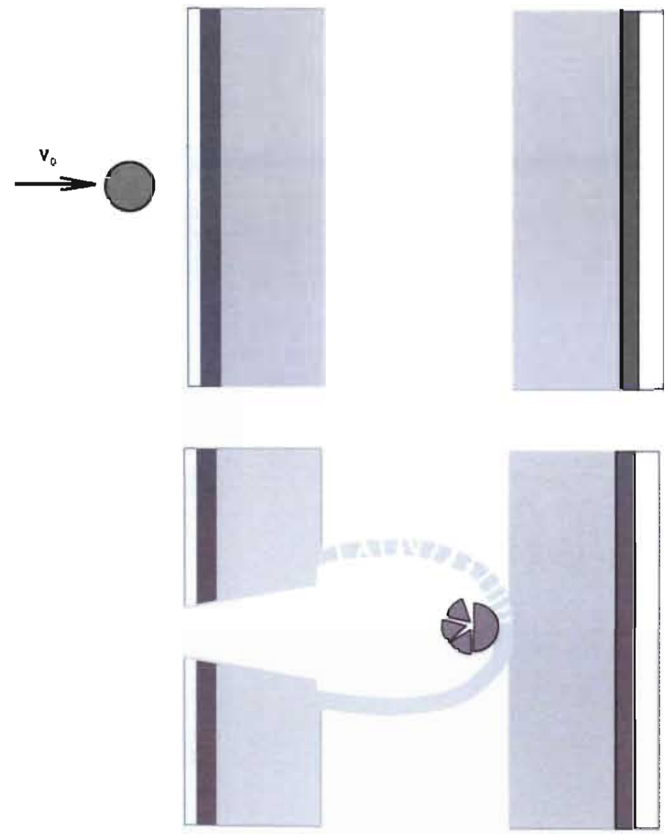
    hard/soft – extent of fragmentation

Penetration of the energetic layer

    elastic expansion and rebound

Formation of a cloud of energetic rubble

    timing, stress state, ...



State of the damaged energetic rubble

    density, size distribution, ...

Energy transfer at impact

Ignition source identification

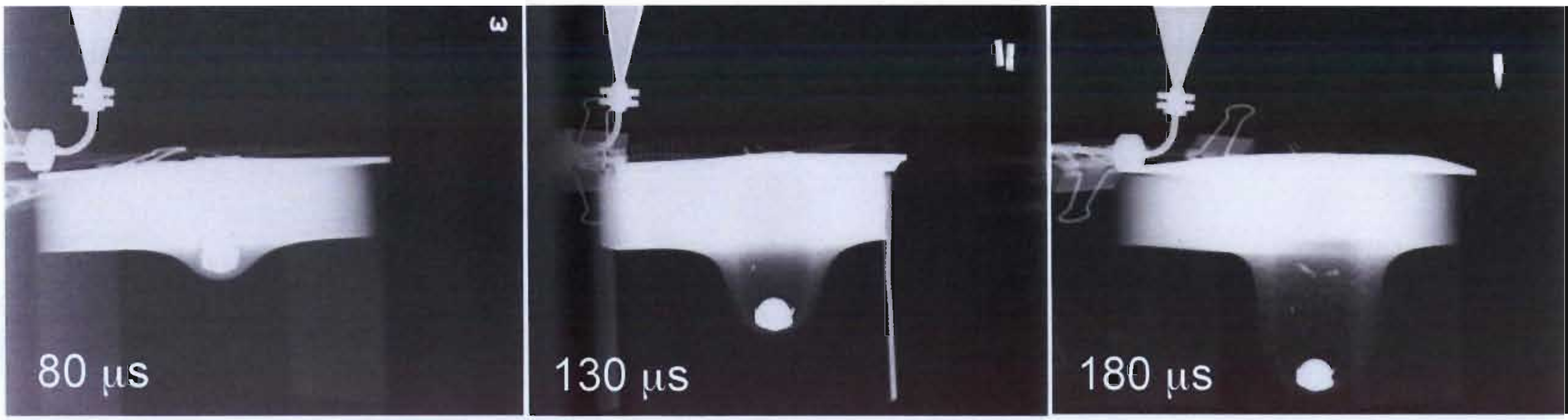
Materials Sub-group: HPP

- **Mechanical Model**
  - Use existing data to inform existing models in the RFG codes
- **Fracture and Fragmentation Data to support calibration of RFG models**
  - X-ray experiments using inert ABVR hardware – FIRE Project TCG-I
  - Further Taylor tests on HPP

Results from LANL Inert ABVR Experiments

Series of x-ray images reveals the evolution of fragment position and physical condition as a function of impact velocity

