EVALUATION OF SYMPATHETIC DETONATION SHIELDING CONCEPTS FOR SHIP-STOWED MUNITIONS

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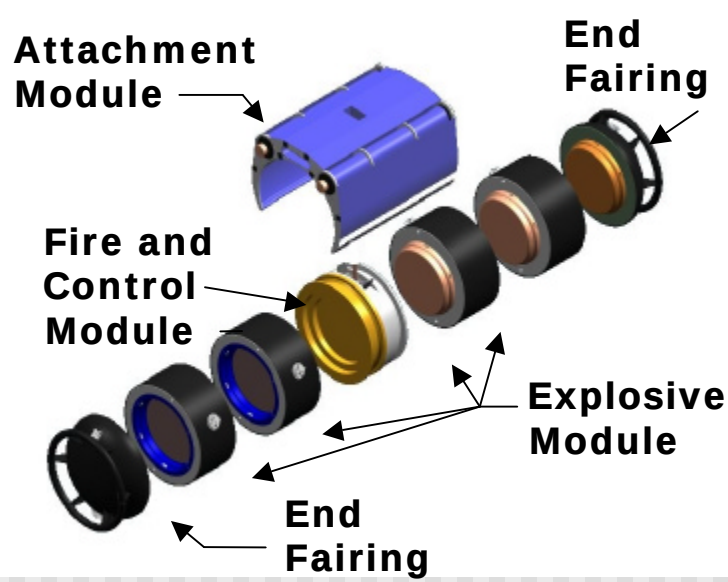
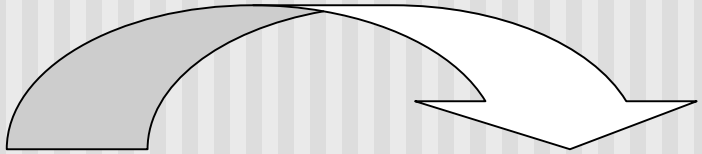
Objectives

- Develop a shielded container system for ship-stowed ILM (Improved Limpet Mine) explosive modules to comply with MIL-STD-2105B section 5.2.5 for prevention of Sympathetic Detonation (SD).



ILM Explosive Module Sectional View



Generic Shipping Container (example)

