U.S. Army Research, Development and Engineering Command

Methodology for Determining Insensitive Explosive Material Interface Reliability

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

Briefed by: Anthony Di Stasio

973-724-4547

anthony.r.distasio.civ@mail.mil

May 18 - 21, 2015

2015 NDIA IM/EM

Rome, Italy

Overview

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

Background

Unclassified

- 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

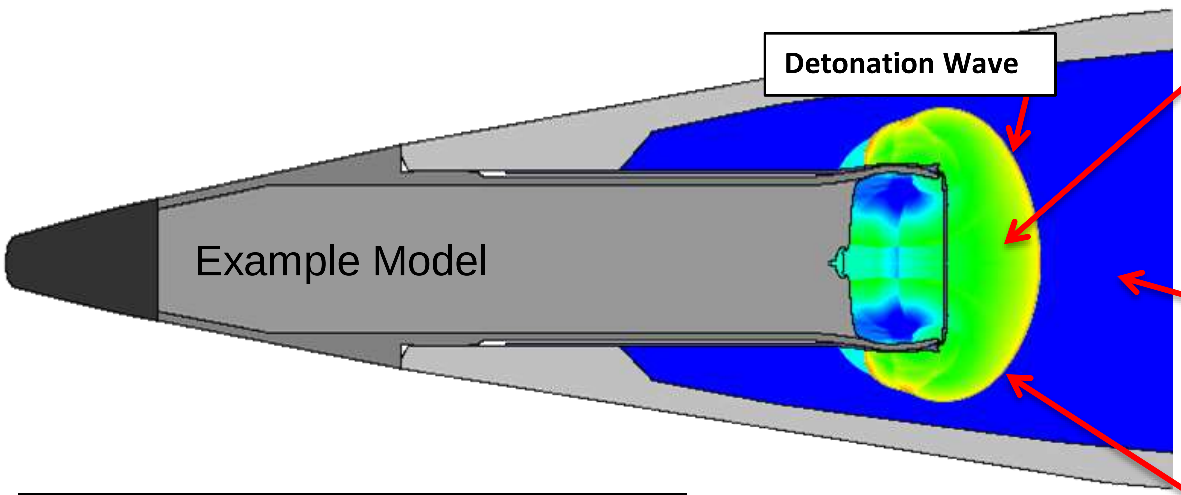

Objective

- 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 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 Model
  - Use Hydrocode Model to evaluate explosive interface design

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**

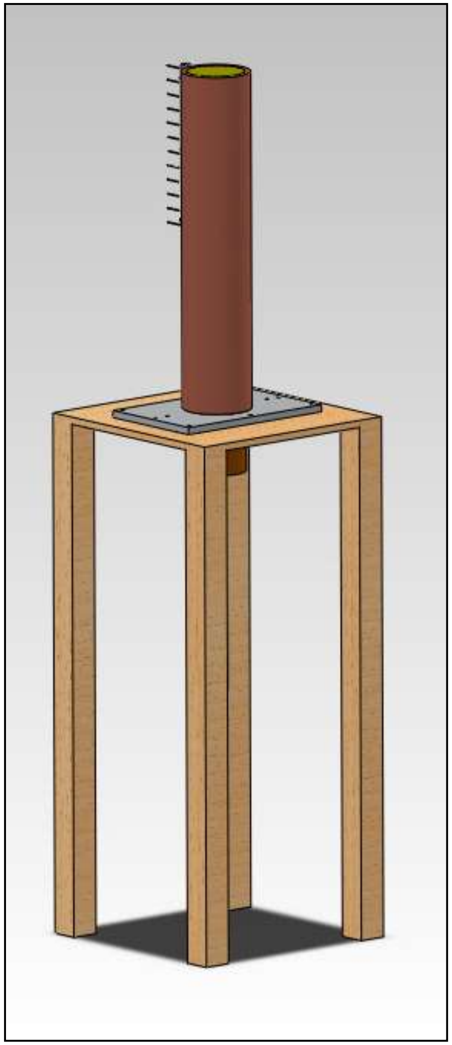
Properties of Unreacted Material
- ***Unreacted Equation of State***
- Test Data Requirement
  - **Wedge Test**
  - **Cutback Test**