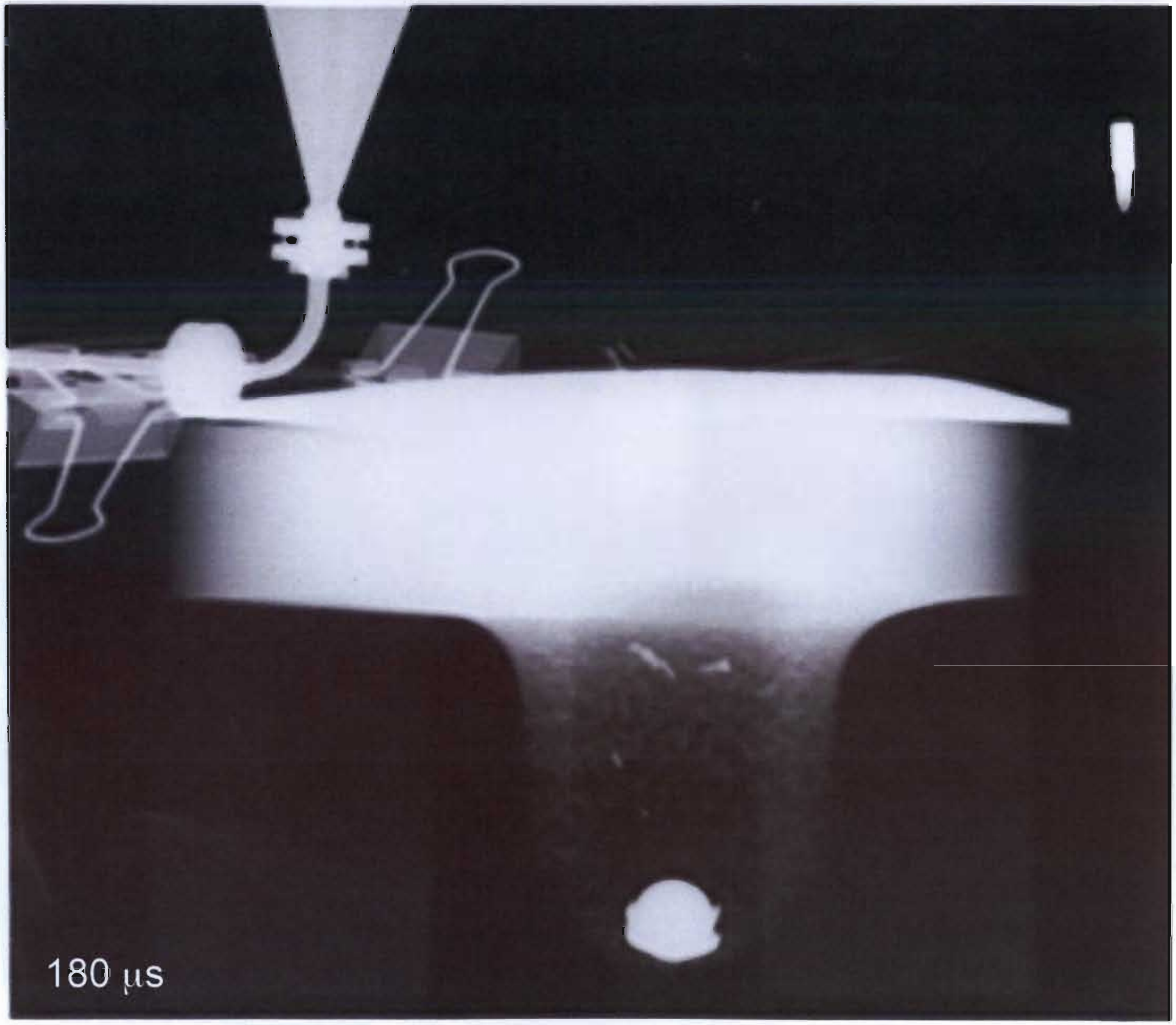
K12-18841 969 m/s (3177 ft/s) 440C sphere HPP mock



