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Title: IM Hazards PA Materials Characterization Subgroup Accomplishments

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Oct 5-6, 2011
Sandia National Laboratory

Los Alamos NATIONAL LABORATORY EST. 1943

IM Hazards PA Materials Characterization Subgroup Accomplishments

US/UK Project Agreement Review Meeting

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This brief presentation covers the accomplishments of the US side of the Materials Subgroup of the US/UK IM Hazards Project Agreement (PA) for the time frame covered under the original agreement. Mention is made of the metals and energetic materials that have been characterized in this effort. This presentation also outlines a number of unresolved technical issues and suggests a path forward for addressing these issues.

Of particular interest is our continued uncertainty regarding the operative physics relating the material properties of the fragments and cover plates to the fragmentation behavior of the interior propellant layers. Additionally, there is concern that the propellant material properties are not adequately characterized.

IM Hazards PA
Materials Characterization Subgroup Accomplishments

Oct. 5-6, 2011

Sandia National Laboratories

LA-UR 11-

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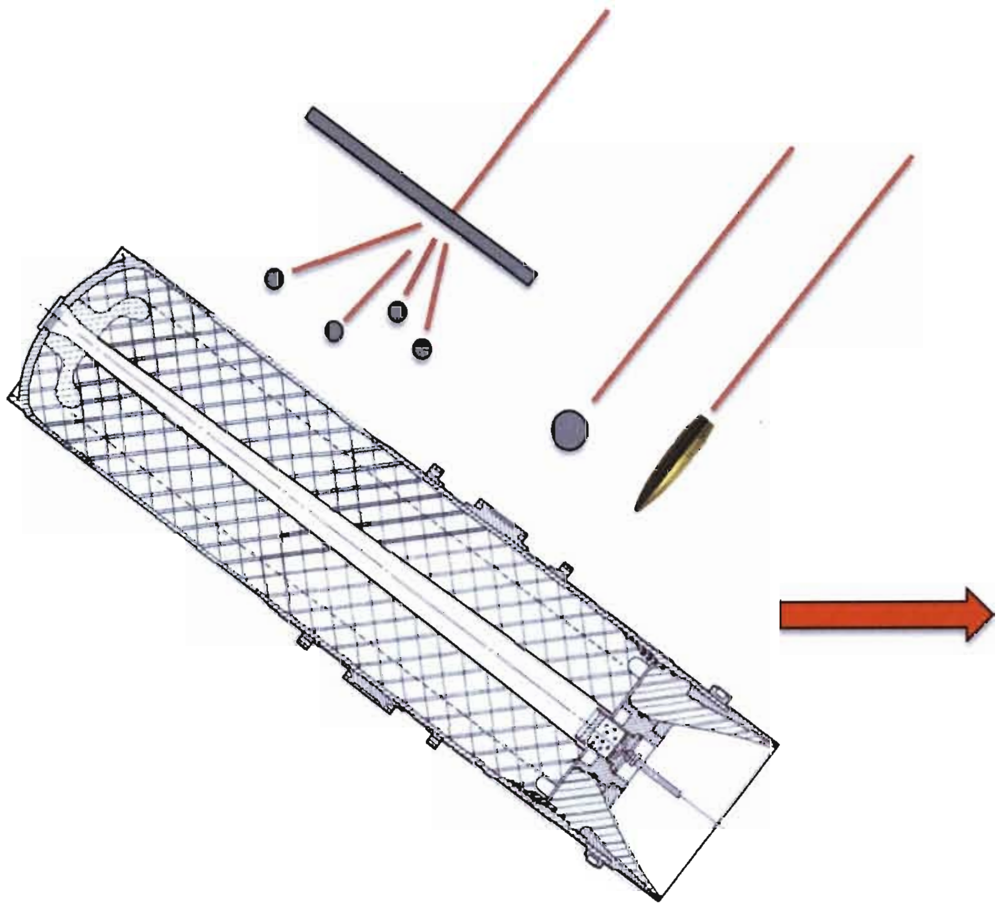
Materials Characterization Accomplishments – US Efforts to Date



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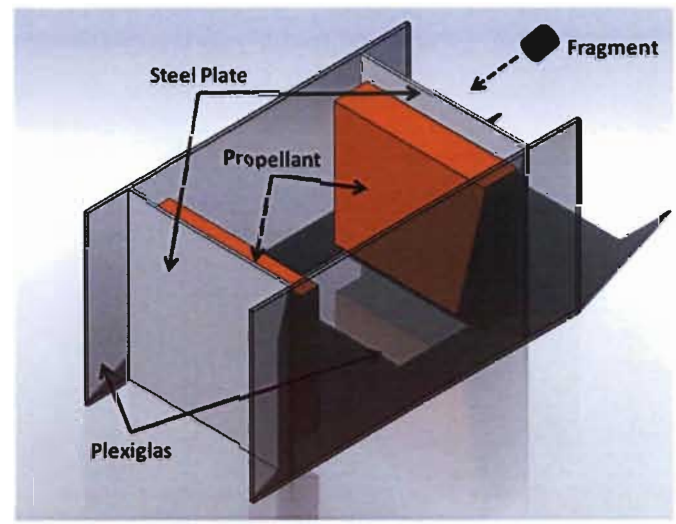

Navy Burn-to-Violent Reaction Tests

A Planar Rocket Motor Model for Visualization of Violent Reaction Due to Fragment Impact, S.A. Finnegan, et al., NW TCP 7074 May 1990