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**

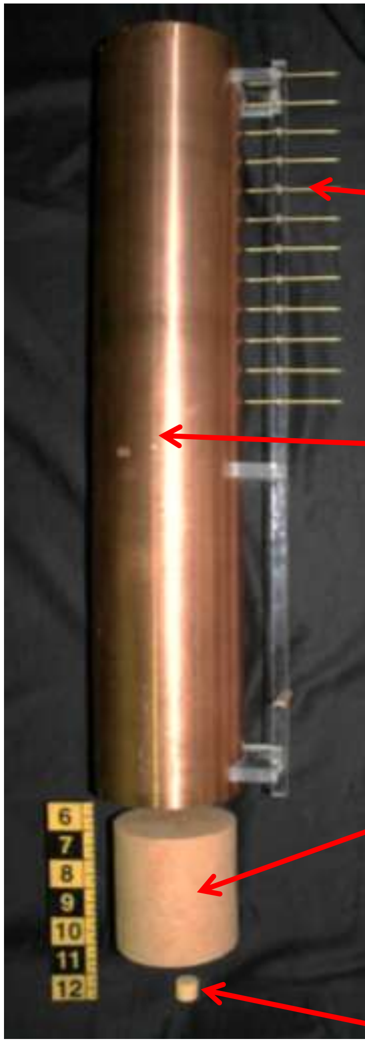
Properties of Reacted Material

- 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



Piezopin fixture

IM filled cylinder

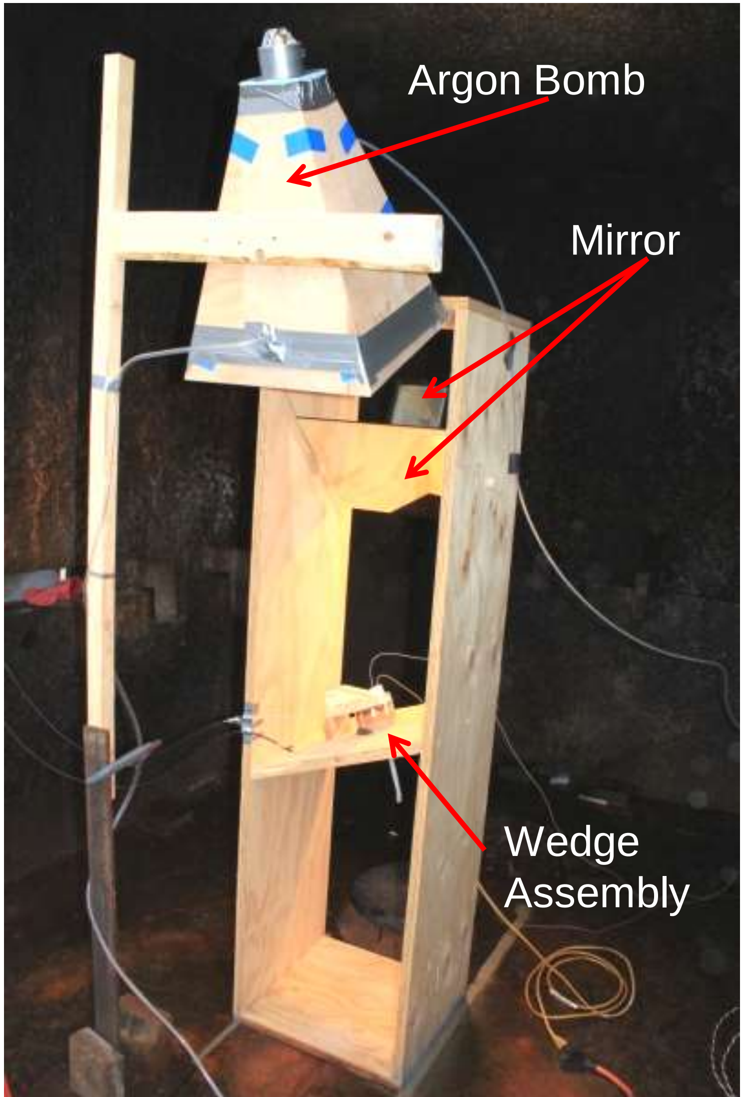
Comp B booster

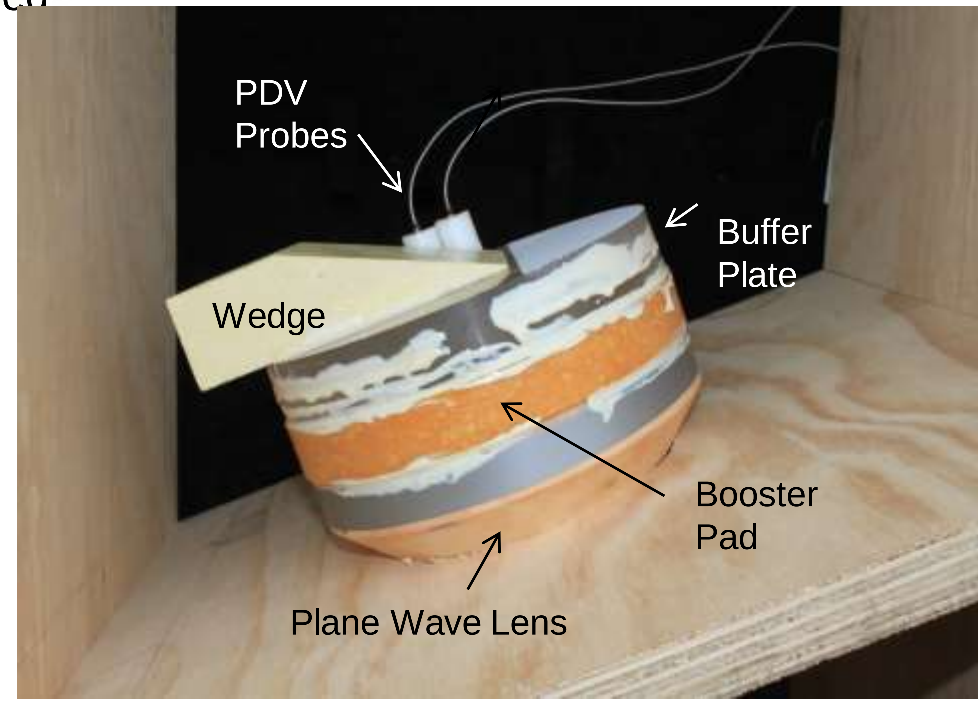
Pentolite pellet

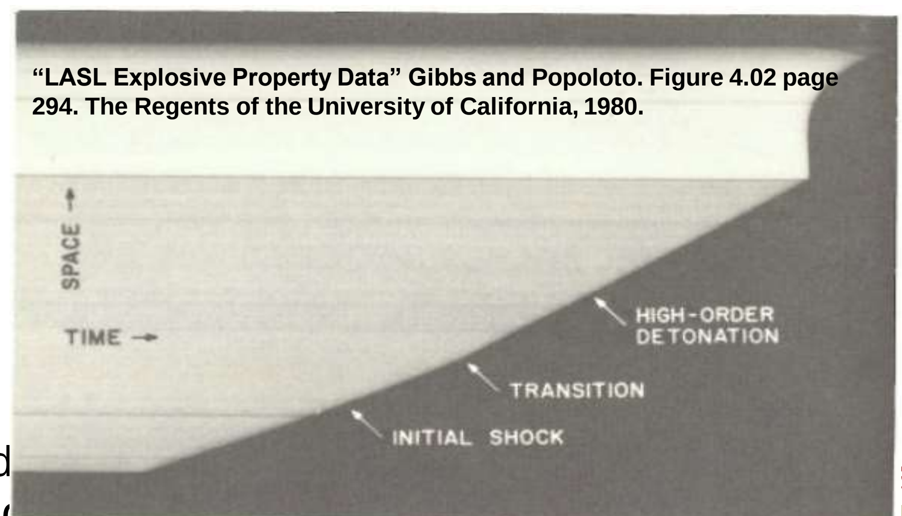
Properties of Un-reacted Material and Reaction at Detonation Front

- To determine the Un-reacted EOS a wedge test and cutback test need to be performed
- The wedge test and cutback test are also used to develop the Reaction Rate Laws
- Wedge test provides the shock initiation characteristics of the explosive material
  - Provides run to detonation of the explosive material
  - Used in conjunction with the cutback test to determine the coefficients for the Un-reacted EOS and the Reaction Rate Laws
  - Test results are configured to a POP Plot
- Cutback test captures how the reaction grows through the explosive material
  - Provides detonation ramp up data
  - Used in conjunction with the wedge test to determine the coefficients for the Un-reacted EOS and the Reaction Rate Laws