K12-18843 1344 m/s (4408 ft/s) 440C sphere HPP mock

Results from LANL Inert ABVR Experiments

K12-18841
969 m/s (3177 ft/s)
440C sphere
4130 cover plate
HPP mock



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NNSA

Results from LANL Inert ABVR Experiments

K12-18841
969 m/s (3177 ft/s)
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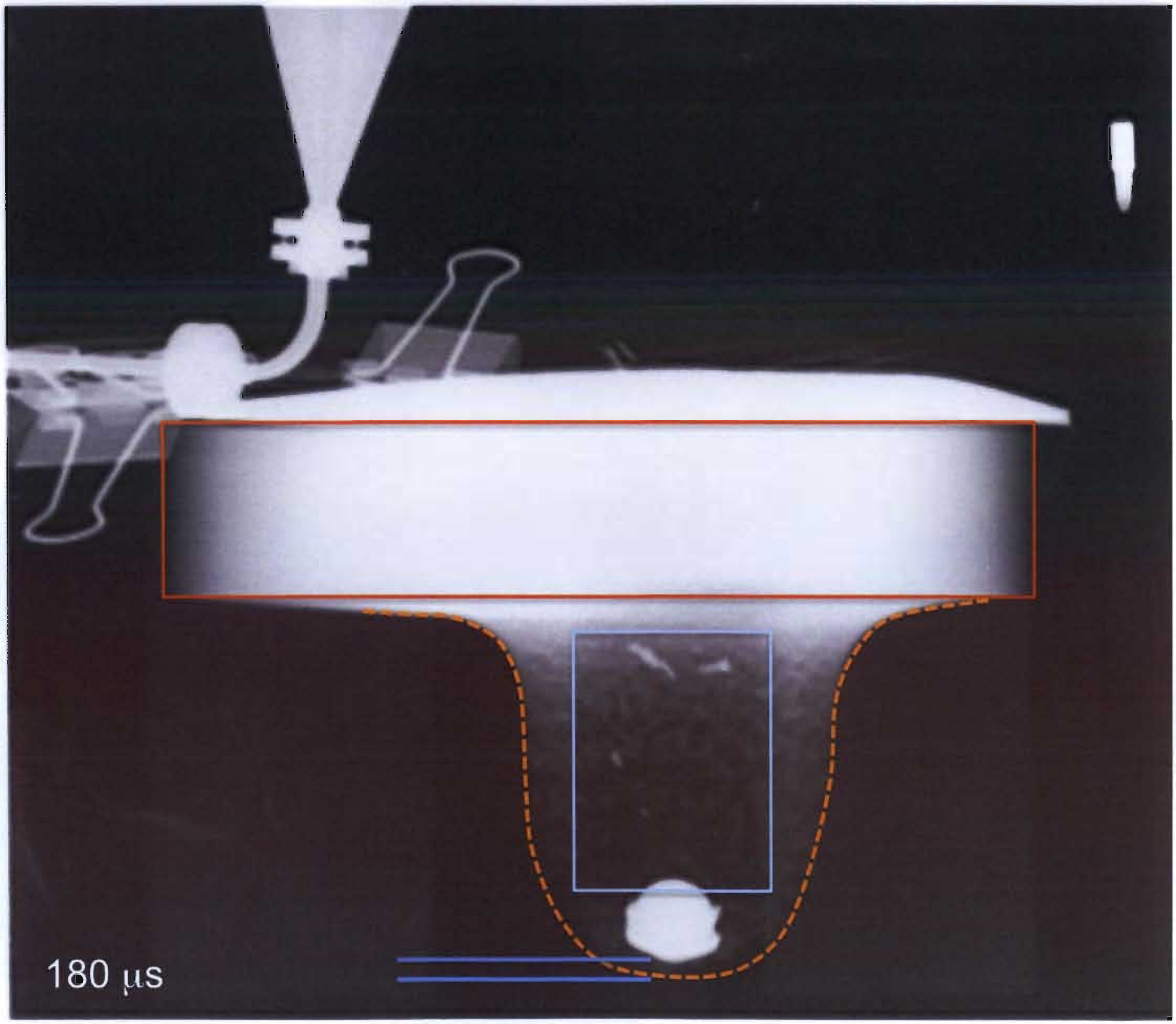
4130 cover plate
HPP mock



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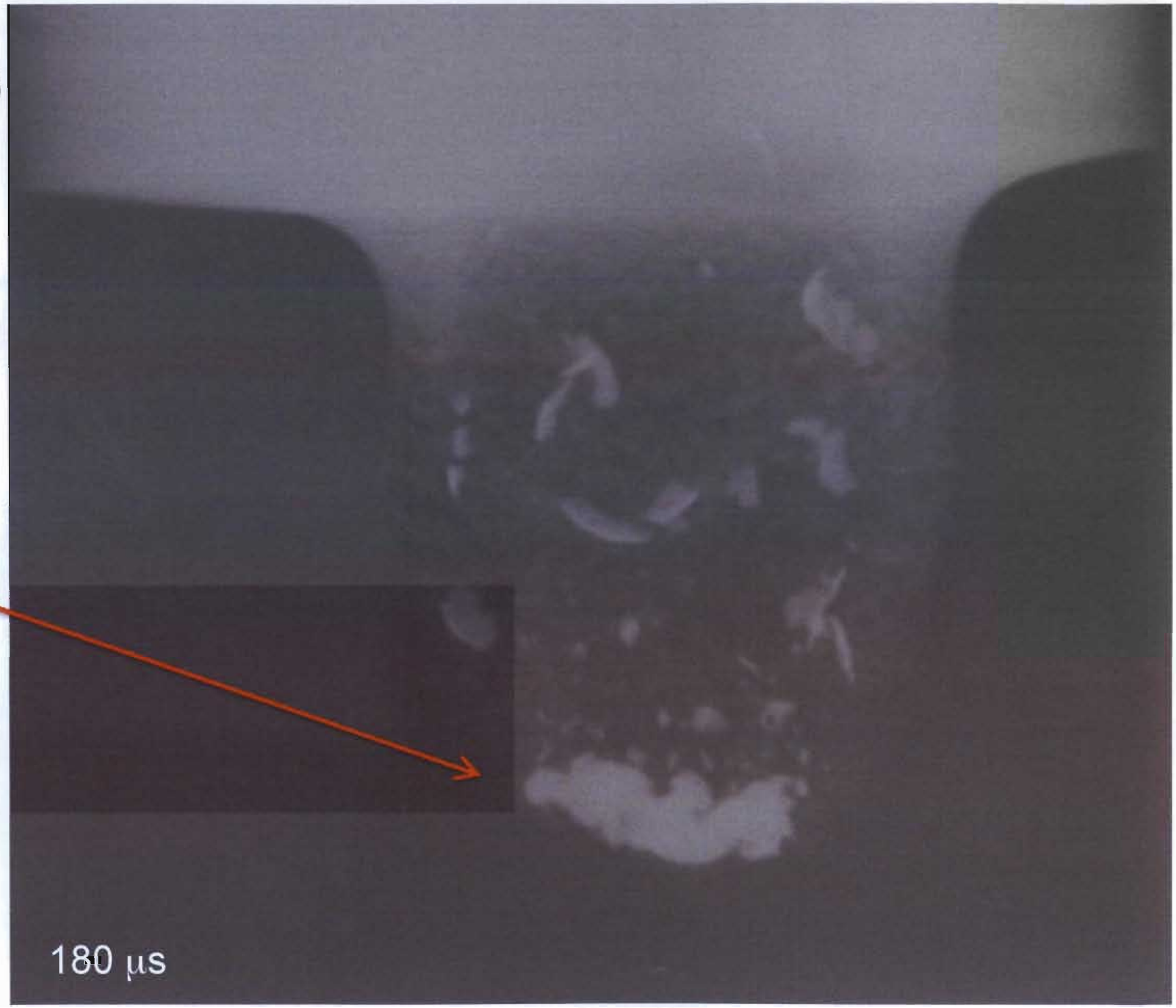
Results from LANL Inert ABVR Experiments

