U.S. Army Research, Development and Engineering Command

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Methodology for Determining Insensitive Explosive Material Interface Reliability

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Overview

- Background
- Objective
- Data Requirements
- Review of Required Tests
- Process Overview
- Conclusion

Background

- The Army is planning to deploy more Insensitive Munitions (IM)
  - Artillery, Mortars, Grenades, etc.
- Traditional explosive interface tests consist of go/no-go tests
  - Penalty, Bruceton, Langlie, and Neyers tests
- IM explosives with larger critical diameters will need more energy to initiate the main charge
- IM explosives require more in-depth techniques to characterize the material

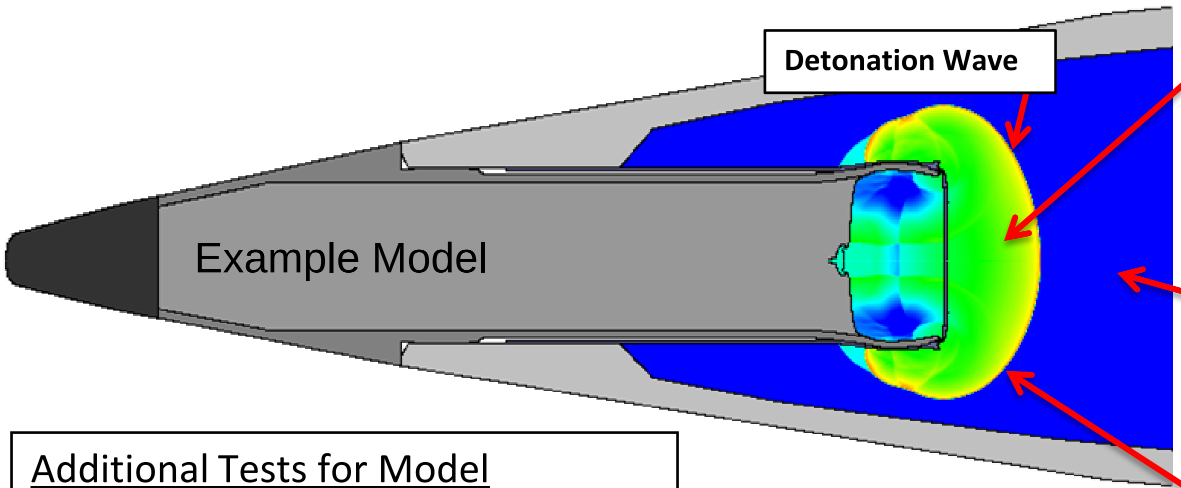
Objective

- The objective of this program is to develop an alternative methodology to characterize the reliability of the interface between the fuze initiator and any high explosive (HE) IM fill
- The following methodology can be used to assess initiator/main fill charge interface reliability
  - Parameterize Reactive Flow Model(s)
  - Feed Reactive Flow Model into Hydrocode Simulation
  - Use Hydrocode Simulation to evaluate explosive interface design
    - Optimize initiator geometry, materials, and interface gaps

Data Requirements for Modeling

- Test data required to parameterize Reactive Flow Models
  - Lee Tarver Ignition & Growth, CREST, JWL++

Data Requirements for Reactive Flow Model



Properties of Reacted Material
- ***Reacted JWL Equation of State***
- Test Data Requirement
  - **- Cylinder Expansion Test**

Properties of Unreacted Material
- ***Unreacted Equation of State***
- Test Data Requirement
  - **- Wedge Test**
  - **- Cutback Test**

Properties of the Reaction at Det Front
- ***Reaction Rate Laws***
- Test Data Requirement
  - **- Wedge Test**
  - **- Cutback Test**

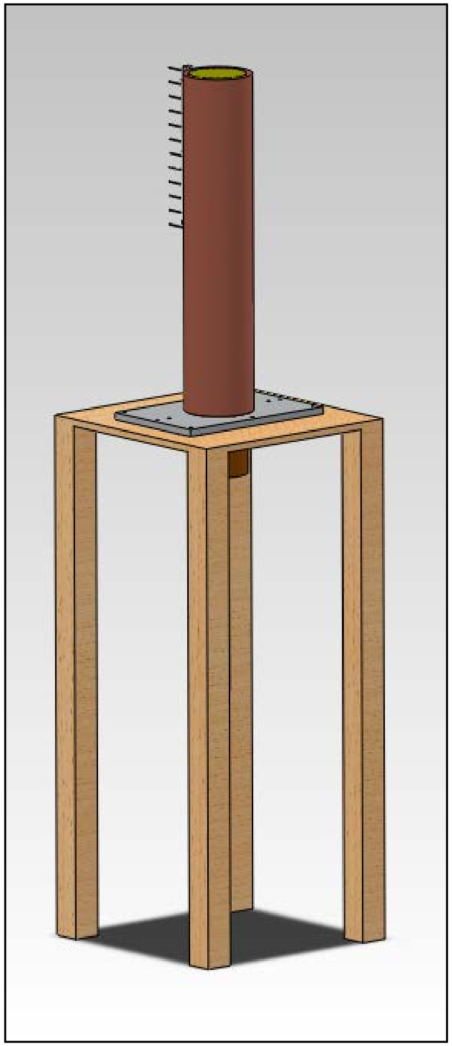
Additional Tests for Model Verification

- **Expanded Large Scale Gap Test (ELSGT)**
- **Detonation Velocity Test**
- **2D Corner Turning Test**