Wedge Test



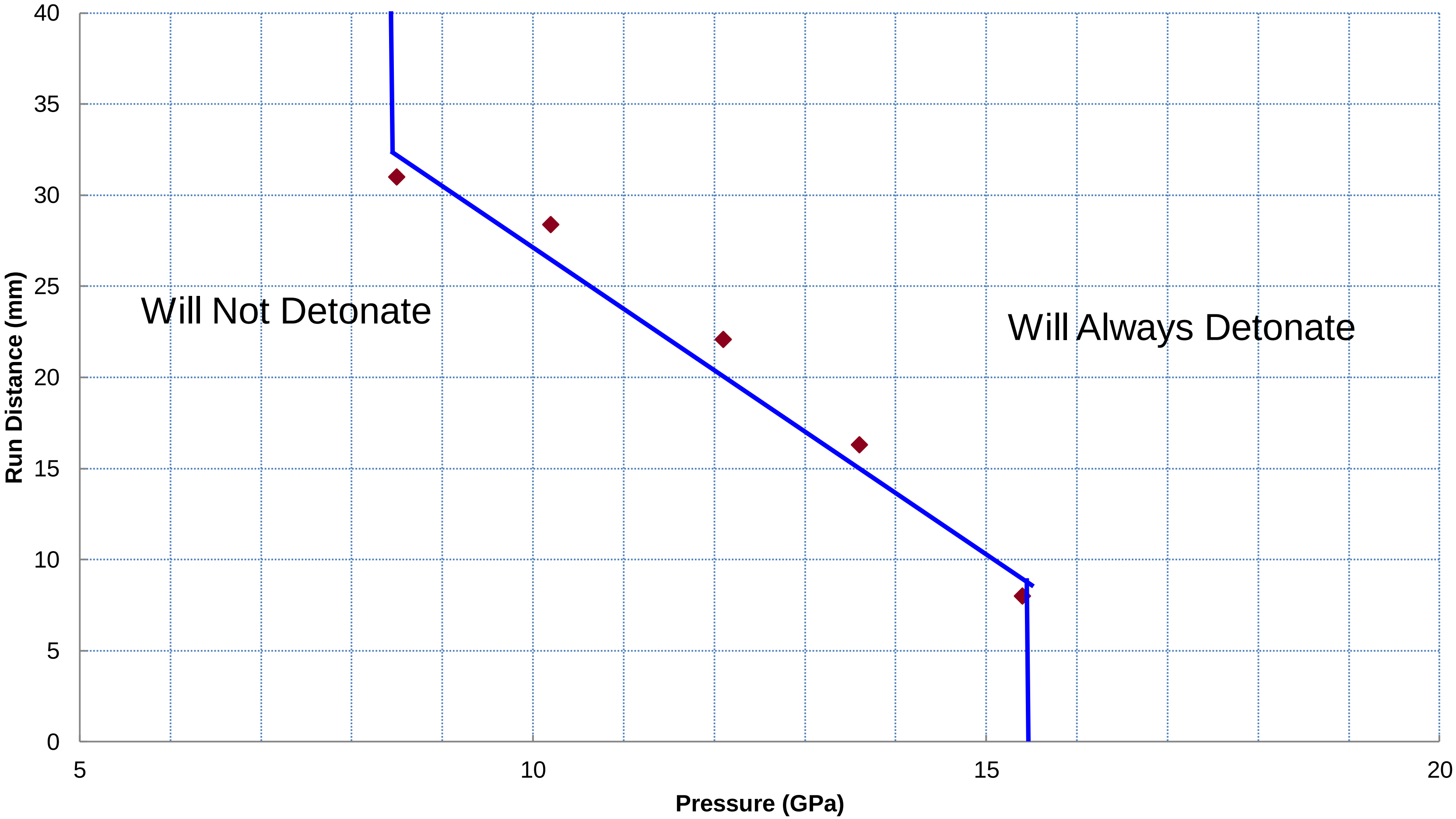




"LASL Explosive Property Data" Gibbs and Popoloto. Figure 4.02 page 294. The Regents of the University of California, 1980.

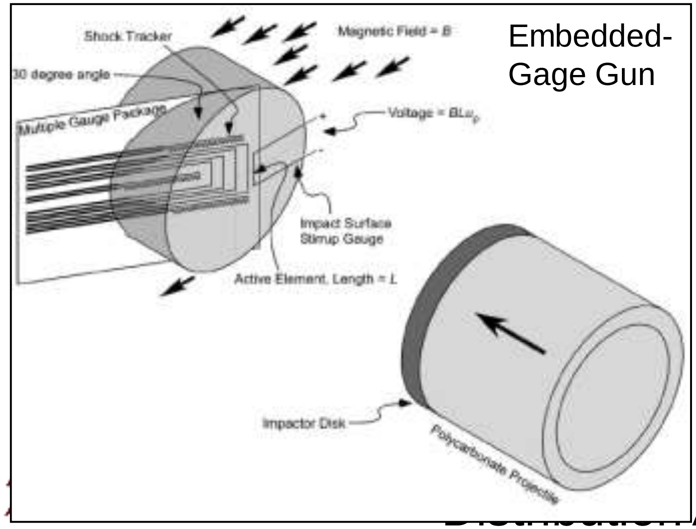
Unclassified

POP Plot



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
  - Cost-effective alternative is booster driven test
    - Provides 2D data instead of 1D so additional computational time required for modeling