K12-18843
1344 m/s (4408 ft/s)
440C sphere
4130 cover plate
HPP mock

'less correlated' fragment



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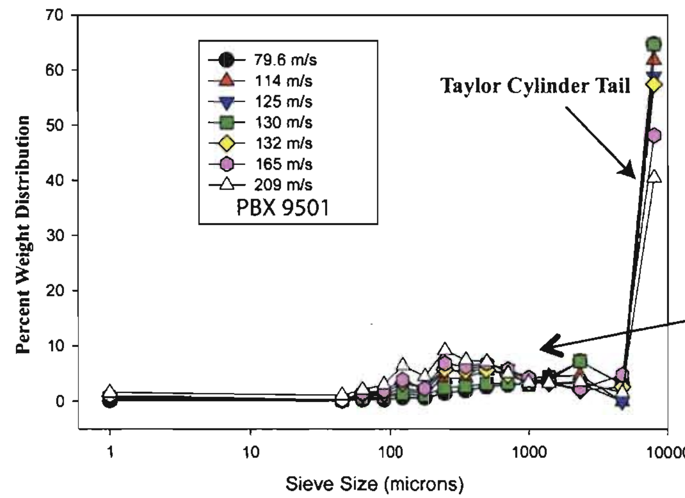
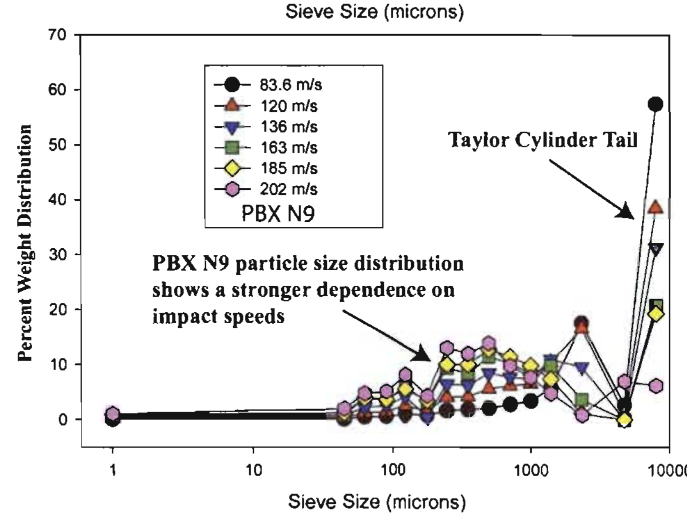
Visual and Quantitative Comparison of Powder and Fragments

PBX N9 PBX 9501



PBX 9501

Size distribution is rather insensitive to impact speed



PBX N9

Sieve analysis data collected by Jose Archuleta, WX-7

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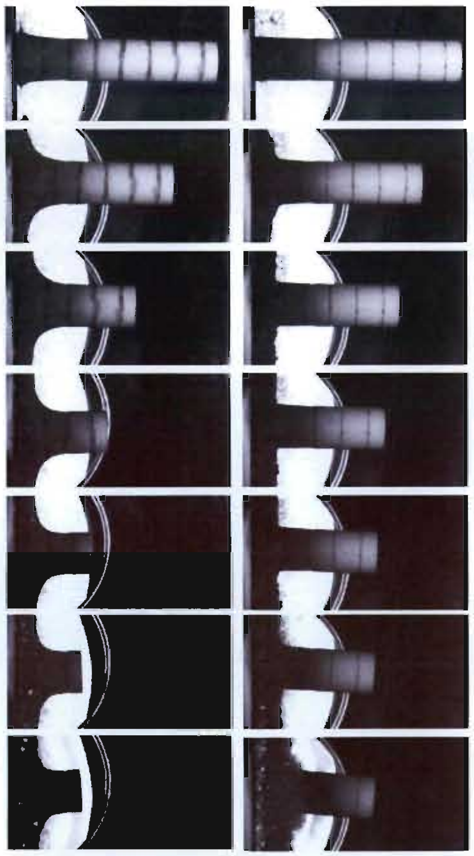
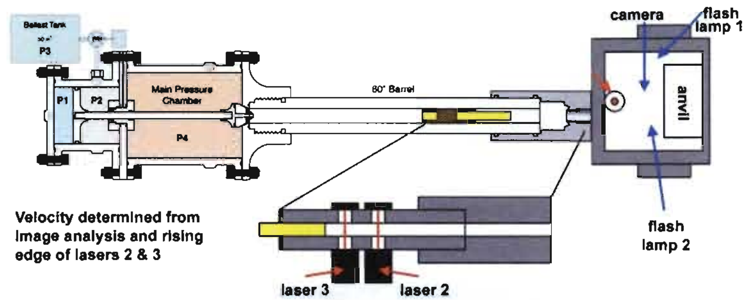
Taylor impact tests & simulations of energetics are being done to study high rate damage formation in unconfined geometries