Properties of Reacted Material

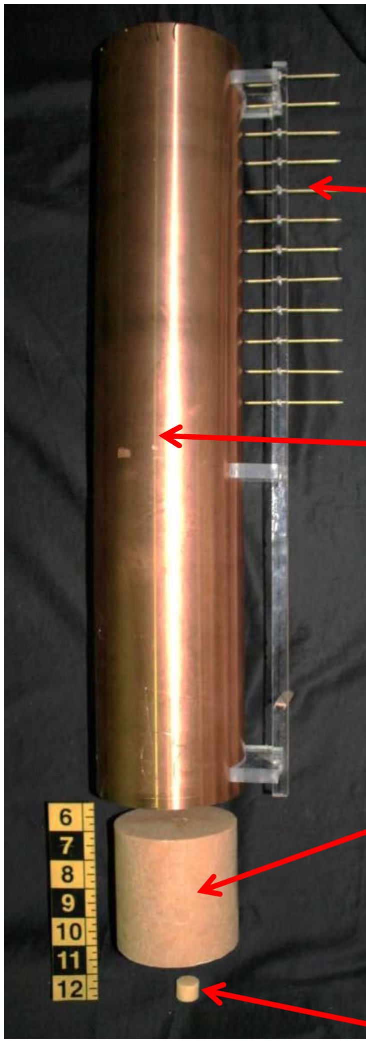
Reacted EOS

- Cylinder Expansion (Cylex) Test performed to determine Reacted Equation of State (EOS)
  - Provides Gurney Energy and explosive performance
- Explosive is detonated while enclosed in a copper cylinder
- Resultant expanding wall velocities recorded with a streak camera
- Allows for determination of parameters for reacted equation of state



Cylex Test

Cylinder Expansion Test



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Properties of Unreacted Material

Unreacted EOS

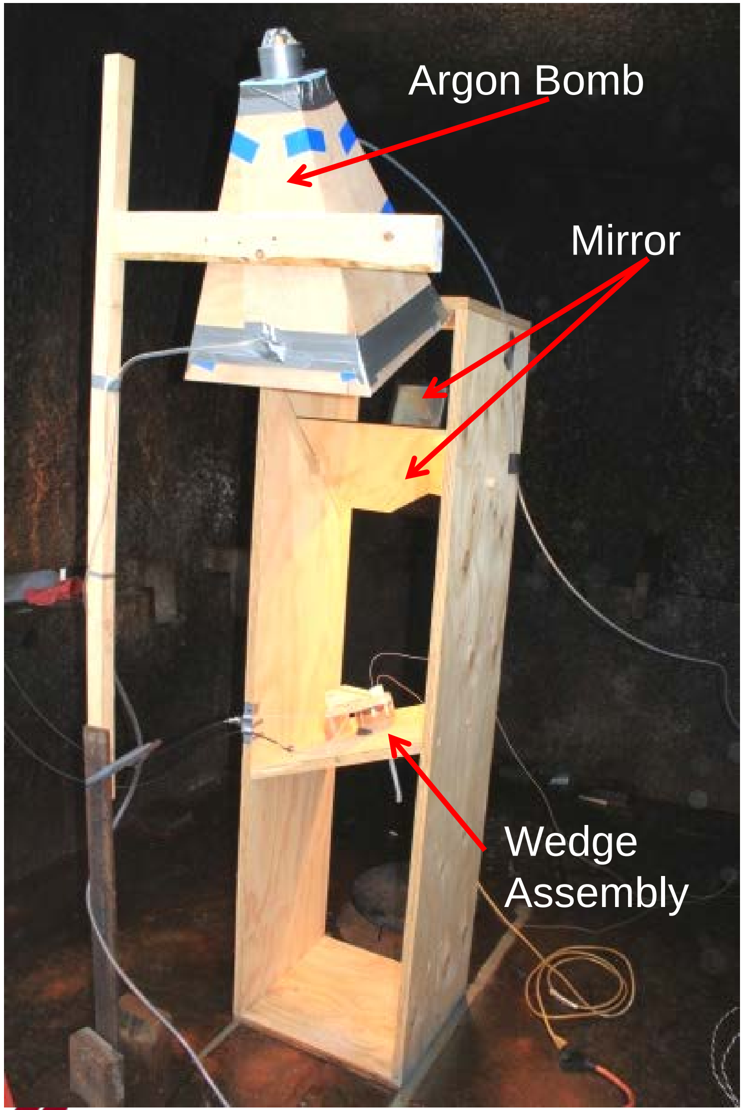
- Determined by measuring shock speed into unreacted HE at varying pressures
  - Wedge Test
    - Wedge of HE is shocked with a high explosive to see the detonation run-up distance
    - Data is plotted in a “POP Plot” (Pressure vs Run-Distance)
    - Unreacted EOS is determined from shock speed of HE before detonation
  - Cutback Tests
    - “Cutback” lengths of HE is shocked using a projectile or explosive
    - Cutback lengths need to be very short, so no reaction takes place
    - Unreacted EOS is determined from the particle velocity from the output of the charge