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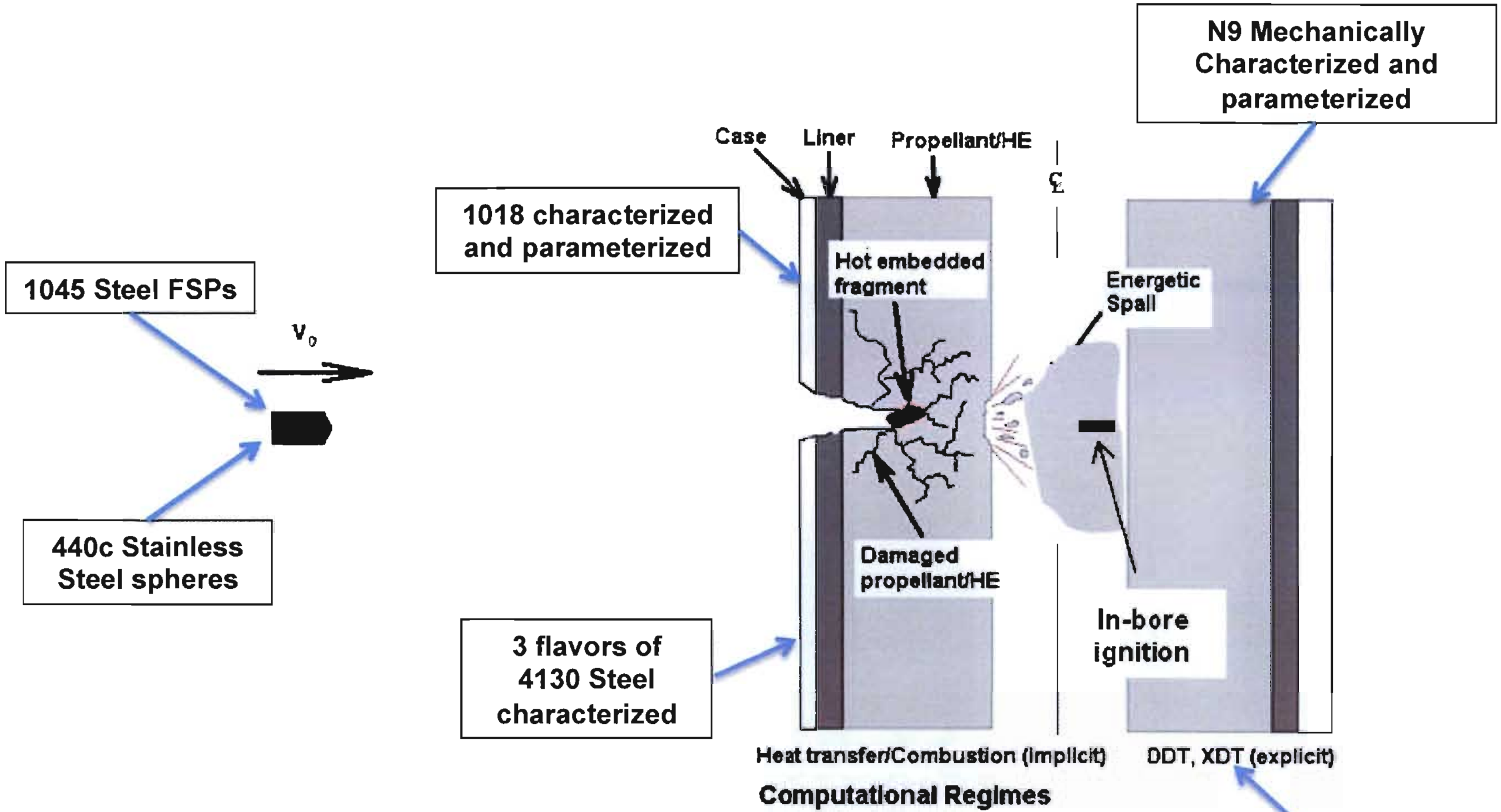
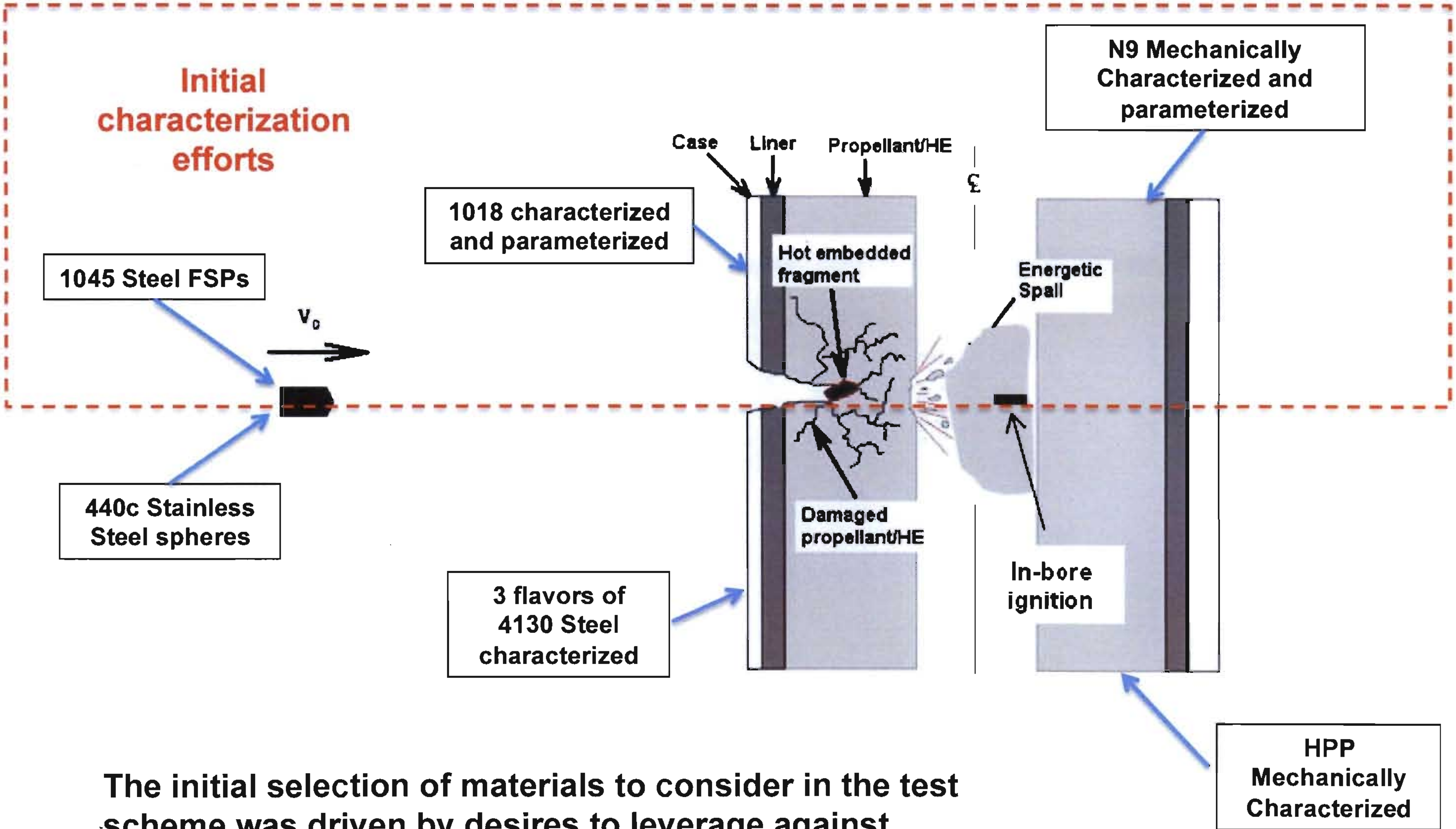
Materials Characterization Accomplishments – US Efforts to Date



Example of the preliminary identification process of the operative physics and what materials needed to be characterized to facilitate the modeling efforts.

Materials Characterization Accomplishments – US Efforts to Date



The initial selection of materials to consider in the test scheme was driven by desires to leverage against STANAG requirements and legacy research efforts.

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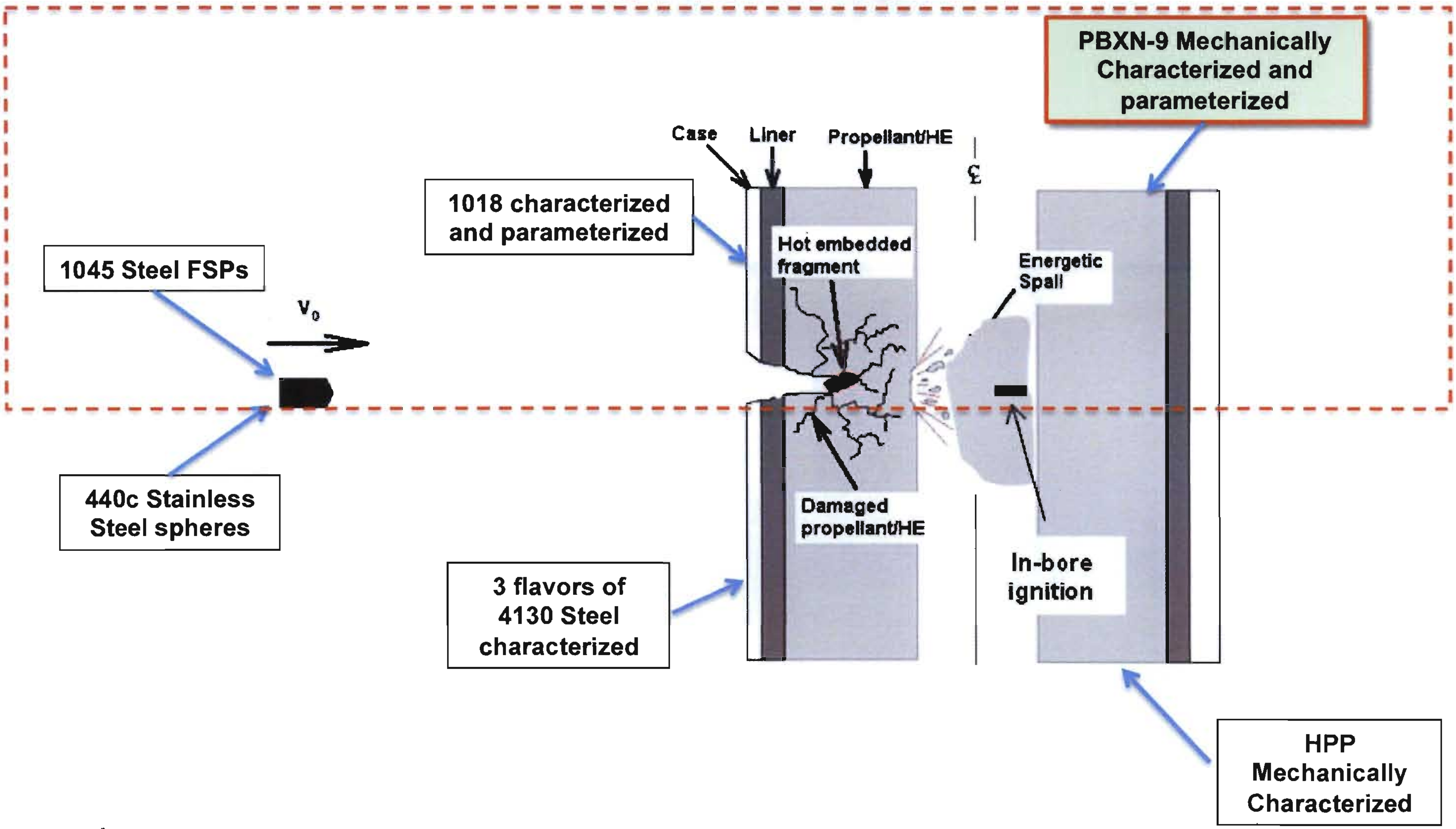
Materials Characterization Accomplishments – US Efforts to Date