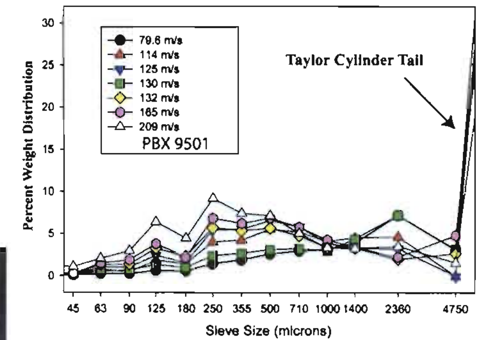
PBX 9501 (L) and PBXN-9 (R)
Impact velocity ~132 m/s

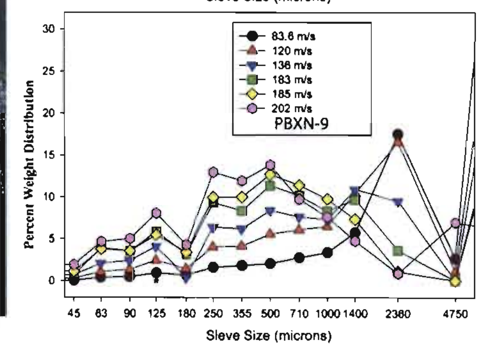




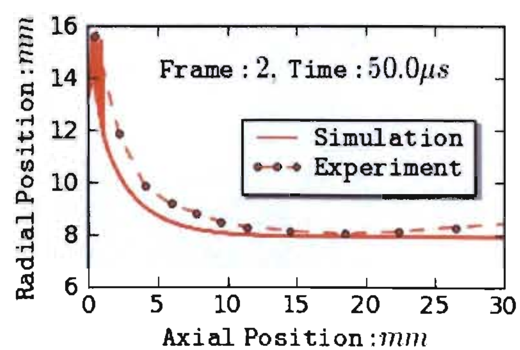
HPP

PBX N9 PBX 9501





Taylor Impact
Experiments & Simulations
(cylinder profile for PBXN-9).



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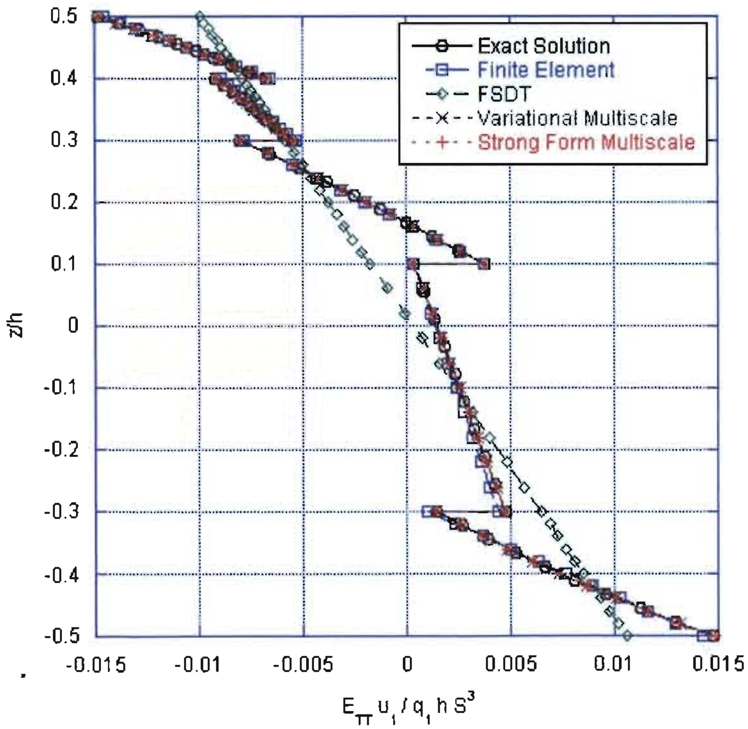
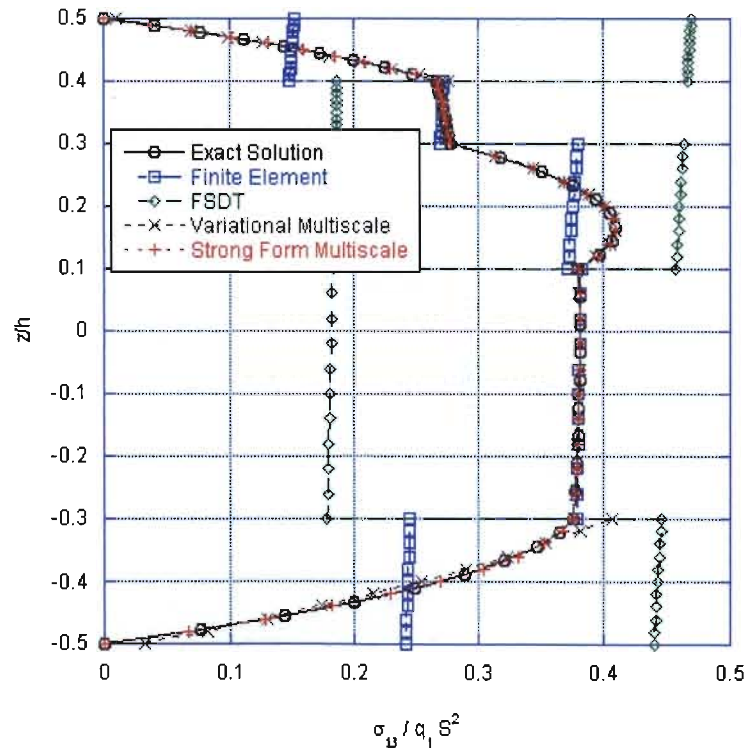
Global-Local Plate/Shell Theories applied to Composite Case