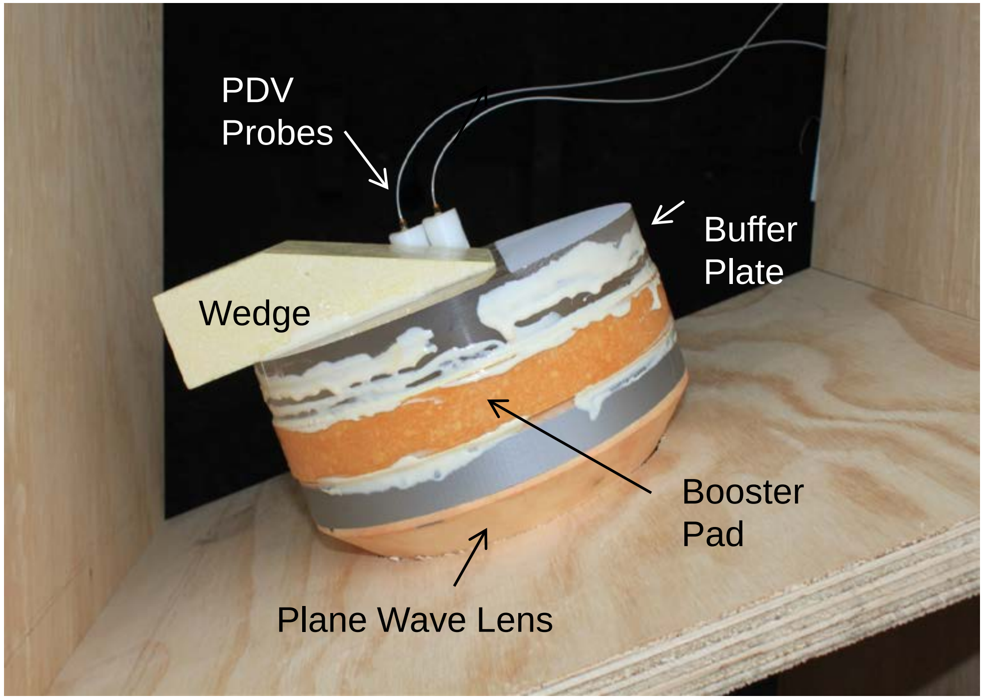
Reaction at Detonation Front

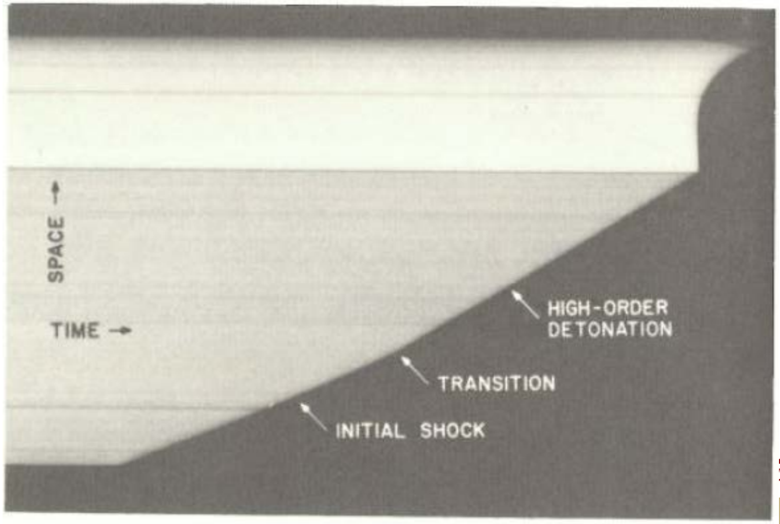
Reaction Rates at the Detonation Front

- Pressure build-up during the detonation ramp-up is required to tune the reaction rates
  - Wedge Tests
    - The run-up distance and other run-up characteristics will be applied to the Reaction Rate Law
  - Cutback Tests
    - Cutbacks of various lengths are tested to determine the pressure build-up
    - Cutback tests are preformed at multiple pressures