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PBXN-9 Characterization Effort

- 62 page report
  - Mechanical Properties Characterization
  - Fracture Characterization
  - Shock Behavior and Initiation
  - Theory, Modelling and Simulation
- DSC, TGA and ODTX for developing a chemical kinetics model
- DSC/TGA also performed on constituents DOA & Hytemp to explore effects of binder/plasticizer on thermal response
- Measure high pressure burn rate in pristine and thermally-damaged conditions to explore influence of HMX β-δ phase transition on deconsolidative burning
- STEX (Scaled Thermal Explosion eXperiment)
  - With/without ullage (allows/prevents β-δ phase transition)
- SITI Experiments
- Z experiments at 20C, 55C, 100C, 155C

Parameters developed for PBXN-9

- Three-term Ignition & Growth reactive flow model for PBXN-9
- ViscoSCRAM parameters determined for PBXN-9
- HVRB model parameters determined

Validation Efforts

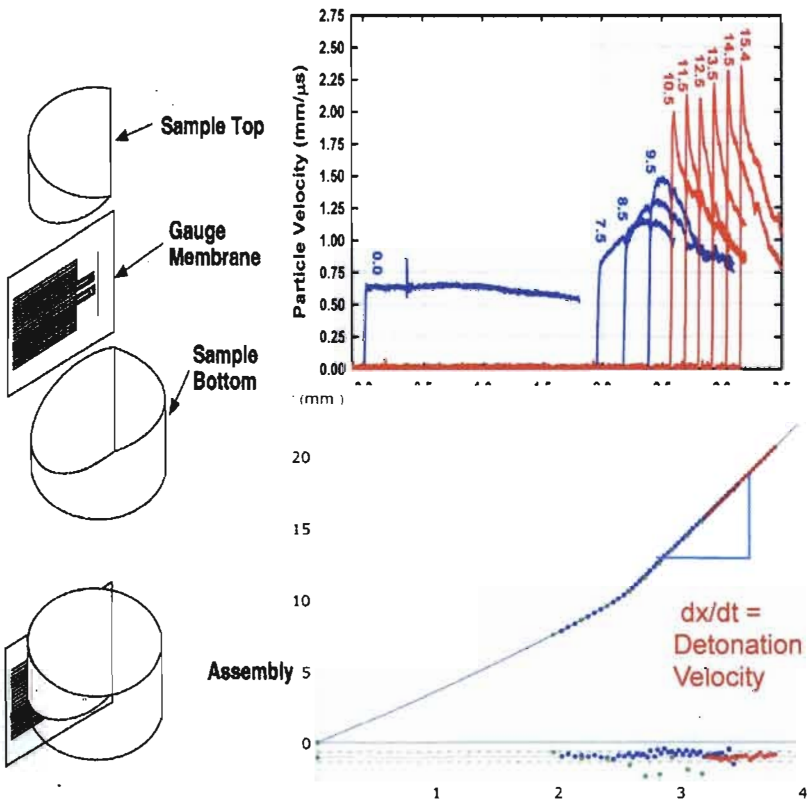
- Pre-/post-test simulations of PBXN-9 SMIS tests
- ViscoSCRAM validated against Taylor Tests

PBXN-9 Characterized, parameterized, and new Pop-plot generated

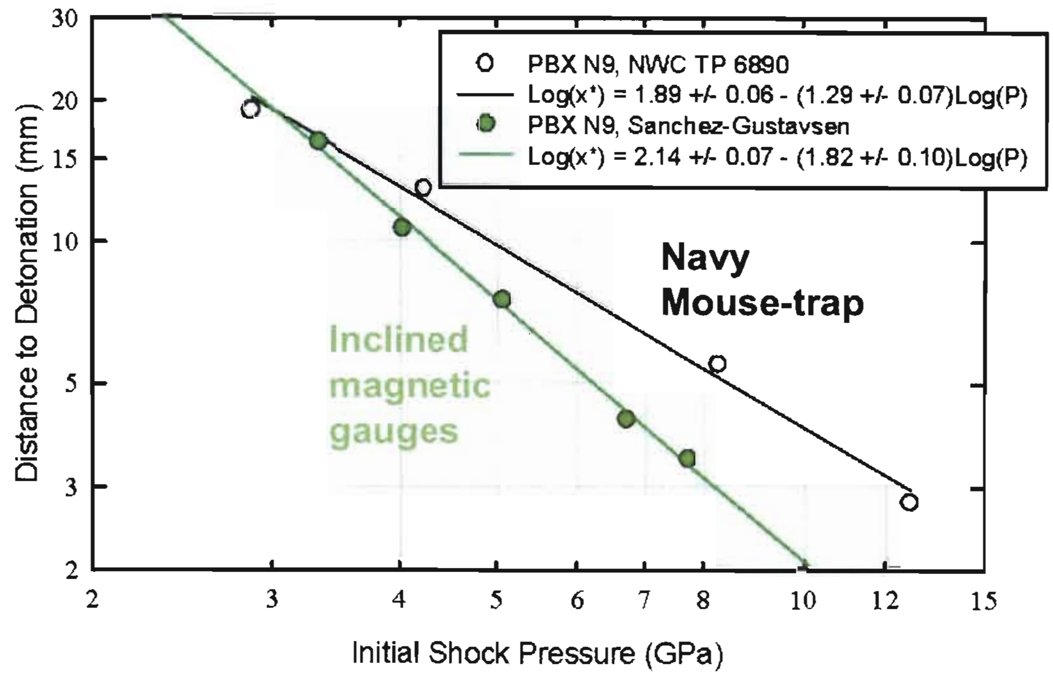
PBXN-9 Characterization and Model parameterization & validation

Redirection to PBXN9 led to a L2 milestone and DP award of excellence

New PBXN-9 Pop-plot shows a more sensitive response than historic data



PBXN-9 pop-plot



Us = 2.32 + 2.21 Up - updated Hugoniot

updated run-to-detonation - log(X) = 2.14 – 1.82 log(P)*

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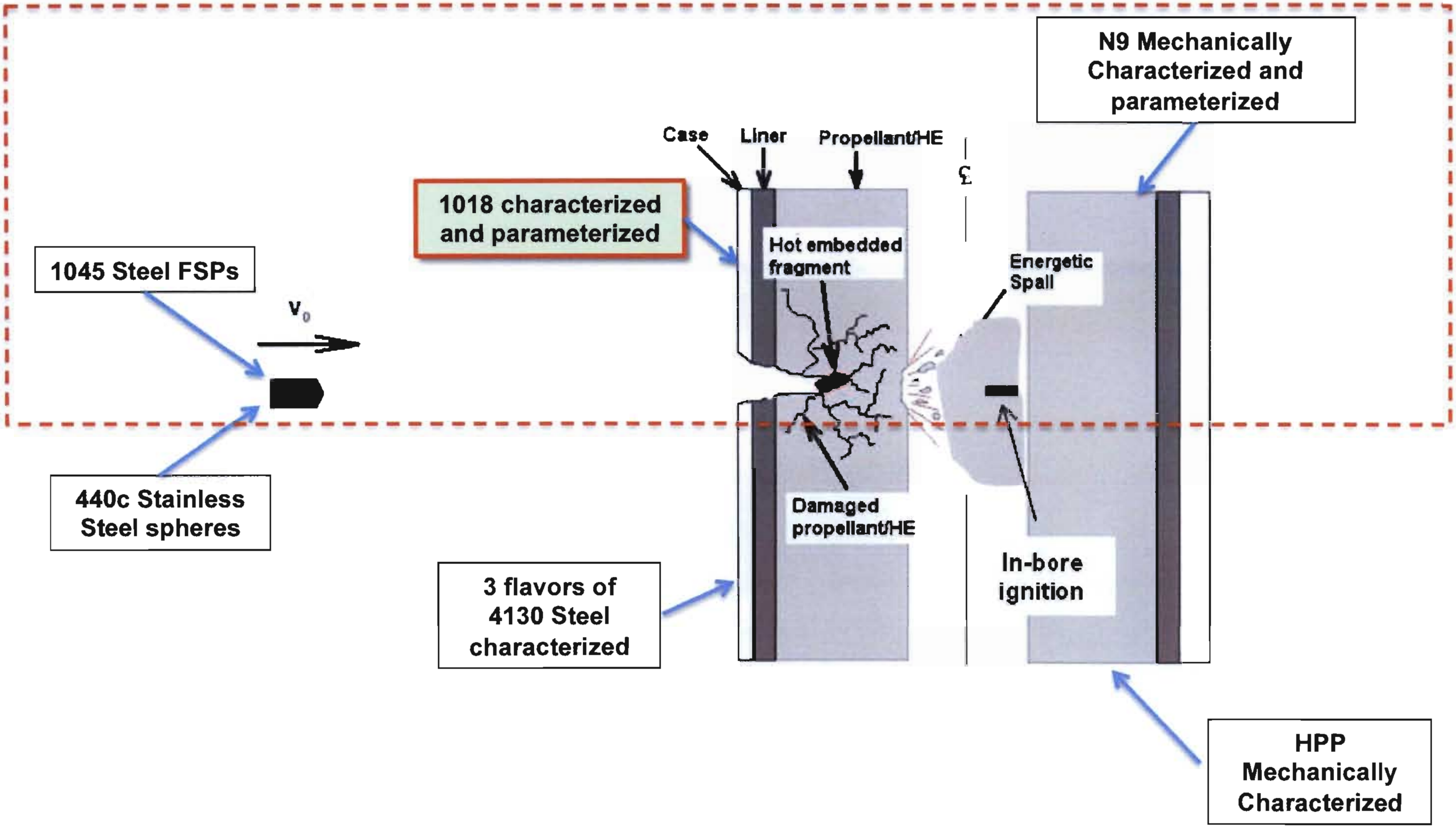
Materials Characterization Accomplishments – US Efforts to Date