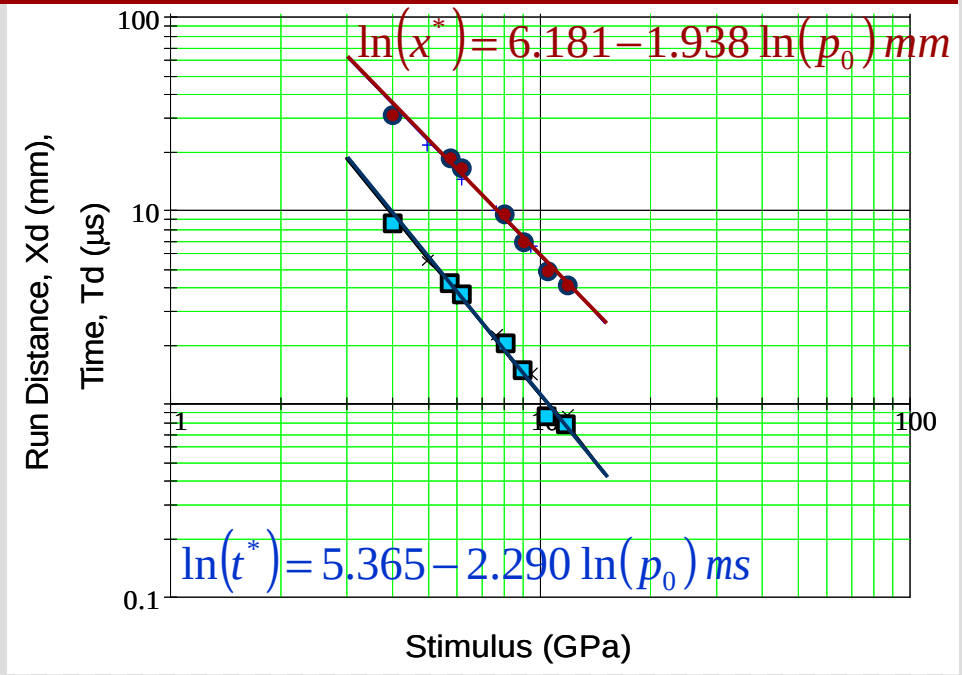
Approach

- Hydrocode analysis
  - Construct & validate a reactive flow model for the main fill explosive (PBXN-111).
  - Investigate baseline stowage configuration
    - foam dunnage, no shielding.
  - Explore effectiveness of SD shielding material
    - Pumice in an HTPB binder system (Kandell, NAWC - CL).
- Experimental
  - Conduct SD Testing using shielded ILM modules.

Reactive Flow Model

- PBXN-111 wedge test data fit to History Variable Reactive Burn (HVRB) model for CTH hydrocode.
- Model exercised (validated) in simulations of the Large Scale Gap Test (LSGT).

Experimental and Predicted Pop Plots



	Gap, PMMA	Peak Pressure
Experimental	1.30 inch	47 kbar
Calculated	1.68 inch	58 kbar

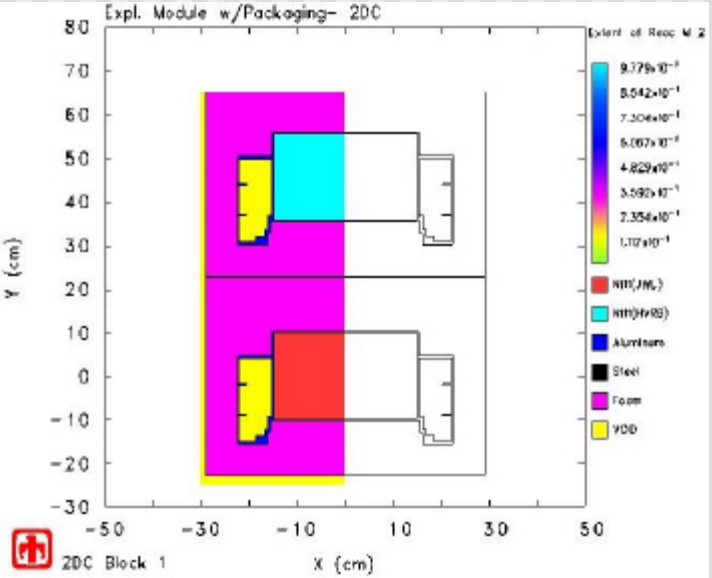
Experimental and Predicted LSGT Results

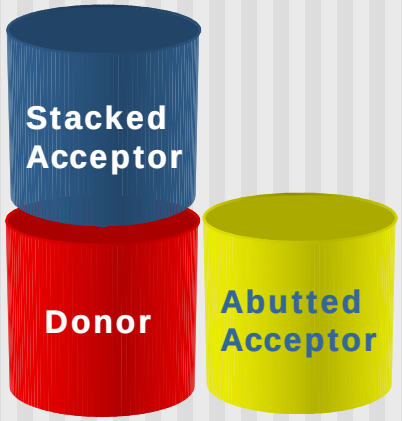
- **PMMA attenuation in model?**
- **Model likely 'insensitive', but…**
- **…qualitative agreement with experiment**