Wedge Test

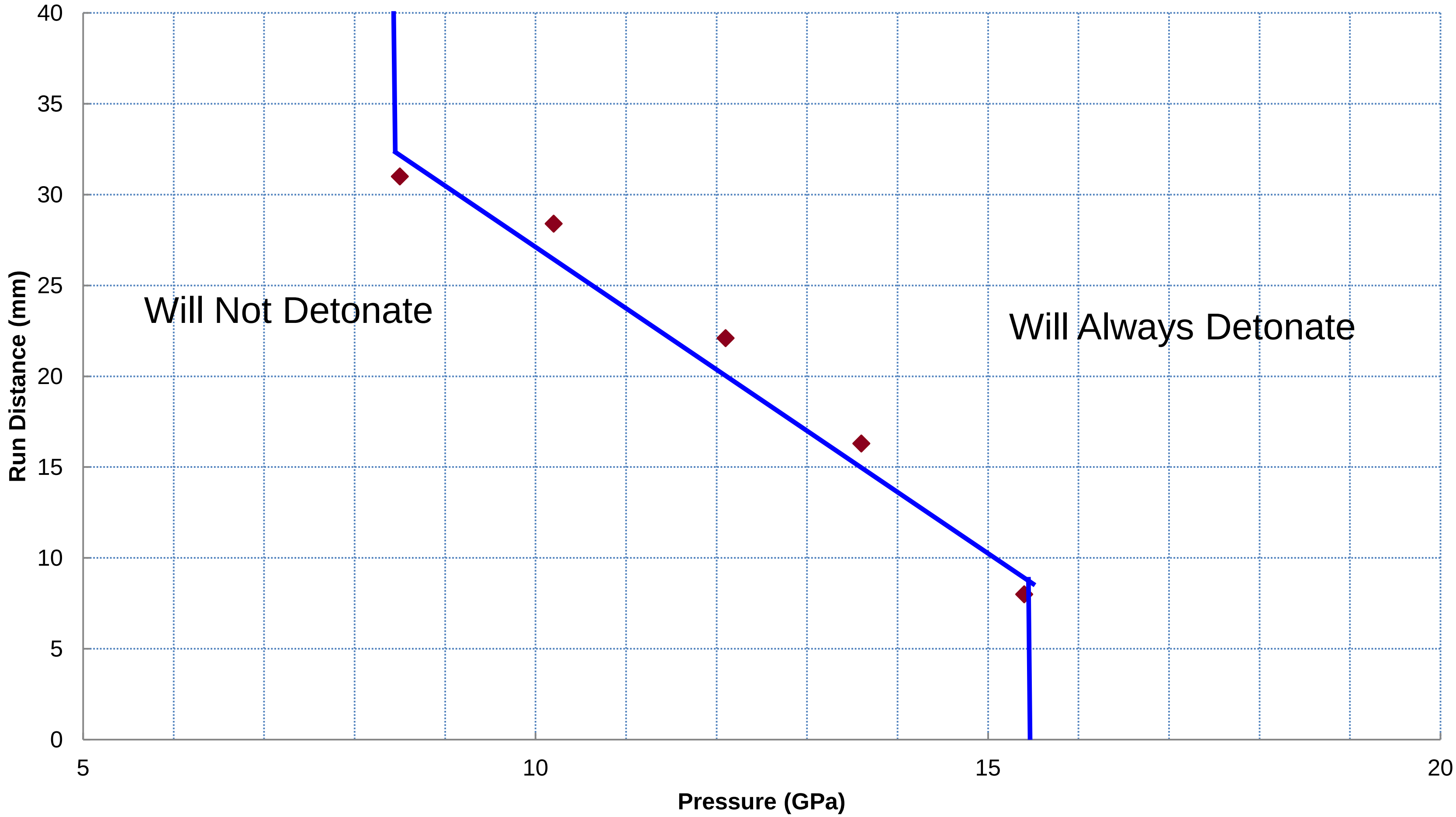






“LASL Explosive Property Data” Gibbs and Popoloto. Figure 4.02 page 294. The Regents of the University of California, 1980.

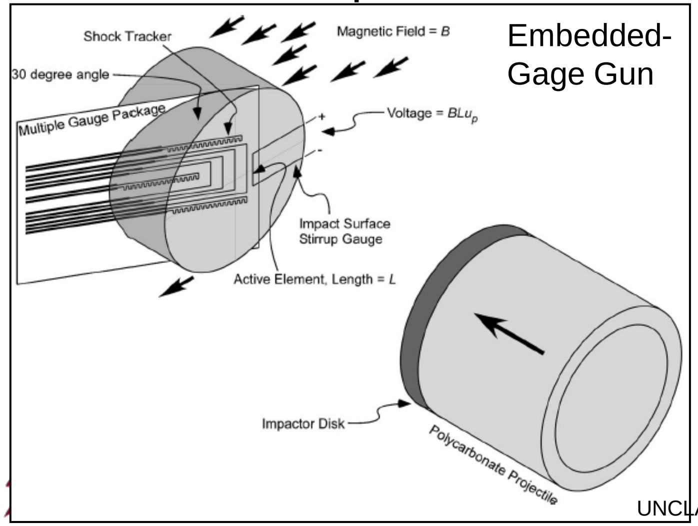
POP Plot

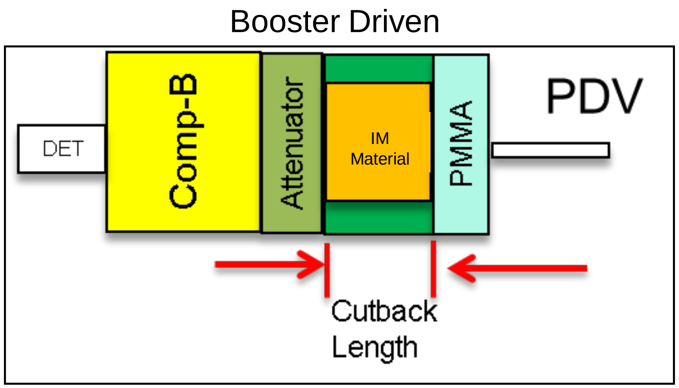


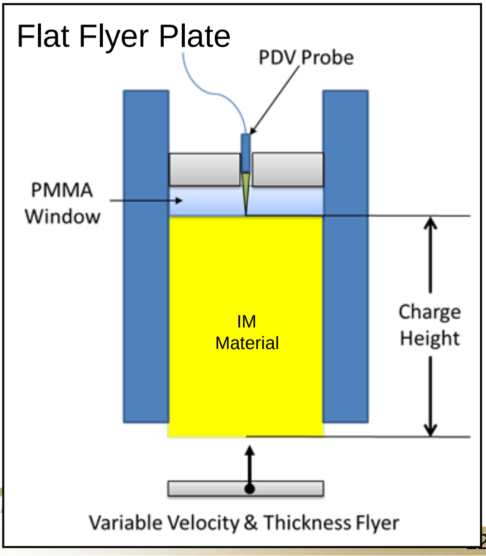
40
35
30
25
20
15
10
5
0
Run Distance (mm)
5
10
15
20
Pressure (GPa)
Will Not Detonate
Will Always Detonate

Cutback Test

- Detonation ramp-up data is needed to parameterize the reaction rates for explosive material
- Cutback test can be accomplished with an embedded-gage gun test, booster driven test, or flat flyer plate impact test
  - Embedded-Gage Gun Test provides 1D data but is expensive
    - Captures wedge test and cutback test data
  - Cost-effective alternative is booster driven test
    - Provides 2D data instead of 1D so additional computational time required for modeling