Cutback Test Results

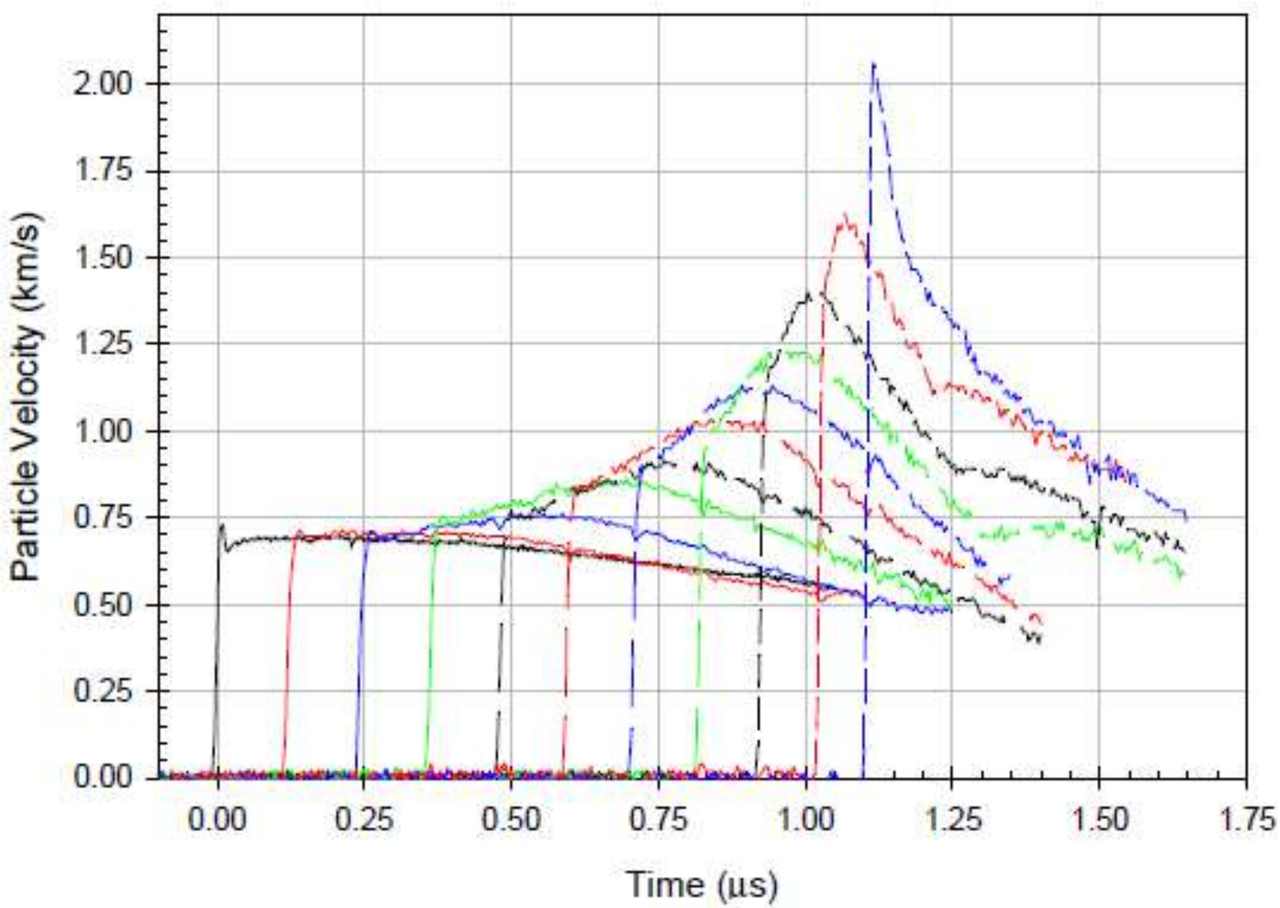


Figure A1. Particle velocity wave profiles from Shot 1133. The input is 5.12 GPa and was created by impacting Vistal on the PBX 9501 at 0.817 km/s. The PBX is of type A.