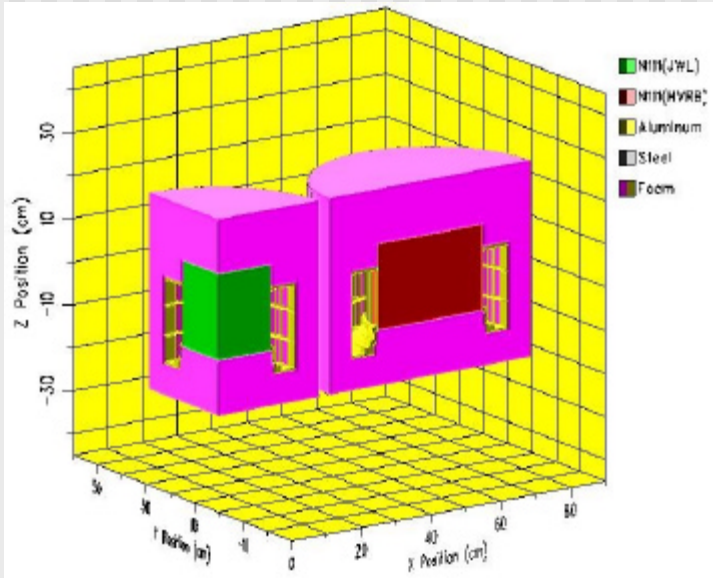
Hydrocode Analysis

- Purpose
  - Use PBXN-111 reactive flow model to assess SD risk.
- Analysis Matrix (2 x 2)
  - Shielded verses Unshielded stowage configurations.
  - Stacked and Abutted munitions.

Shipping Canisters
(shielding inside canisters, not between)

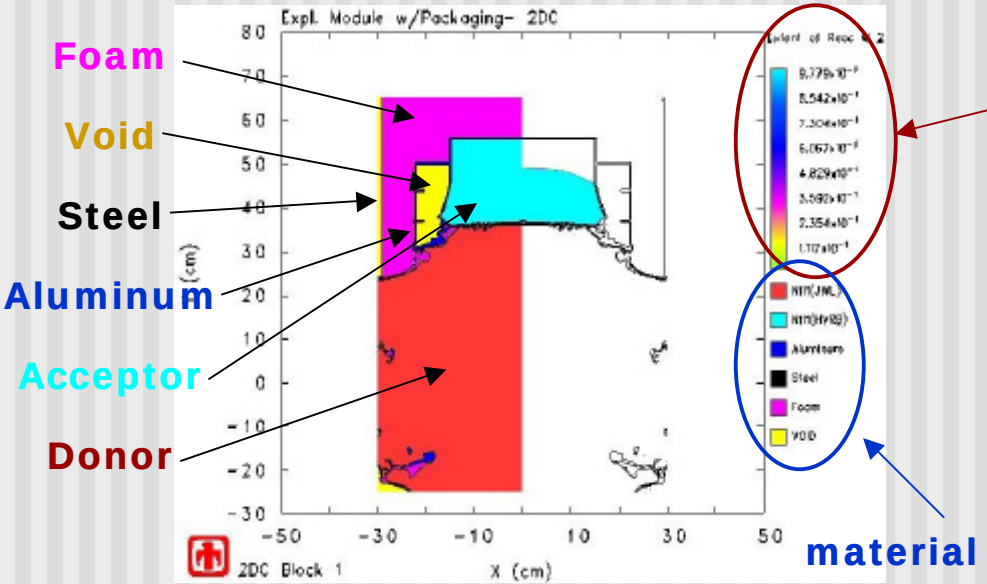




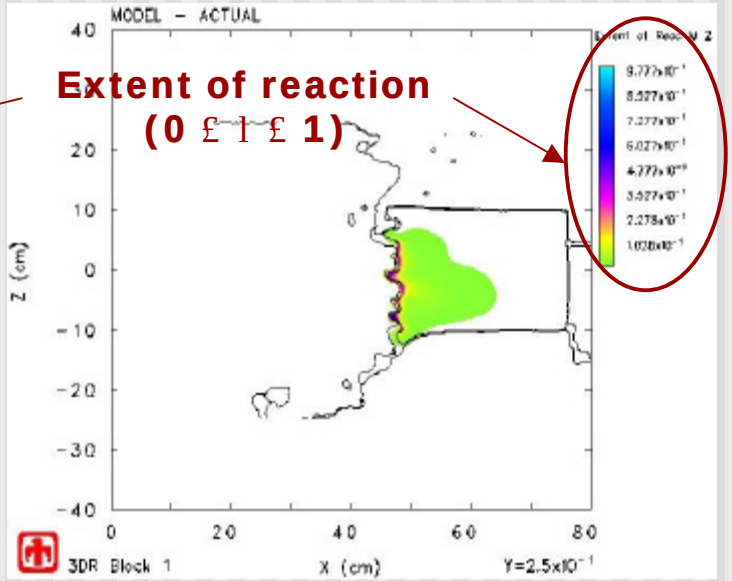


Baseline Configuration (Unshielded)