- Predicts the system response based on a direct analysis of underlying (smaller scale) structure and the constitutive behavior of the individual materials/phases in the system
- Important Characteristics
  - Provides average AND detailed local responses
    - Directly accounts of smaller length scale structural influences
    - Naturally captures the influences of the extremes in the local responses
    - Can incorporate statistical effects naturally
  - Fewer *a priori* assumptions about relevant physics – many aspects of physics naturally and directly incorporated due to consideration of underlying structural features
    - More forgiving if physics changes – No reformulation

Global-Local Plate/Shell Theories applied to Composite Case

- **Delaminated cross-ply plate composed of elastic Gr/Ep composite**





Materials Sub-group: Other Future Work

- Fragment impacts on covered energetics with and without buffers
- Small scale impact experiments on mock HE to validate HE models
- Data on rubber-tearing failure relevant to HPP
- Shock-shear investigations on PBX 9501
- Henson kinetics into ViscoSCRAM
-

Data on rubber-tearing failure relevant to HPP

C. Liu (MST-8, LANL) & D.G. Thompson (WX-7, LANL)

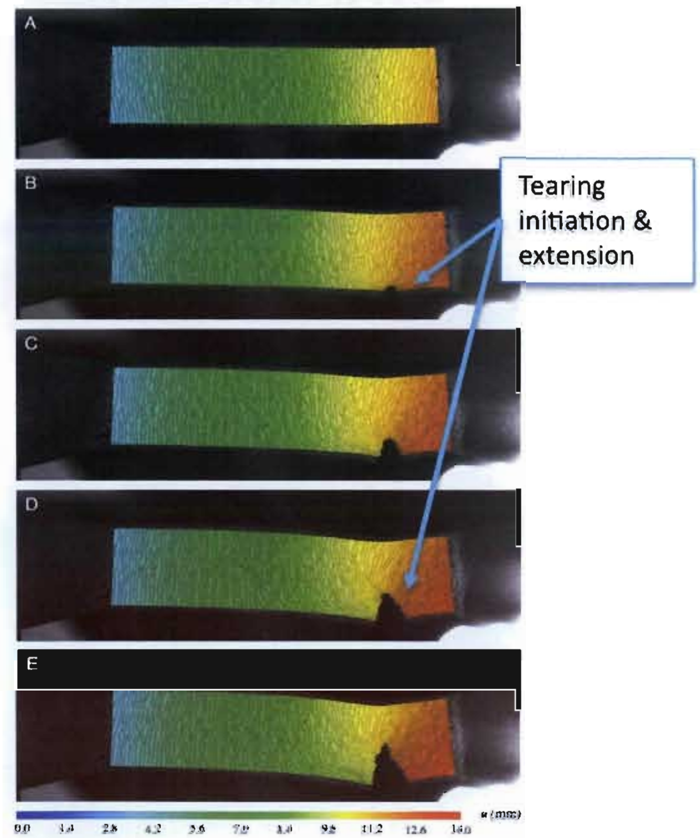
One remaining issue:

- *Quantitative description and modeling of the mechanical failure process in HPP.*

Some preliminary observations:

- Tensile tearing is the failure mechanism observed in HPP, as illustrated by the sequence of images on the right.
- It is observed in all test temperatures, from cold to warm.
- It has also been observed in simple shear.
- Compared to the failure process in other energetics (brittle or quasi-brittle), the tearing process in HPP is relatively slow.
- Our current testing capability can capture the detailed field evolution in front of the notch.