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AISI 1018 steel was originally chosen as the cover plate and projectile material

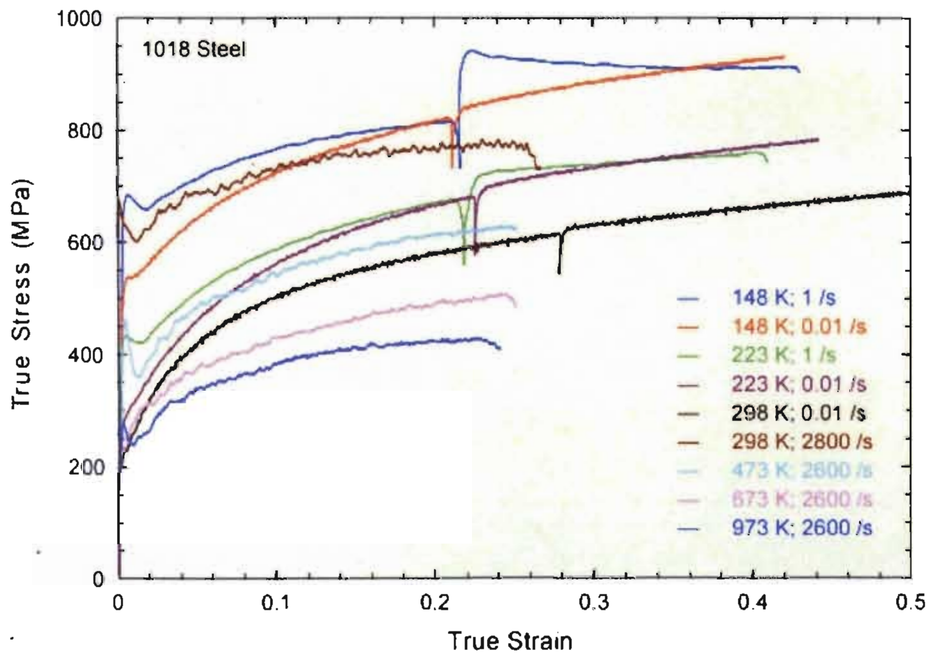
Characterization Experiments

- **Quasi-static testing**
- **Notched tensile Split-Hopkinson Pressure bars**

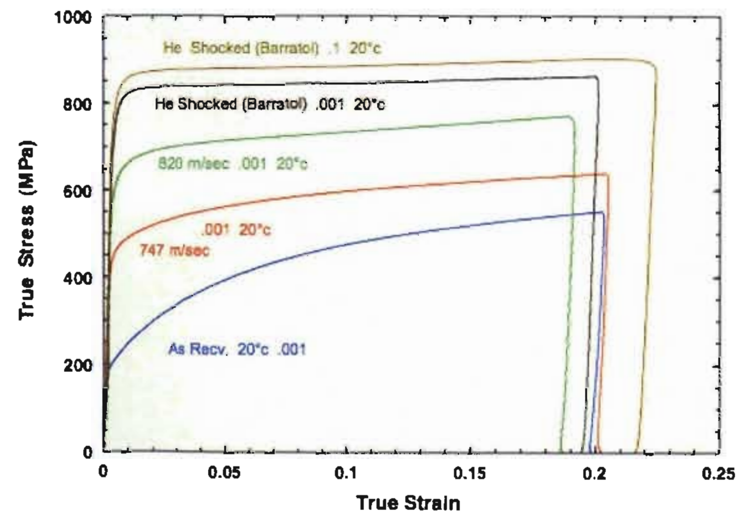
Johnson-Cook and MTS parameters determined

Used in SMIS testing and simulations

Smooth and notch bar testing

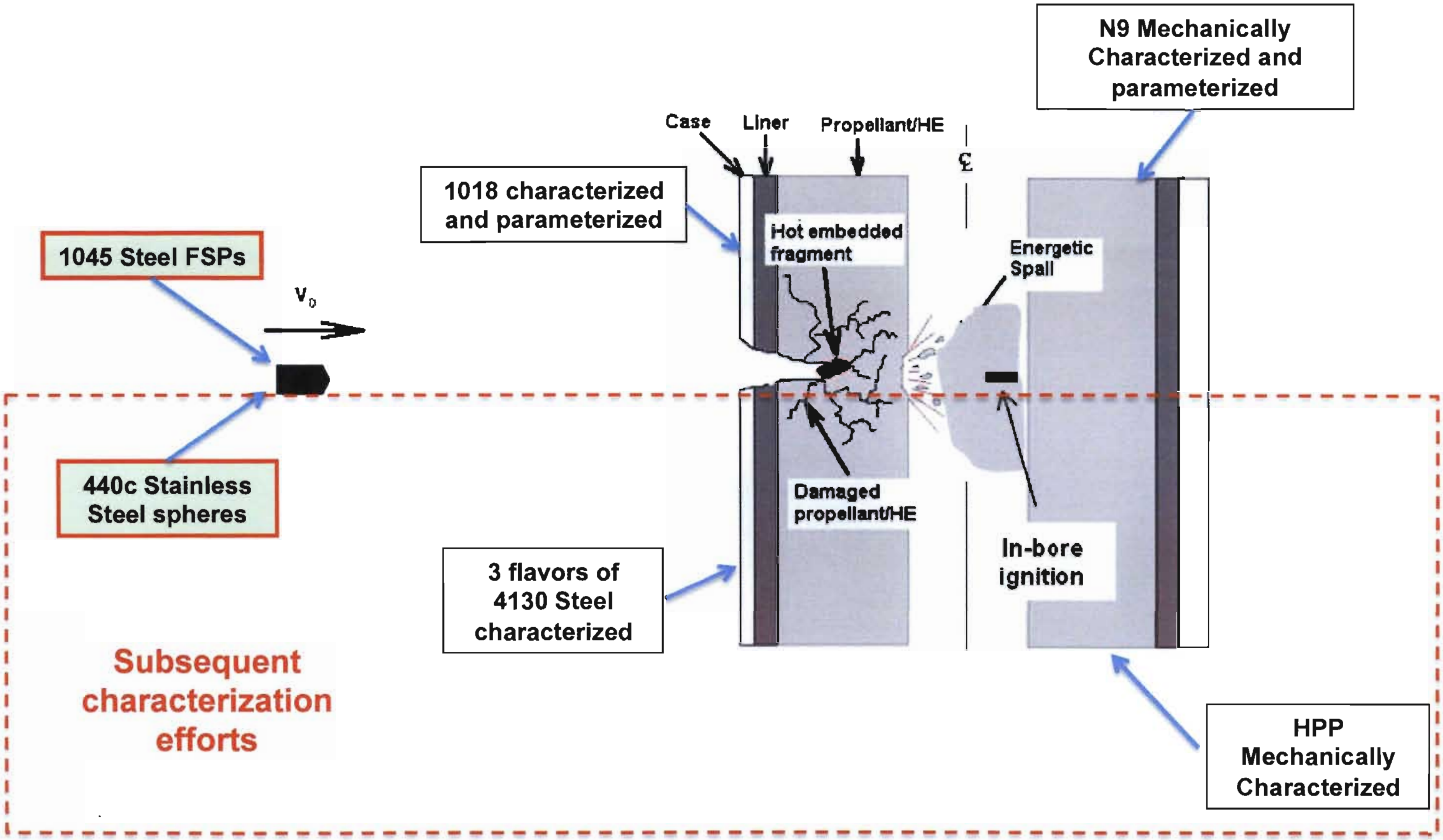


Stress-strain response of 1018 steel



Shock hardening of 1018 steel

Materials Characterization Accomplishments – US Efforts to Date



1045 Steel used for Fragment Simulating Projectiles in ABVR tests

1045 Literature Data was shared -

Material behaviour in conditions similar to metal cutting : flow stress in the primary shear zone