Stacked Munition at 175µs



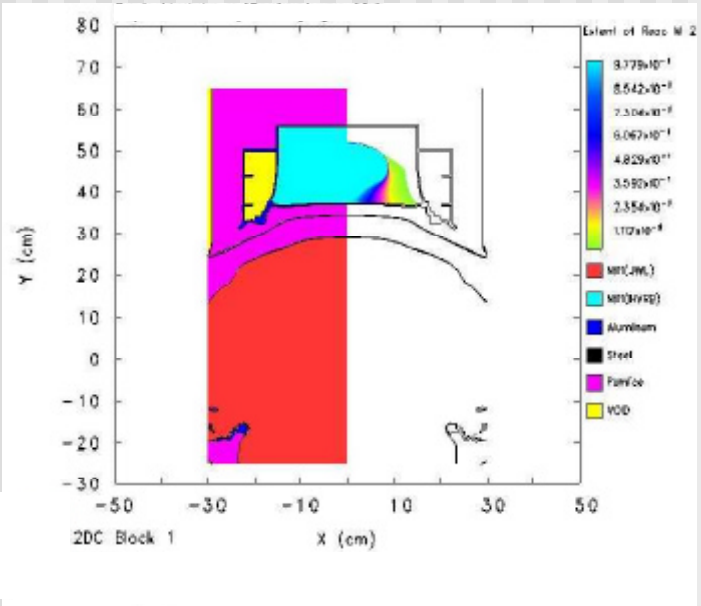
Abutted Munition at 275µs



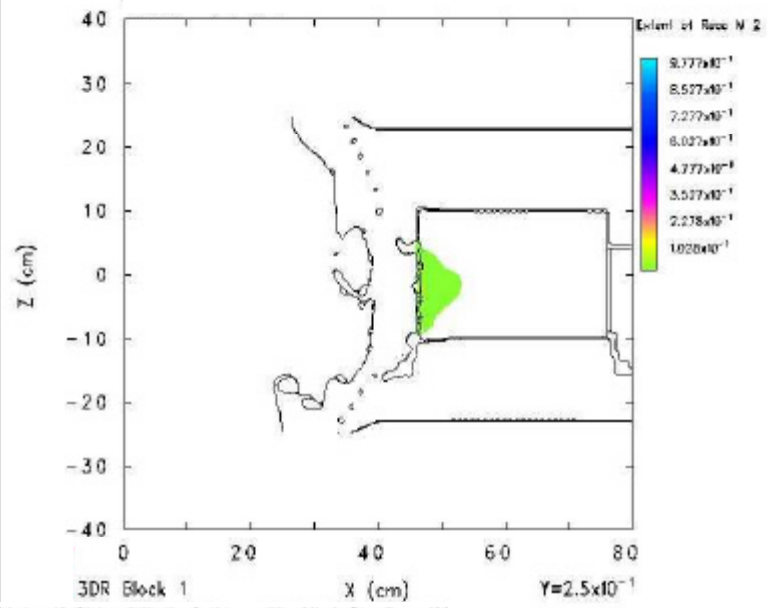
- Stacked – Full Reaction (prompt SDT)
- Abutted – Partial Reaction (low order XDT?)