Cutback Test Results

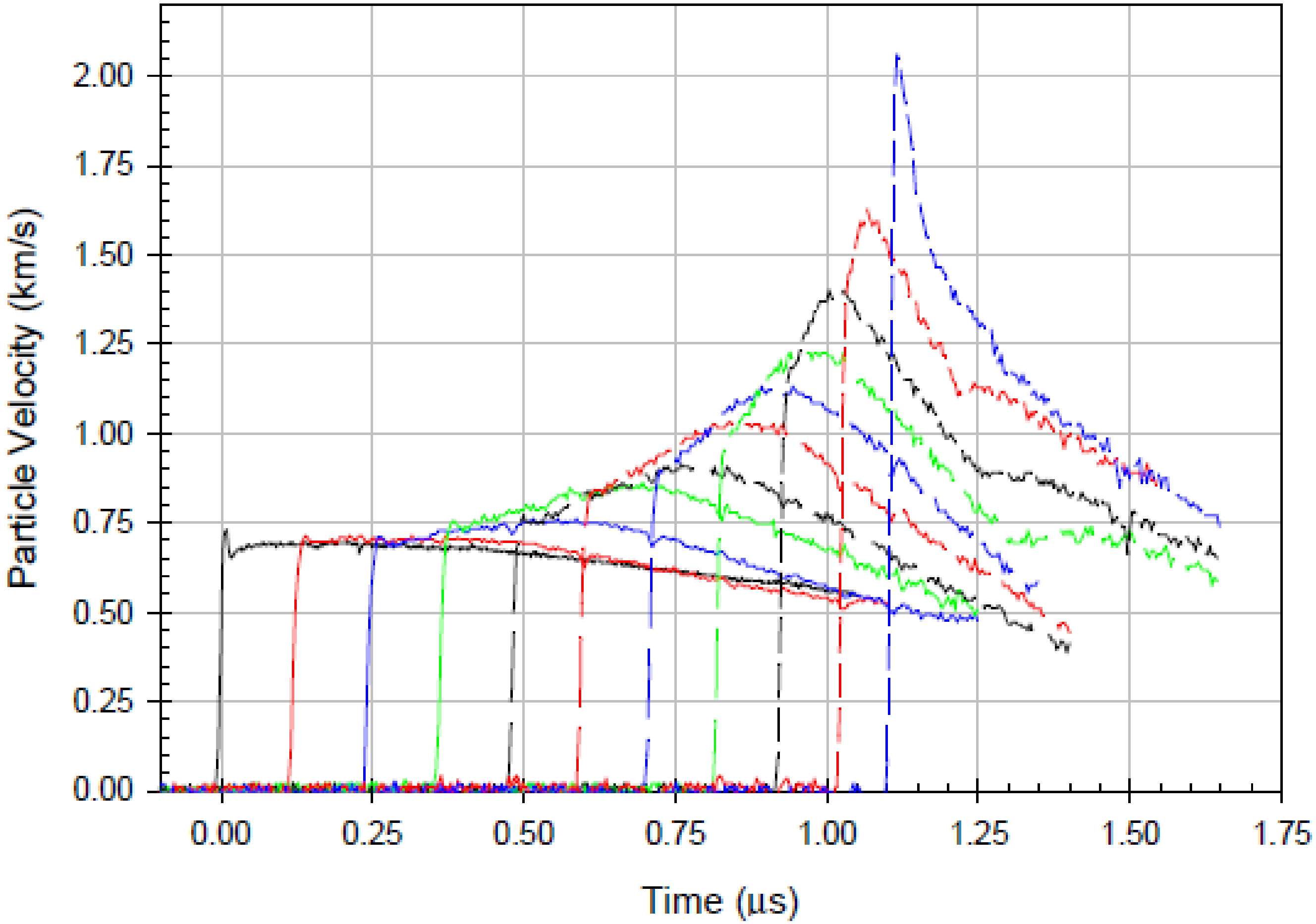


Figure A1. Particle velocity wave profiles from Shot 1133. The input is 5.12 GPa and was created by impacting Vistal on the PBX 9501 at 0.817 km/s. The PBX is of type A.

"Shock Initiation of New and Aged PBX 9501 Measured with Embedded Electromagnetic Particle Velocity Gauges" Gustavsen, Sheffield, Alcon, and Hill. Page 20, <http://library.lanl.gov/cgi-bin/getfile?00416767.pdf>

Model Validation

- Additional validation tests are necessary to ensure the predictive capabilities of the simulation
- Additional Tests include:
  - Expanded Large Scale Gap Test (ELSGT)
  - Unconfined Detonation Velocity Tests
  - 2D Corner Turning Test