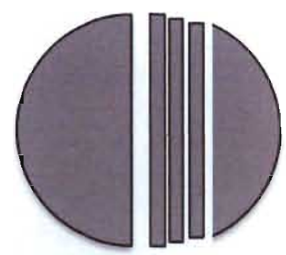
S.P.F.C. Jaspers and J.H. Dautzenberg, Journal of Materials Processing Technology, Vol. 122 (2002) p. 322–330.

440C stainless steel –

Little data exists for this material in a ballistic application

440C SS sphere
center and surface specimens

Three compression specimens per sphere



440C SS sphere
– sectioning ball for spall experiments

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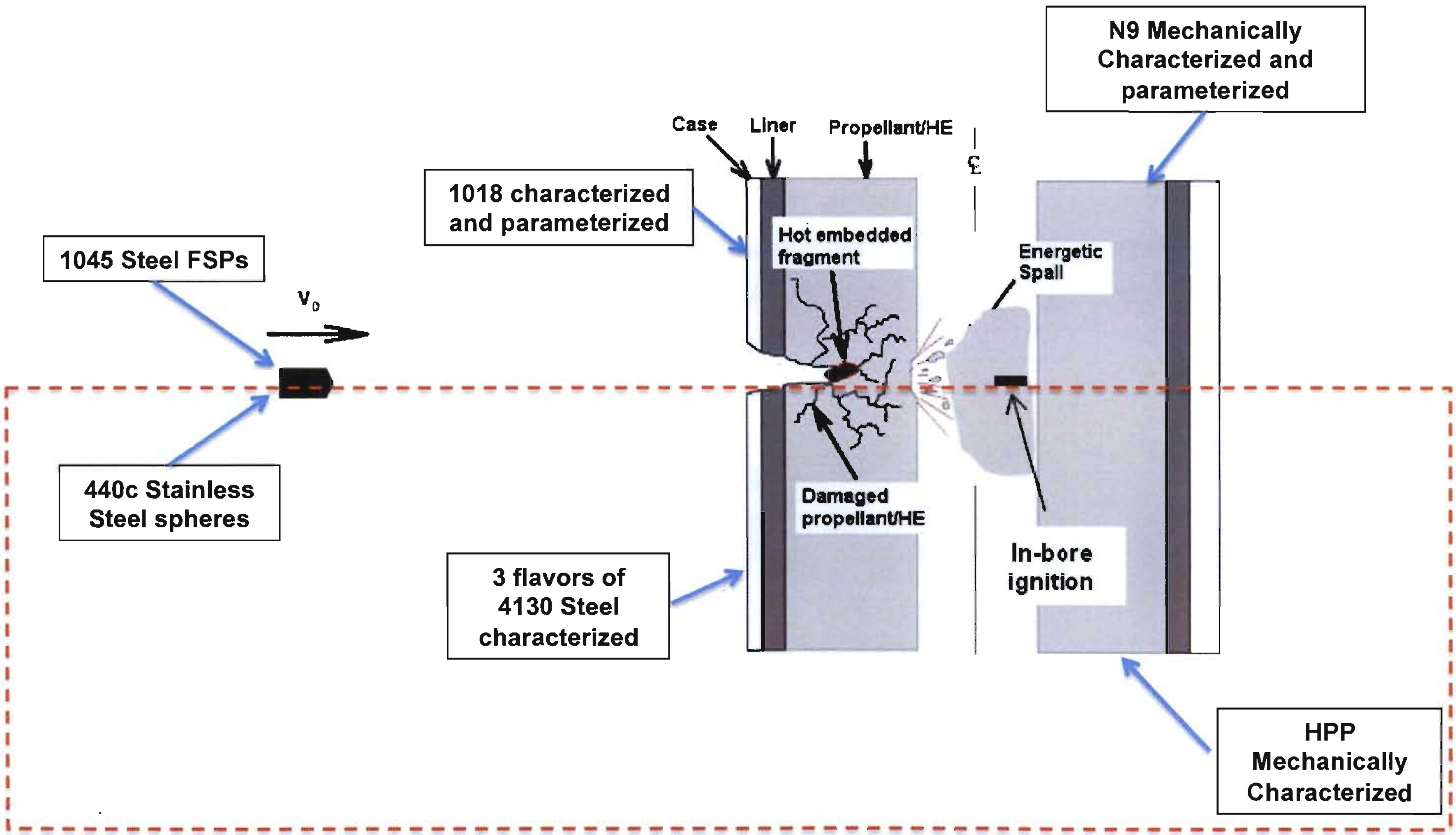

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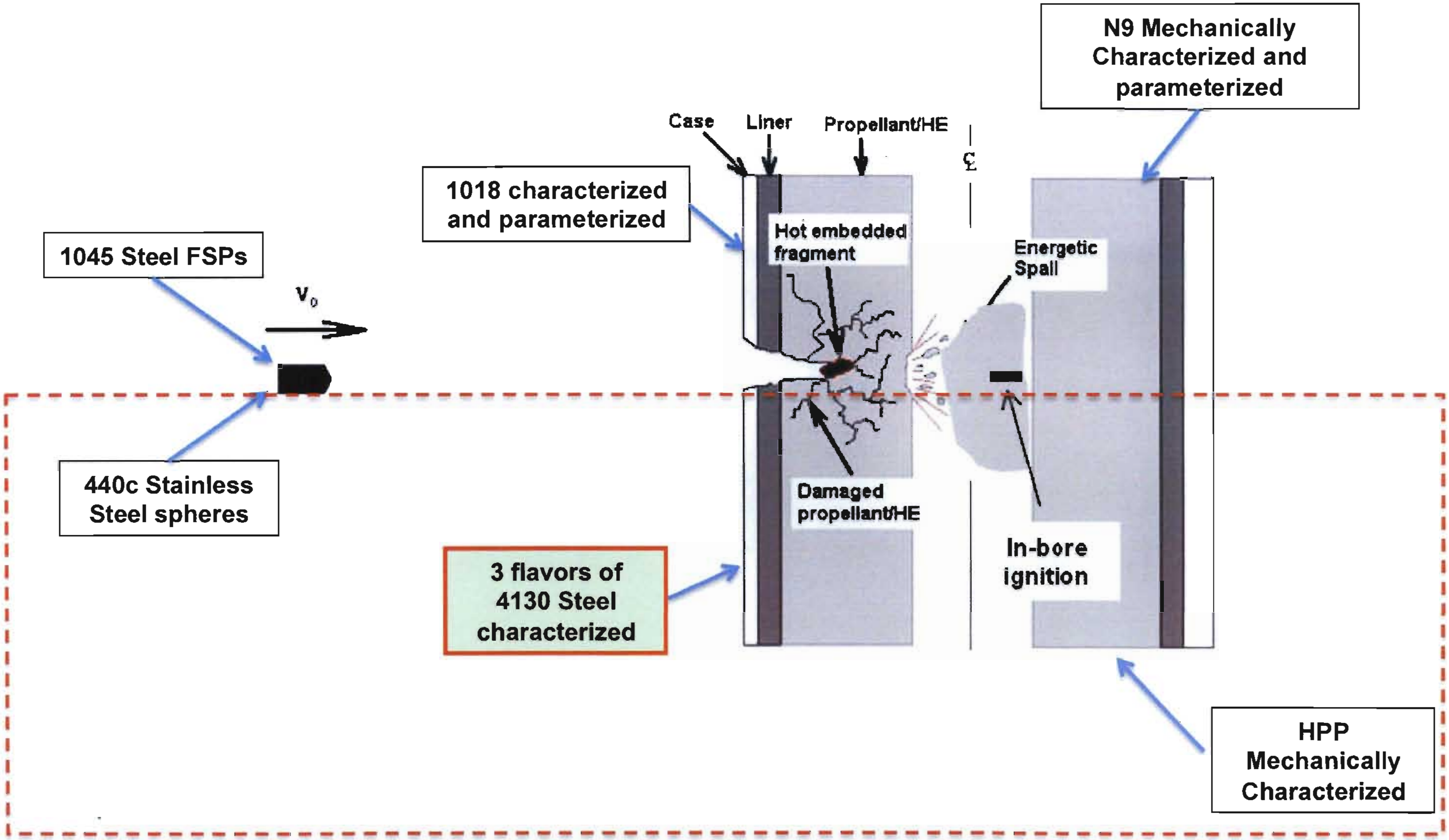
Materials Characterization Accomplishments – US Efforts to Date