Tearing process during uniaxial tension of HPP



Suggested further investigations:

- Quantitative experimental measurement of tearing initiation & propagation subject to different loading mode mixities .
- Quantitative modeling of the failure process in HPP (e.g. using the theory of Hyperelasticity with Softening by Volokh).

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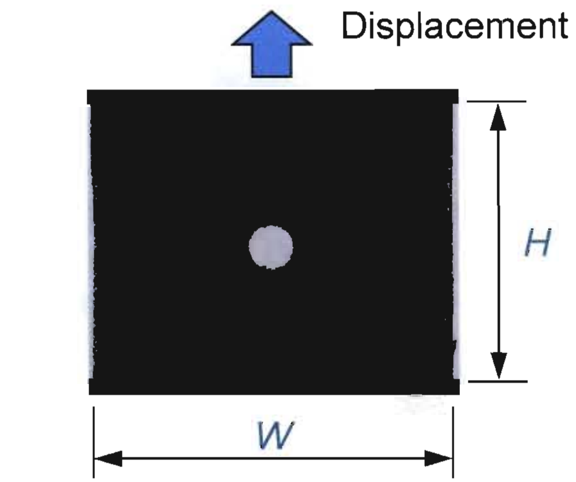
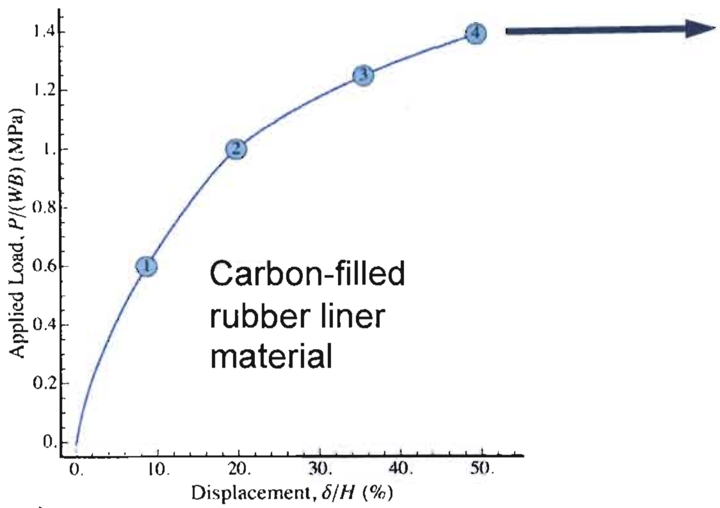
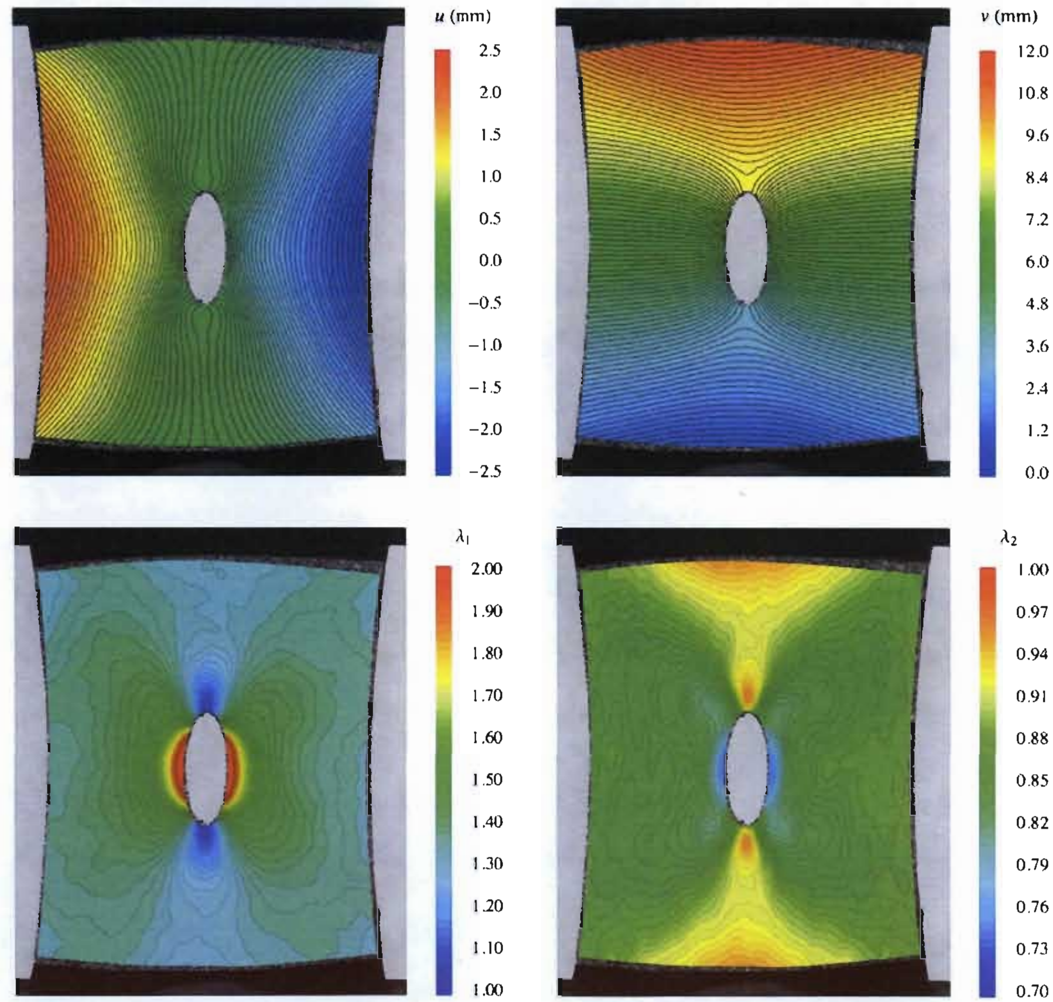
Thin Rubber Sheet with a Circular Hole Subject to Tension