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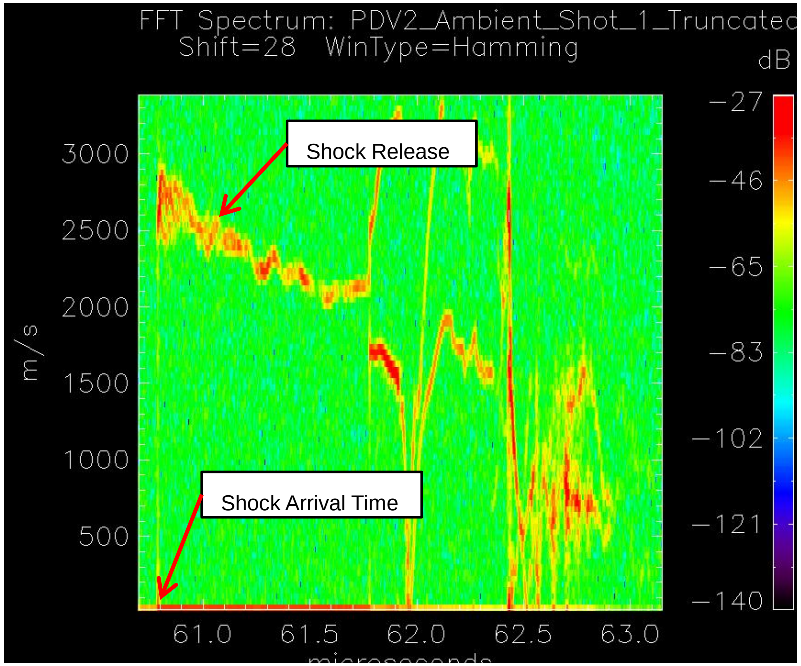
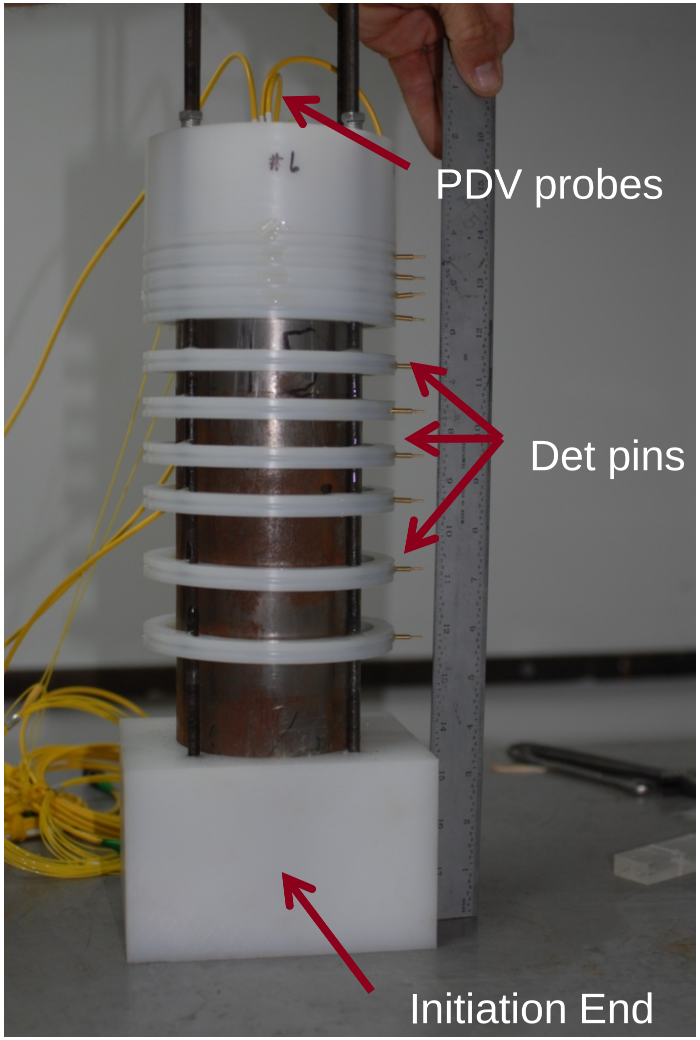
Expanded Large Scale Gap Test (ELSGT)

- ELSGT is performed to capture the detonation wave curvature and particle velocity at the output of the test cylinder
  - The results are used to validate the Reactive Flow Model





Courtesy of Eric Welle

National Quality Award 2007 Award Recipient

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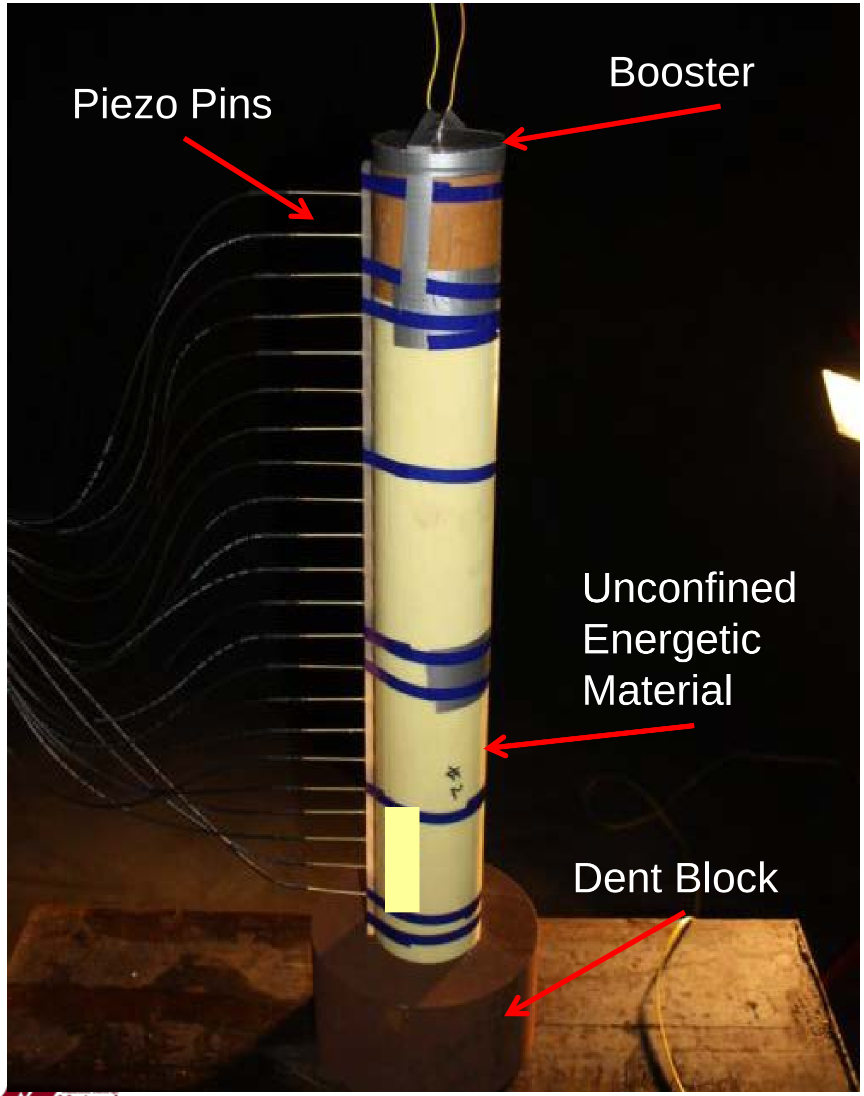
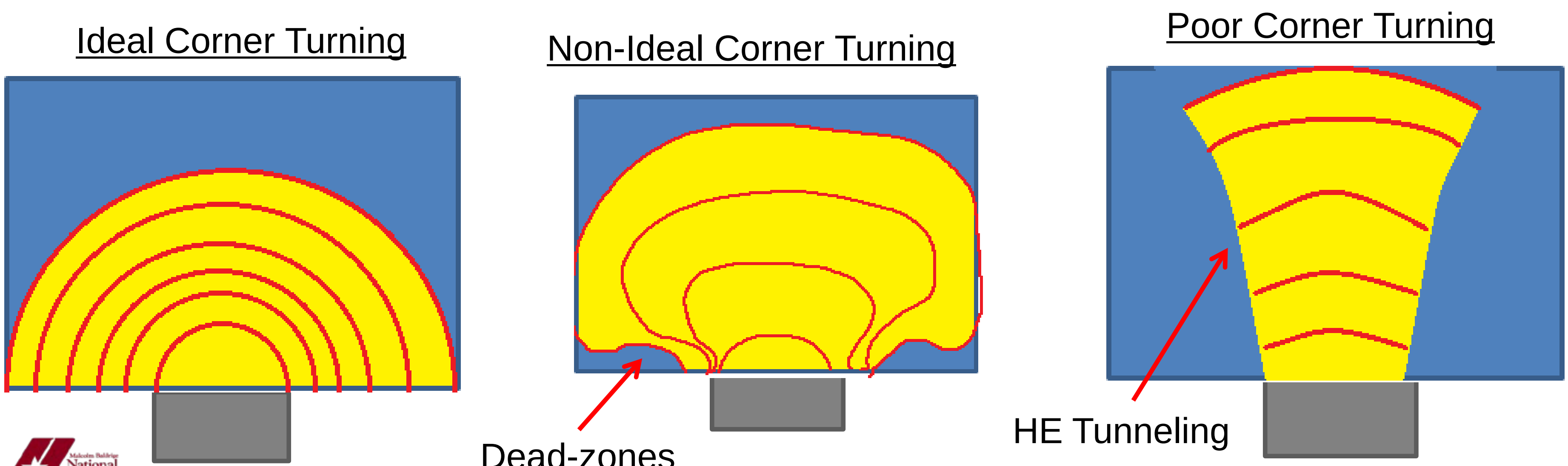
Unconfined Detonation Velocity Test