"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>

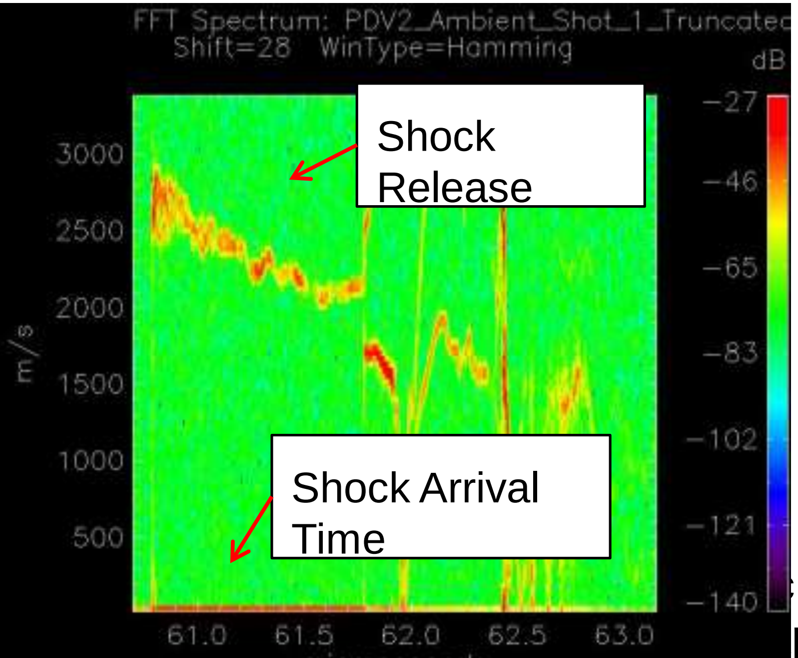
Model Validation

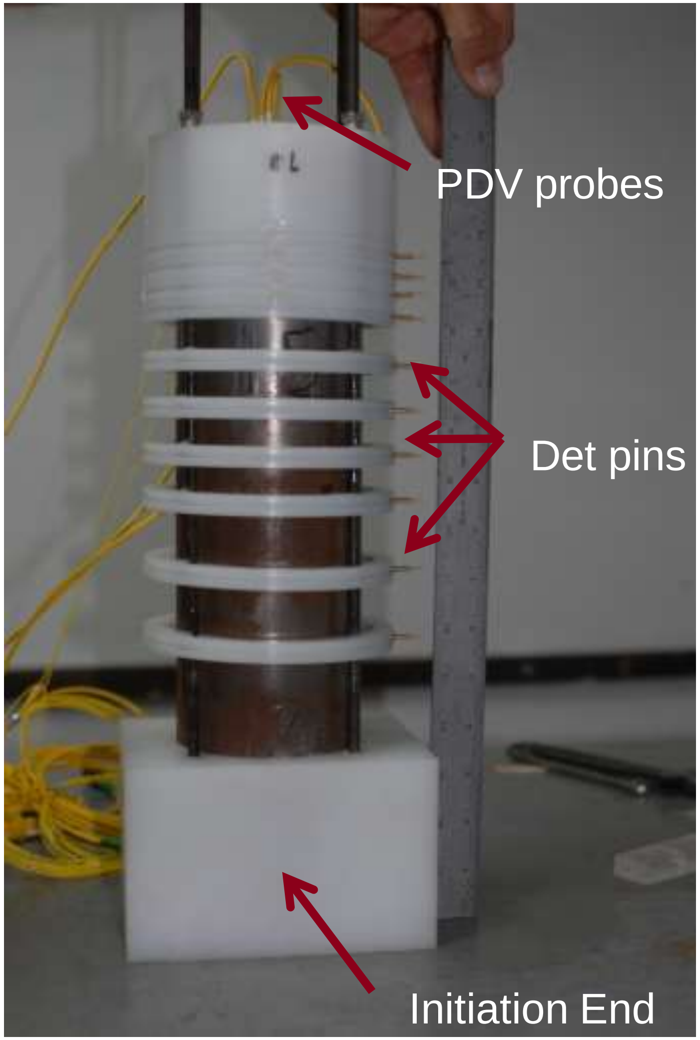
- In order to ensure the Reactive Flow models are correct, additional testing is required
  - Results of the tests will be compared to results of the Reactive Flow Model via Hydrocode Models
    - If results do not match, experimental data can be used to tune the Reactive Flow Model
  - Additional Tests include:
    - Expanded Large Scale Gap Test (ELSGT)
    - Unconfined Detonation Velocity Tests
    - 2D Corner Turning Test

Cold Confined Detonation Velocity and CJ Pressure Testing

Unclassified

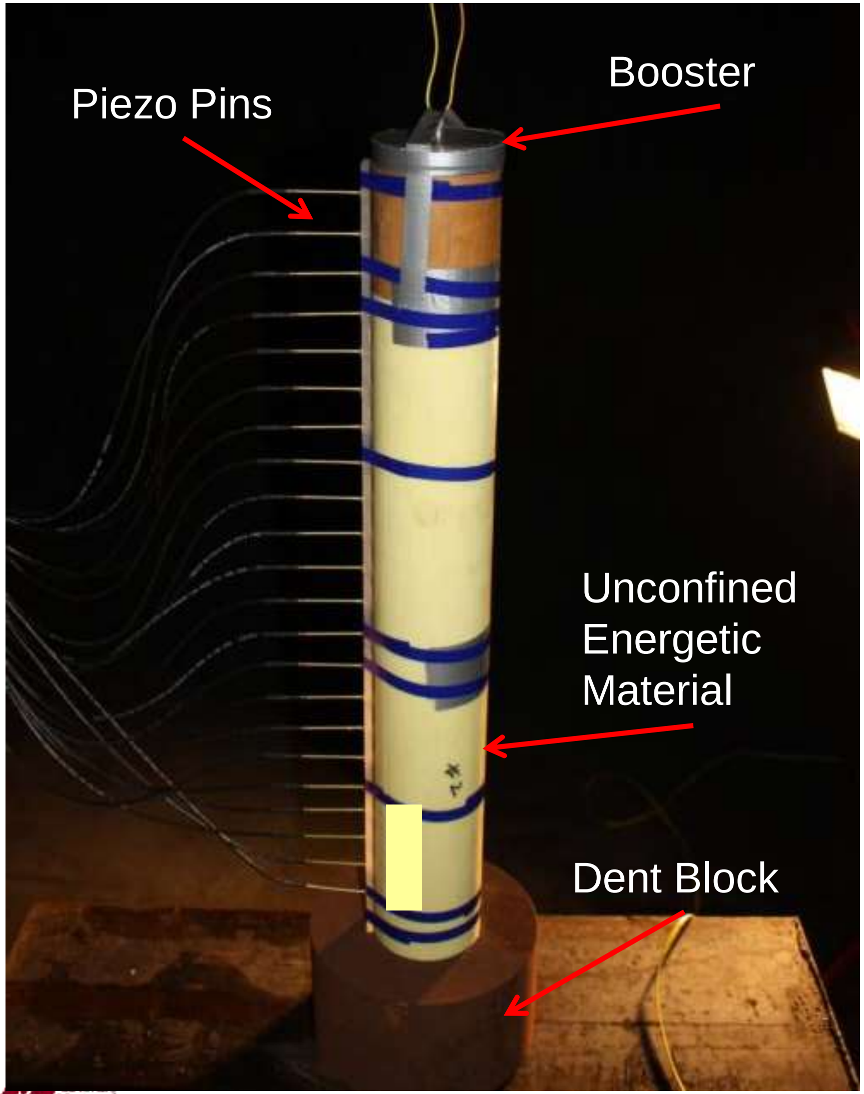
- Cold temperatures have been shown to have an effect on the kinetics of IM explosives, especially initiating at near critical diameter, temperature could cause a change in the performance that would affect the likelihood of initiation.
  - The results are used to validate the Reactive Flow Model