Shielded Configuration (HTPB/Pumice)

Stacked Munition at 250µs



Abutted Munition at 275µs



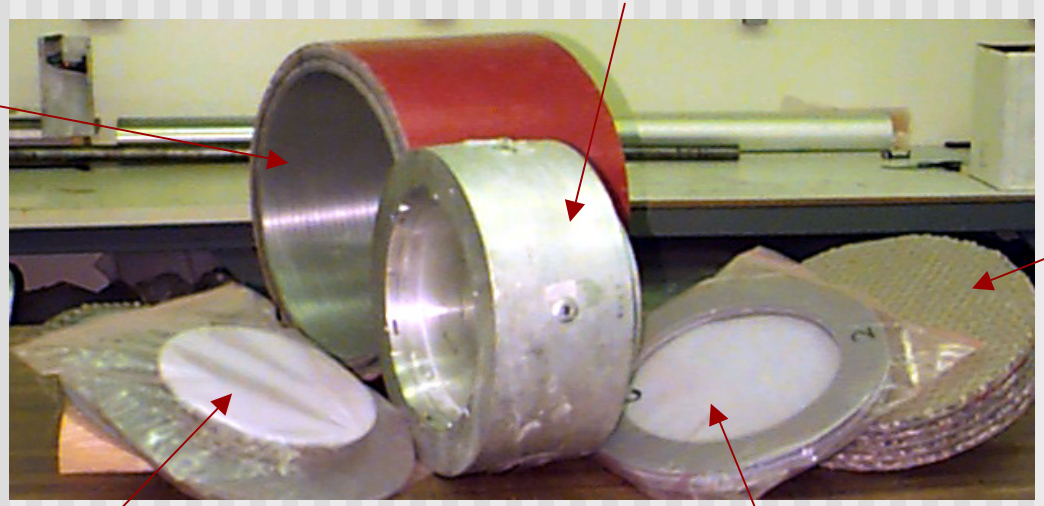
- Stacked – Full Reaction (slightly delayed SDT)
- Abutted – Almost No Reaction (< 1% over small region)

Analysis — Findings

- Unshielded ILM modules do not comply with MIL-2105B for SD
  - Stacked – prompt SDT
  - Abutted – some (low order) reaction likely
- HTPB / pumice shielded modules not compliant
  - Stacked – delayed SDT
  - Abutted – slight reaction
- …investigate advanced shielding concepts.

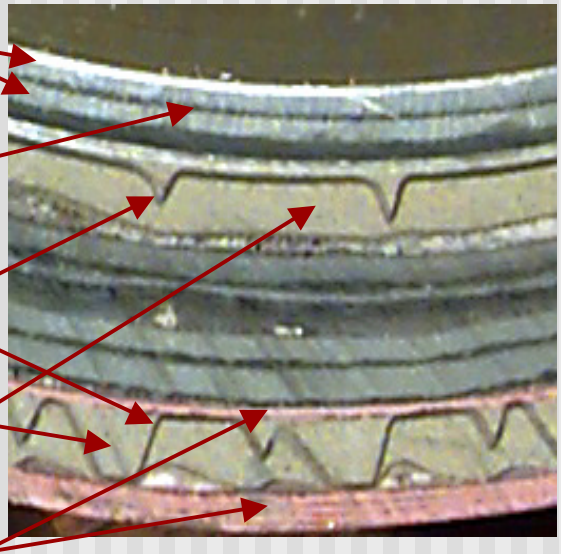
Experimental Effort

- Purpose
  - Investigate ARC (Atlantic Research Corporation) Tuff-Core™ barriers as a possible alternative to HTPB/Pumice.



Barrier Structure

Filament-Wound Cylinder



- Complex engineered structure.
- Cost & weight issues.
- Challenging to model.