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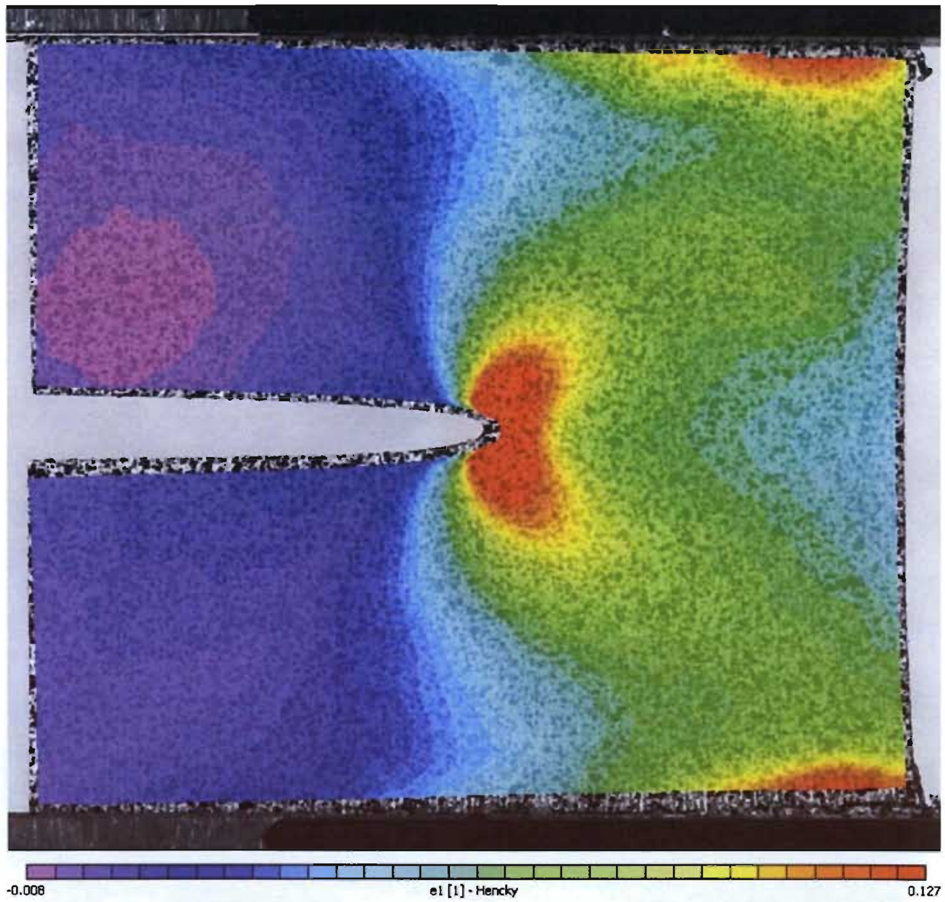
- Fields of displacements and principal stretches are presented.
- Tearing failure eventually starts from the hole boundary and extends perpendicular to the loading direction.
- Modeling challenges: Large deformation (several hundred percent strain) and the process of tearing failure.

Notched Crack Growth in HPP



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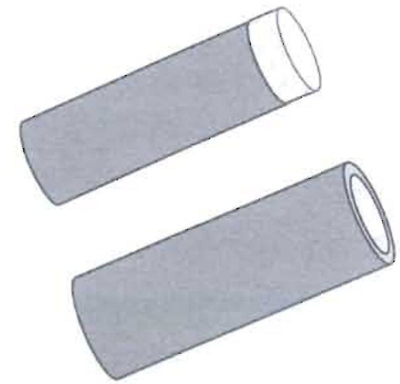
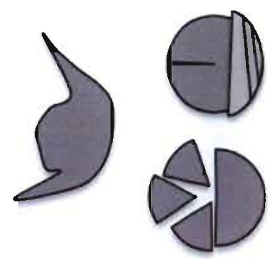
Material Sub-group Possible Future Work – requires JMP leadership support



- 'Engineered' Taylor/Shotgun impacts
- Study on the role of back tamping / 'cut backs'
- X-rays of 'soft' steel sphere impacts
- Liner and Insulating layer polymer models



- Henson model in CHARM
- Small scale testing:
  - ball impact experiments
  - Shock/shear
- Particle Methods
- *(See slides lining up JMP and UK work)*