lassified
pproved for public release

Unconfined Detonation Velocity Test

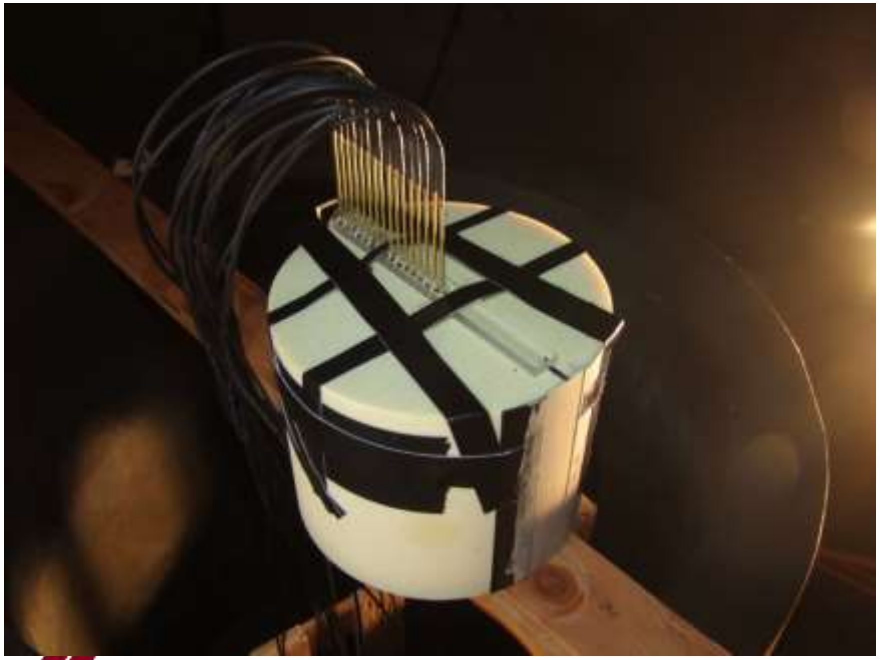


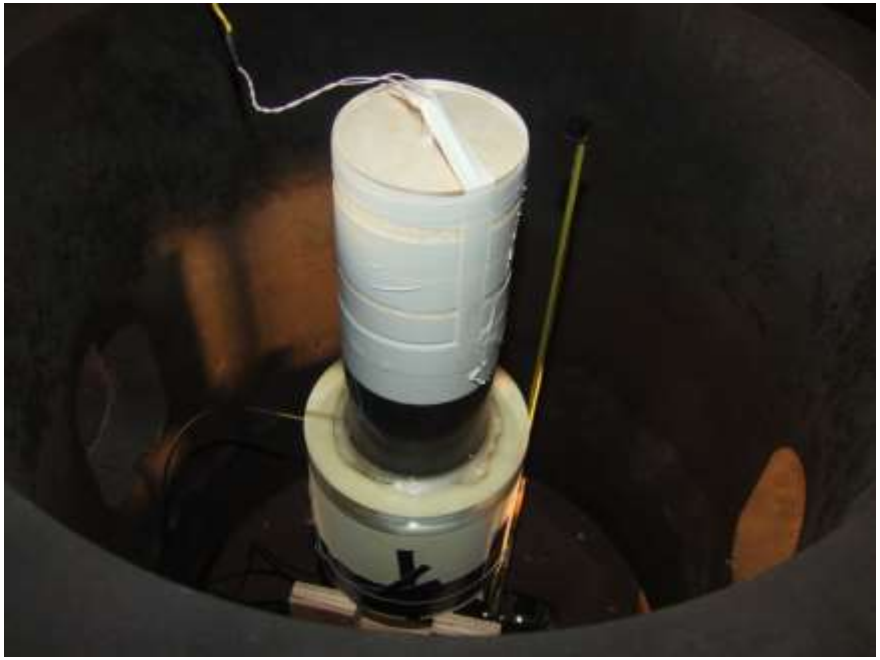
- Unconfined Detonation Velocity Tests are performed to determine the critical diameter of the energetic material
  - The results are used to validate the Reactive Flow Model