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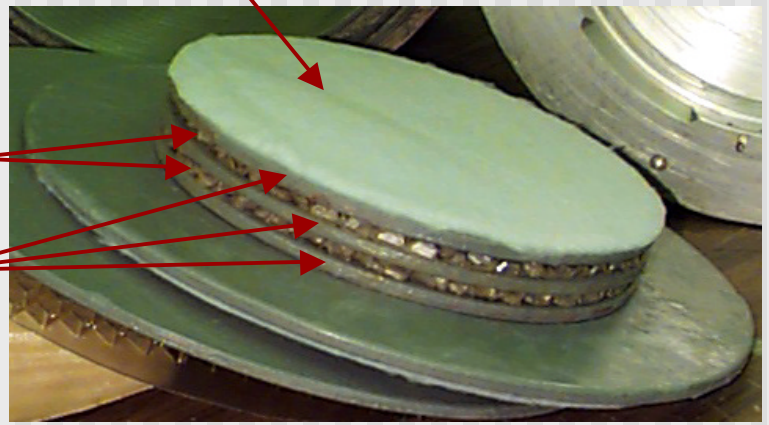
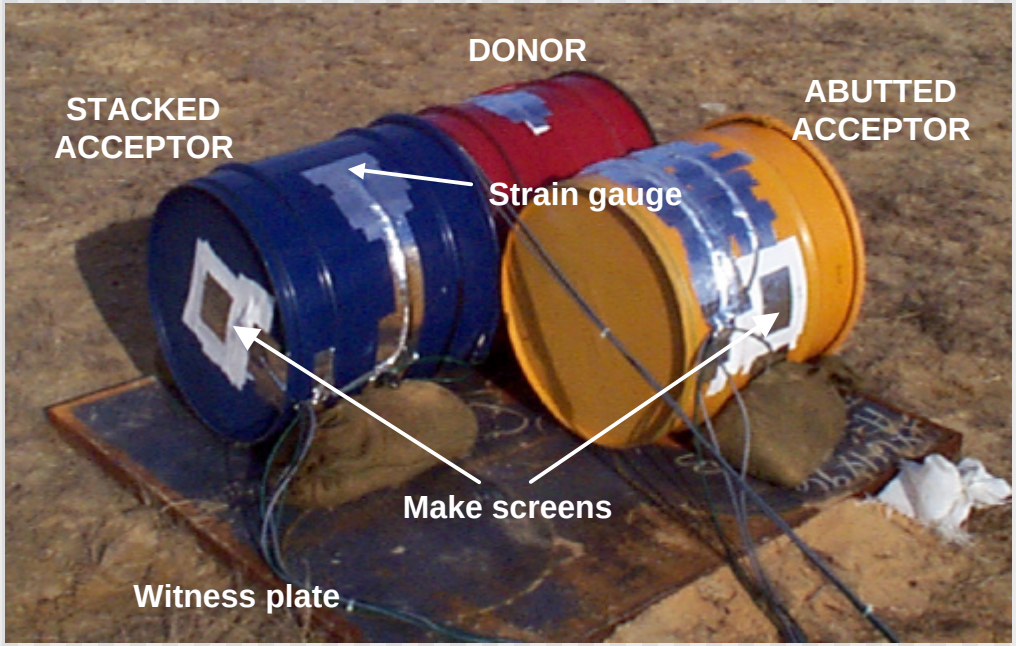