4130 steel was later identified as a material of interest due to the availability of test items

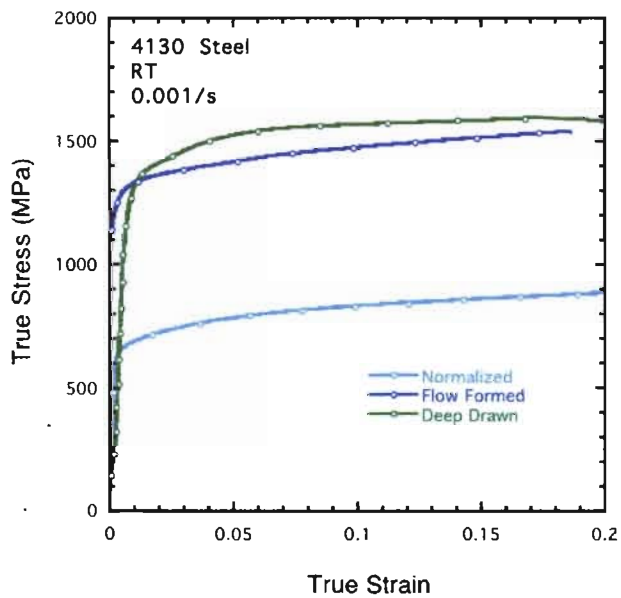
Zerilli-Armstrong fits distributed for material taken from deep-drawn and flow-formed tubes

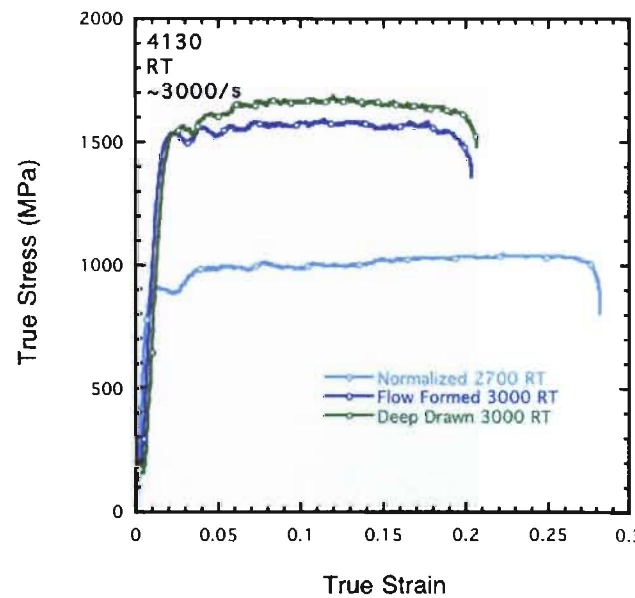
$$\sigma = C_0 + C_1 \cdot \exp\left(-C_3 \cdot T + C_4 \cdot T \cdot \ln \dot{\varepsilon}\right) + C_5 \cdot \varepsilon^n$$

$$C_0 = 450\,MPa,\ C_1 = 800\,MPa,\ C_3 = 0.00325;$$
$$C_4 = 0.0001;\ C_5 = 1025\,MPa,\ n = 0.1$$

Deep Drawn Tube - AMRDEC

Raw stress-strain data distributed to code projects





AISI 4130, Aluminum, Composite samples - AMRDEC

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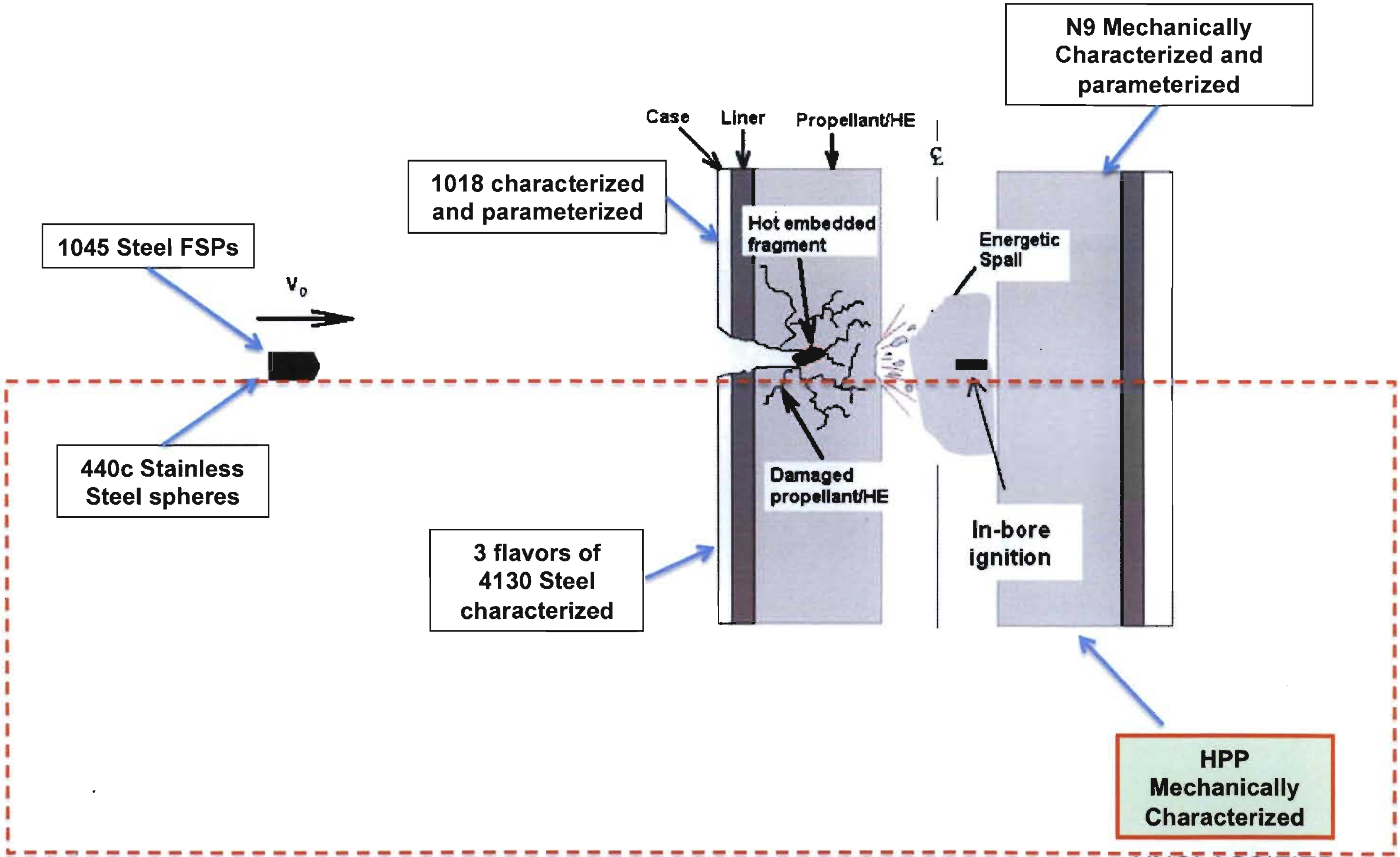
Materials Characterization Accomplishments – US Efforts to Date



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HPP Mechanically Characterized

- Triaxial testing – SNL report
- SHPB, Quasi-static – compression and tension
- Plate Impact to determine Hugoniot
- Iosipescu Simple Shear
- SITI experiments
- DSC, TGA and ODTX for developing a chemical kinetics model
- Developed HPP chemical kinetic model
- Current ViscoSCRAM model was found to be inappropriate for capturing the behavior of HPP

Status of Current / Recent Work

- HPP Taylor tests
- Sphere impacts on inert ½ ABVR hardware
  - multiple x-ray images
- Component level testing to look at failure modes of cover plates

Initial LANL HPP Taylor Test

One experiment in FY11

Shows "shredding" failure

Is the stress state appropriate?