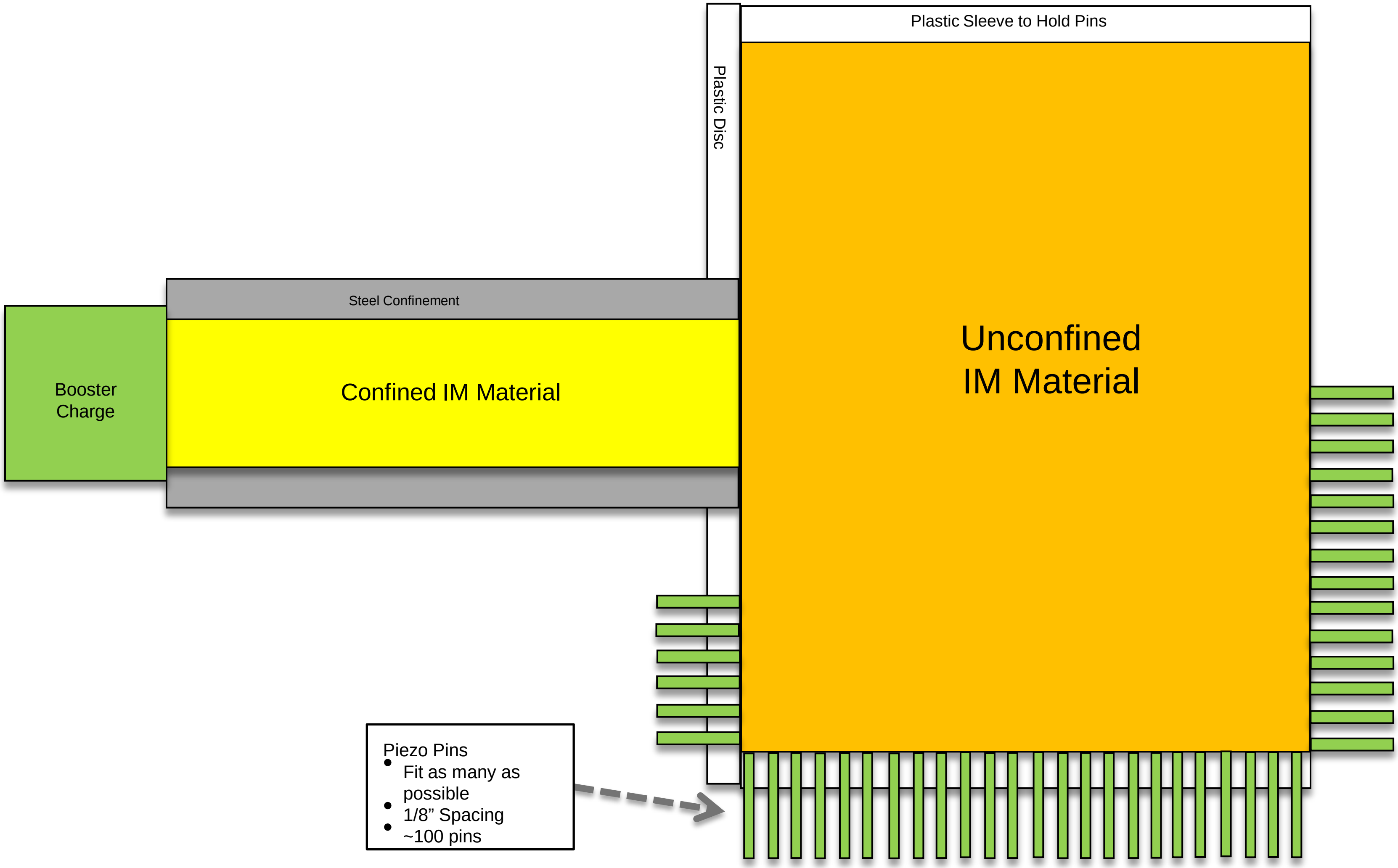
- Unconfined Detonation Velocity Tests are performed to determine the critical diameter of the energetic material
  - Ensure hydrocode simulation will be able to predict critical diameter
    - Full-Order performance above critical diameter
    - Dying detonation wave below critical diameter
- Lesson learned from test:
  - Initial tests had charges that were too short, and showed full order detonation, but further testing in longer charges shows the detonation wave dying
    - Ensure length of unconfined material is long enough for detonation to reach steady state