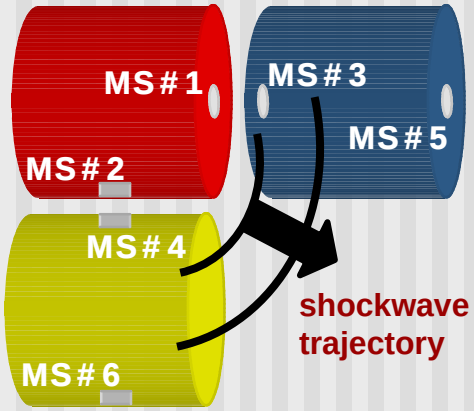
Test Setup

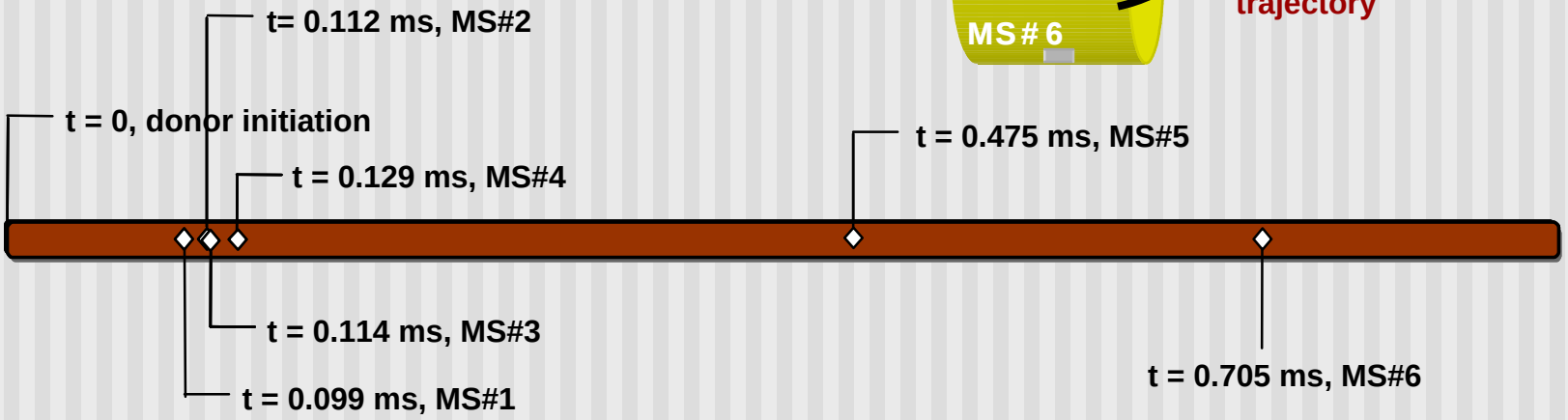
- Electronic Instrumentation
  - 1000Ω strain gauges
    - TOA, acceptor response
  - Make screens
    - TOA
- Camera Coverage
  - 16mm (22K/s, 44K/s)
  - VHS Video
  - Digital Photographs
- Post-Mortem
  - 2” steel witness plate
  - Fragment Collection
- Testing performed at NSWCDD Pumpkin Neck site



Test Results — Electronics

- Make screens
  - Transit time through yellow acceptor > through blue
  - Shock trajectory is more ‘top→bottom’ than ‘right →left’
- Strain gauges
  - No data acquired
  - Gauge survivability at issue
  - Frequency response no problem

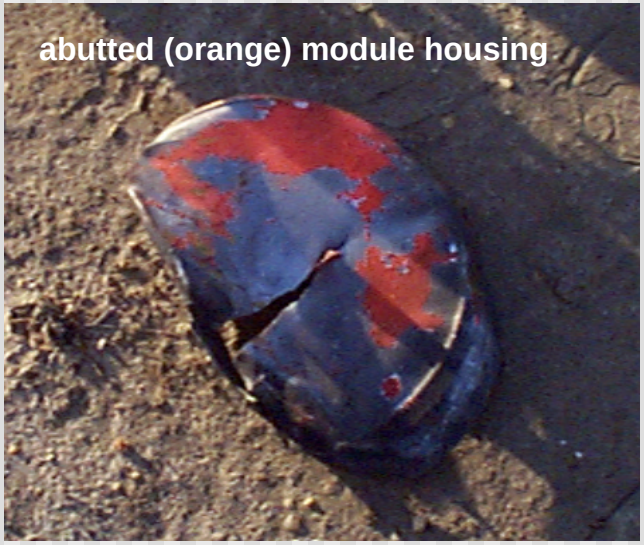




Test Results — Camera Coverage

- 16mm High-Speed Film (22K fps)

Test Results — Post Mortem



Experimental — Findings

- Full detonation of stacked module
- Partial Burning of abutted module
- ARC barrier (cost, weight, and performance)
  - Cost reduces according to production scale
  - Weight reduction being explored
  - Shock attenuation properties being improved

Summary

- Test results using ARC Tuff-Core shielding match hydrocode predictions using HTPB / pumice.
  - SD event for stacked munition
  - No SD for abutted munition
- Test / analysis results bracket a detonation threshold
  - Threshold somewhere between abutted and stacked configurations
- We are close to a solution
  - Can store 4 canisters side-by-side on a single shipping pallet without an SD event.
  - Test / Modeling assumes 8 canisters per pallet with stacking
  - Pallet standoff distance plus additional shielding would likely prevent SD for stacked munitions