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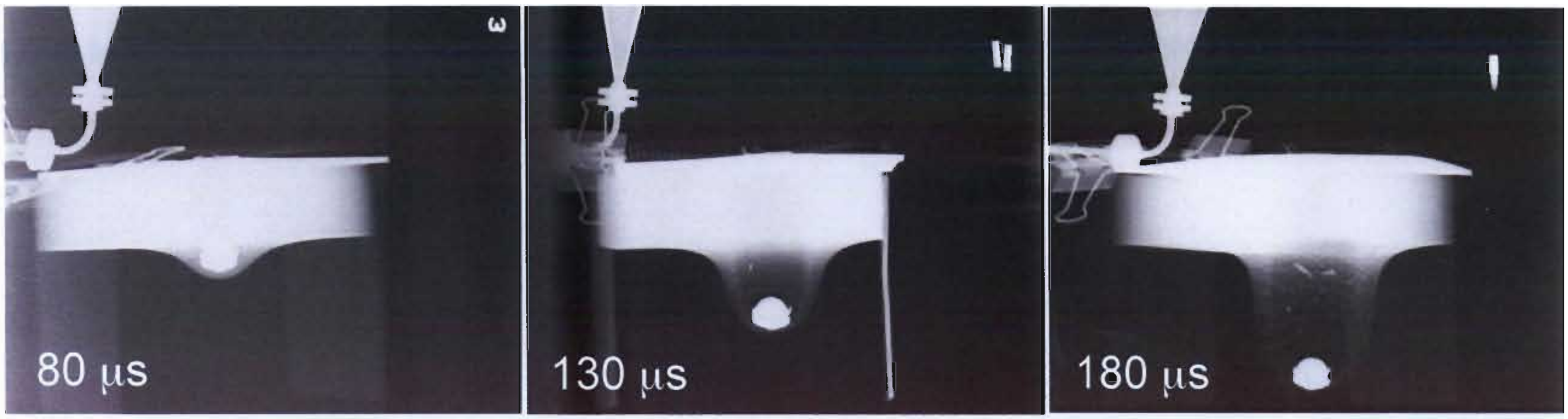
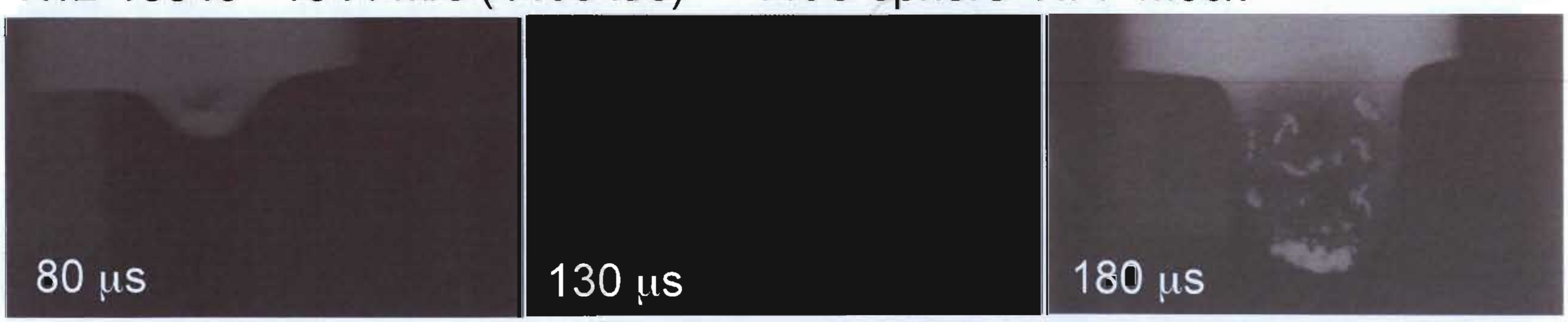
Results from LANL Inert ABVR Experiments

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

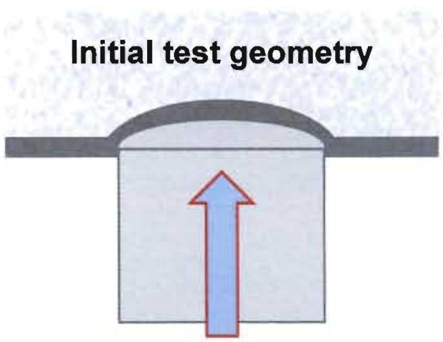


K12-18843 1344 m/s (4408 ft/s) 440C sphere HPP mock

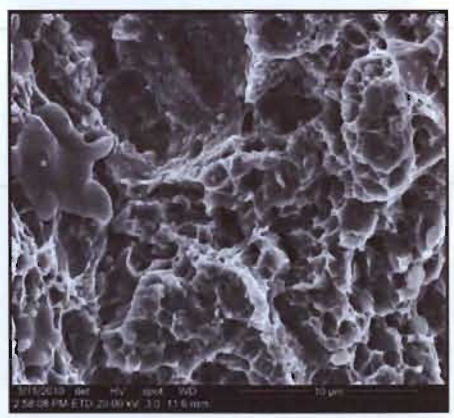


Examination of Recovered Components from AMRDEC Inert ABVR Experiments

The increasing impact speed of the FSPs and inertial support of mock propellant combine to cause a transition of the failure mode exhibited by the cover plates.



4000 ft/s (1220 m/s)
Front of cover plate
Fragment Impact Side



6000 ft/s (1830 m/s)
Front of cover plate
Fragment Impact Side

Recovered FSP & sphere fragments are also being examined

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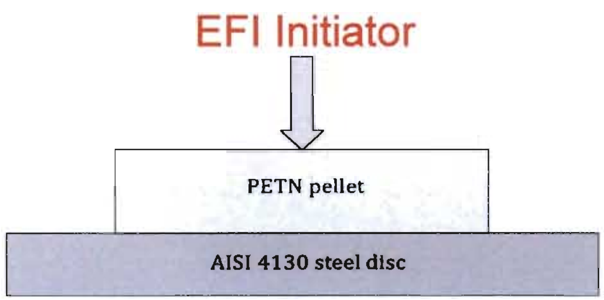
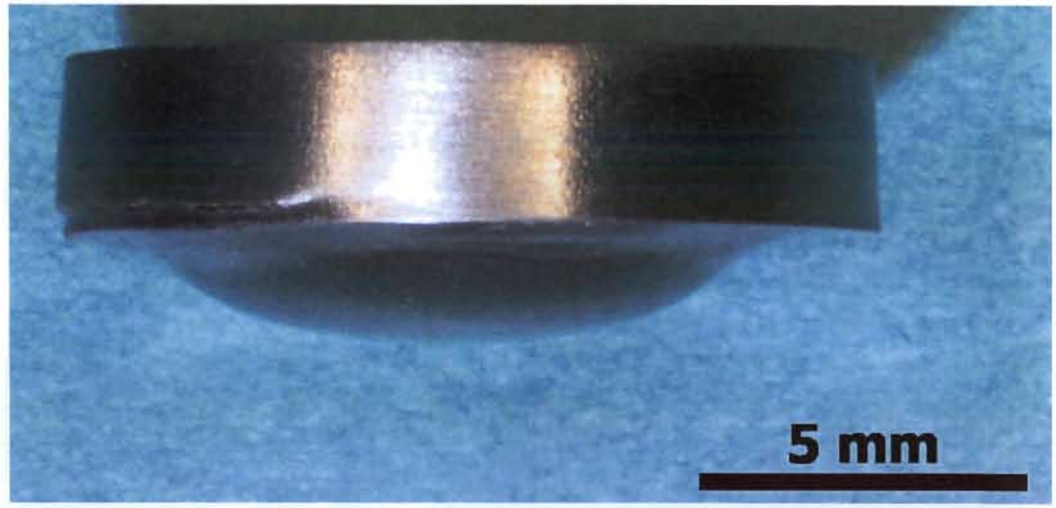
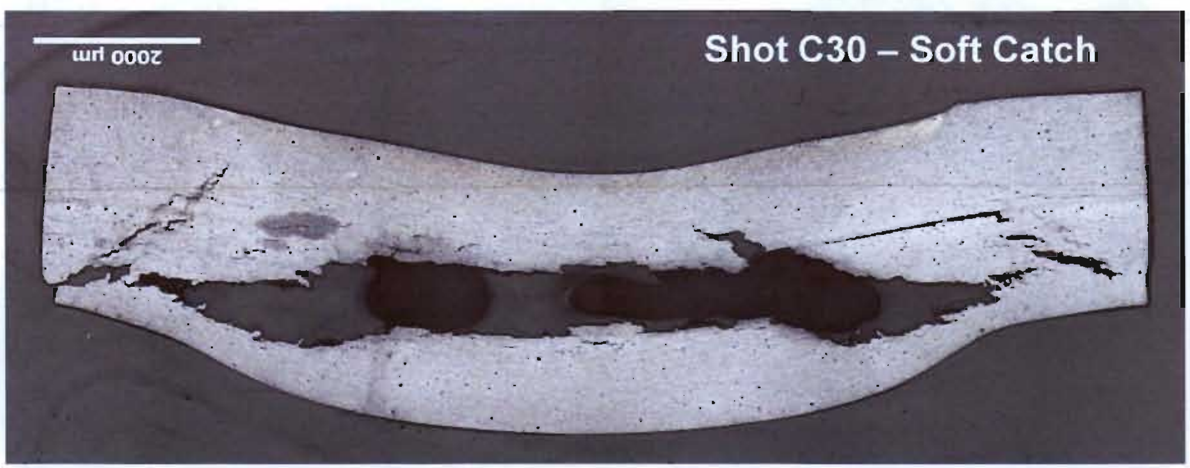
Results from testing ABVR components