- Lesson learned from test:
  - Ensure length of unconfined material is long enough for detonation to reach steady state

2D Corner Turning Test

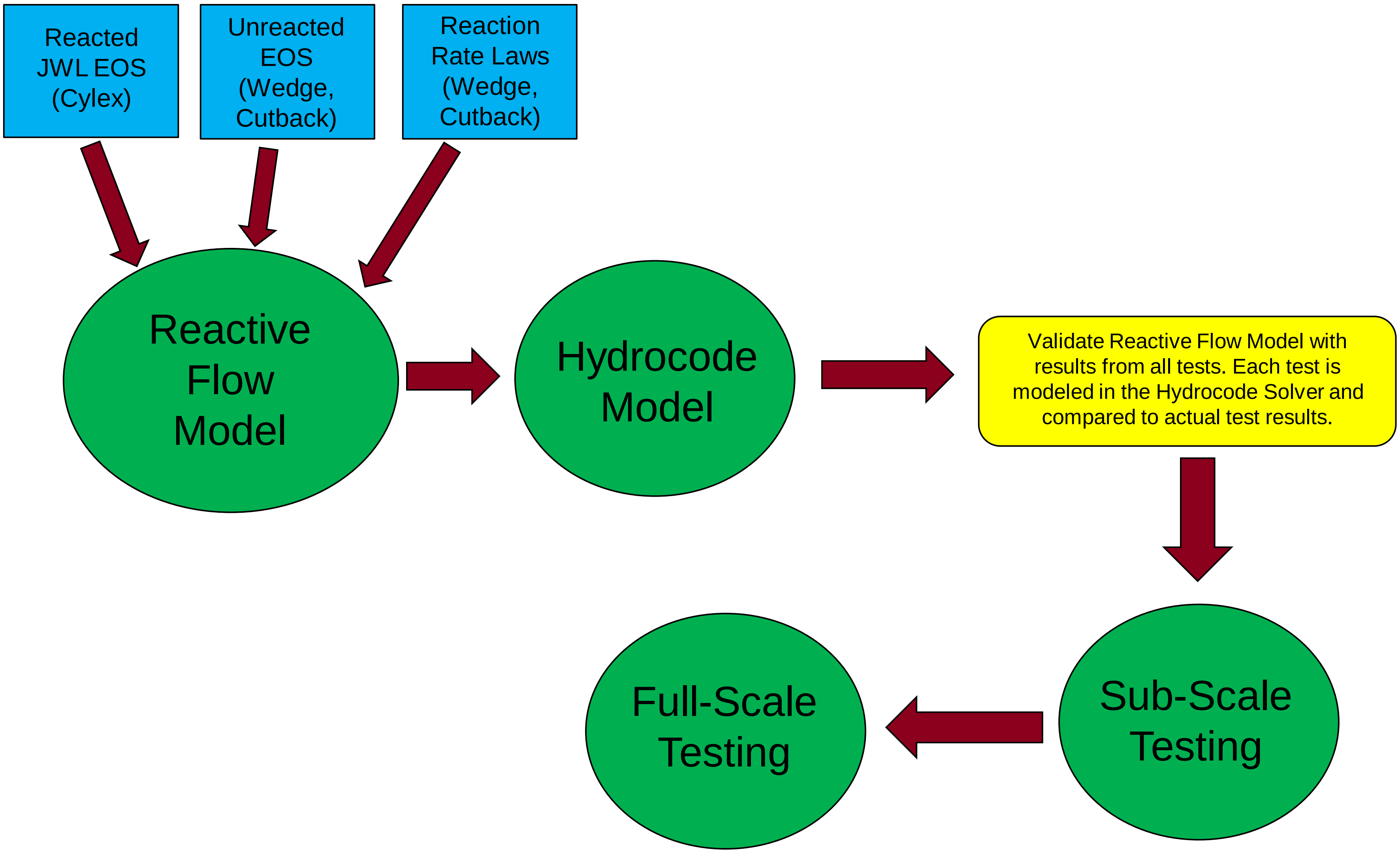
- Insensitive explosive usually have poor corner turning performance
- A relatively simple and easy diagnostic test can be performed to ensure the model predicts the 2D corner turning behaviors of IM explosives
- Test Results will be used to validate the Reactive Flow Model and can be used to tune the model if the results do not match.





Process Overview

Unclassified



Conclusion

- To develop a Hydrocode model the following 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, 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 update system
- The validated Reactive Flow Model can then be applied to any munition application that wishes to utilize the specific insensitive explosive material

Acknowledgements

- ARL
- AFRL
- LLNL
- AFMO
- ARDEC