2D Corner Turning Test

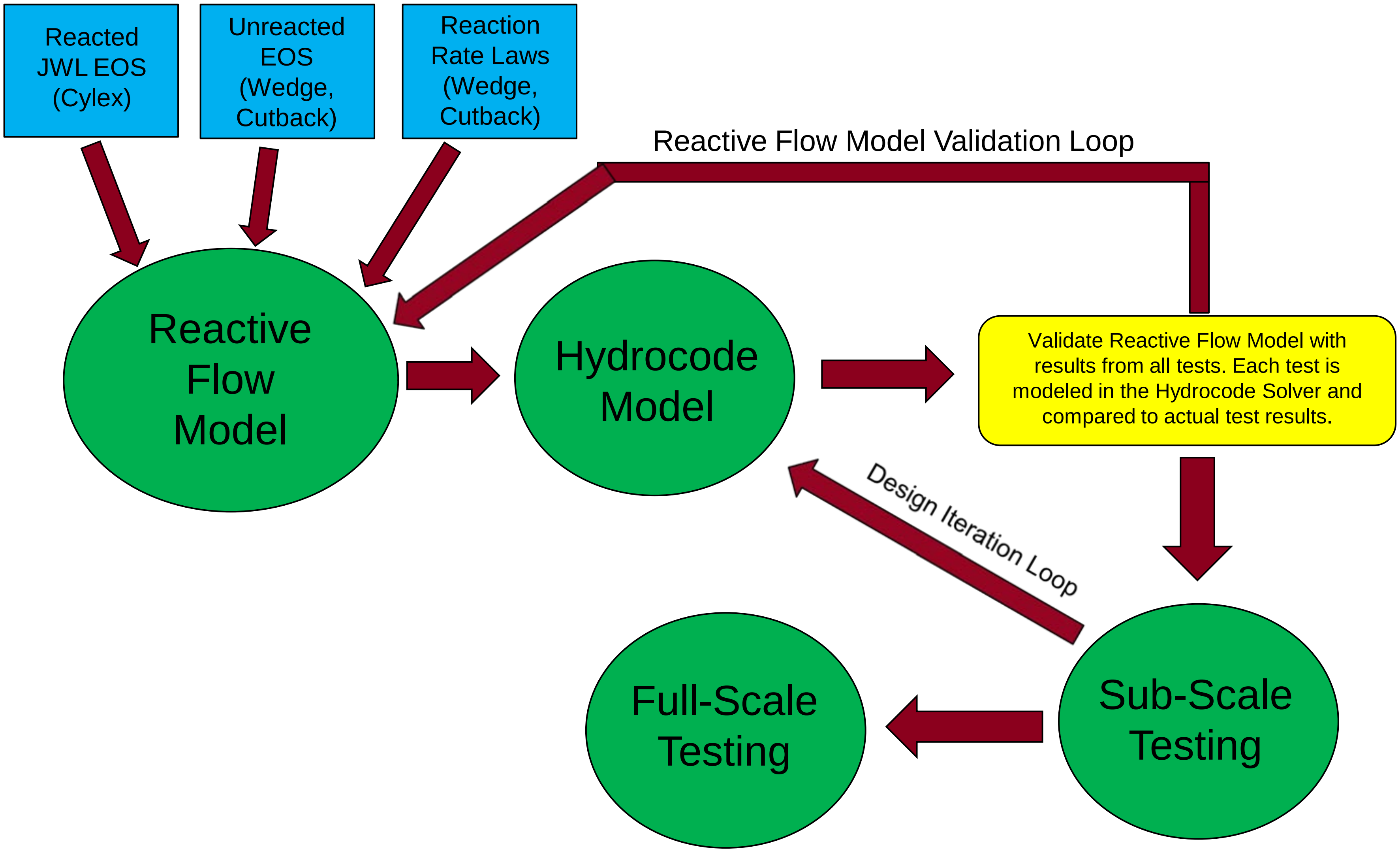
- Insensitive explosives usually have poor corner turning performance
- 2D corner turning test characterizes the corner turning behaviors of the material
  - Results used to validate the Reactive Flow Model



2D Corner Turning Test Setup Example



Process Overview



Conclusion

- To develop a Hydrocode model this process can be followed:
  - Perform Ignitions Studies
  - Use data from Ignition Studies to Parameterize Reactive Flow Model
  - Plug the Reactive Flow Model into Hydrocode Solver (CTH, ARES, CALE, ALE3D)
    - Develop Hydrocode model for each test and compare results to experimental data
      - Validate/Tune Reactive Flow Model until Hydrocode Models match experimental data.
  - Use Hydrocode Solver to asses design iterations and optimize design
- Conduct sub-scale test to confirm performance of new design
- Conduct full-scale test to confirm operation performance of updated system
- The validated Reactive Flow Model can then be applied to any munition application that wishes to utilize the specific insensitive explosive material

Acknowledgements

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