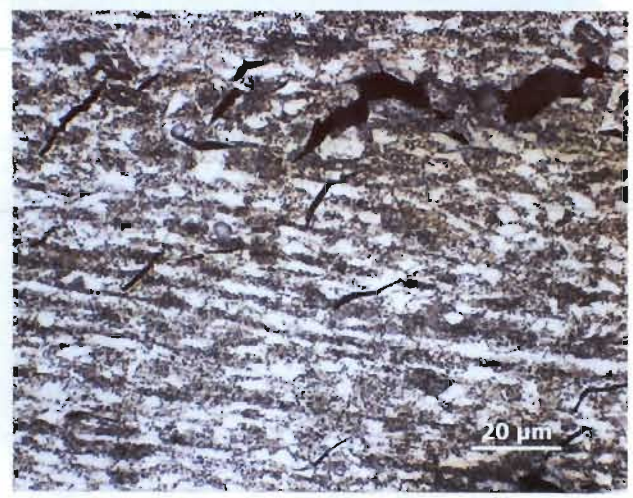
AISI 4130 cover plates - normalized

Small scale spall experiments









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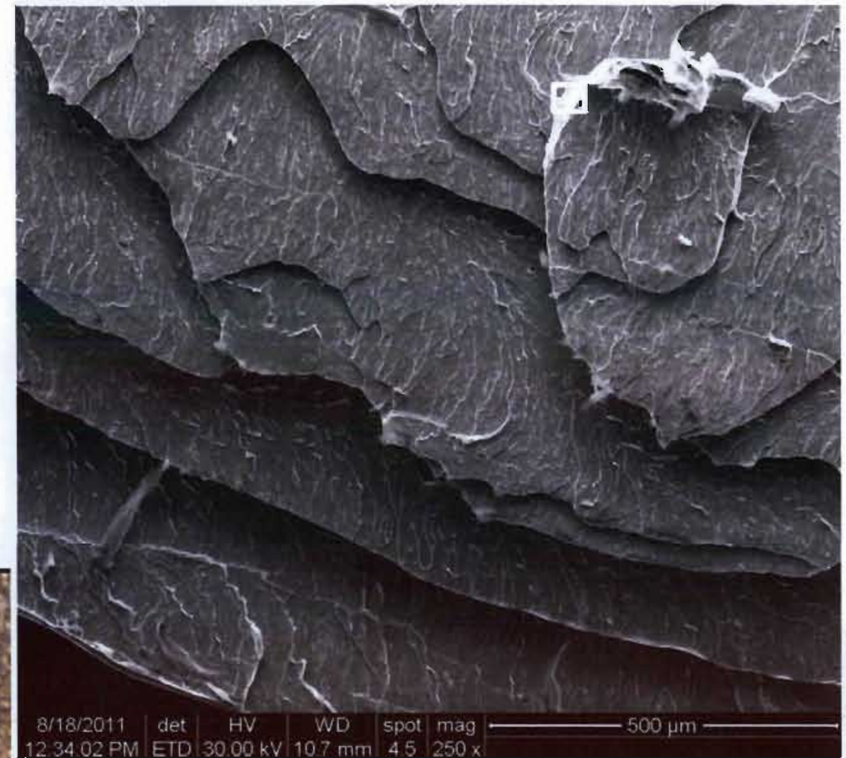
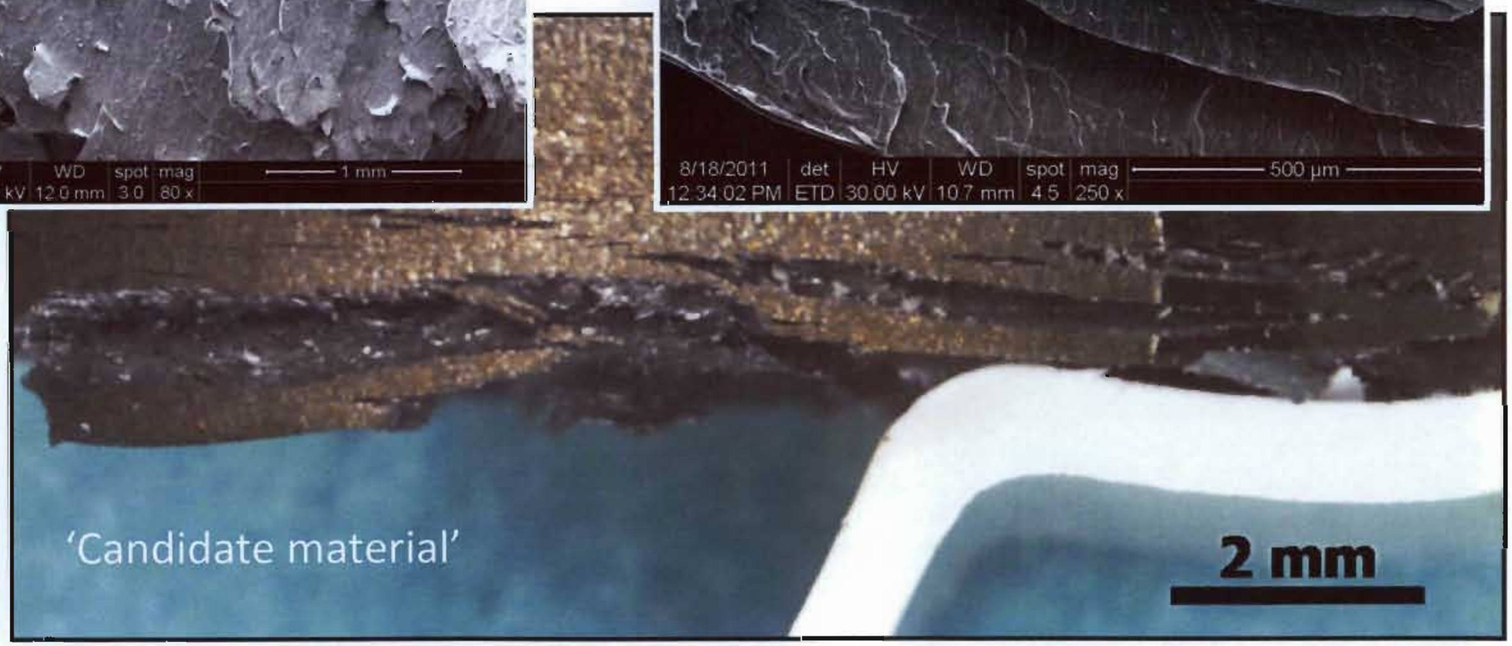
Results from testing ABVR components

AISI 4130 tubes – flow formed



Small scale spall experiments



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