

2010 Insensitive Munitions & Energetic  
Materials Technology Symposium

*Modeling & Simulation — an Enabler for IM  
Development & Assessments*

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STRATEGIC INSIGHT



*Weapons & Munitions M&S Initiative  
In the US DoD*



- The DoD is leveraging and adapting the *science-based* M&S tools developed by the DOE to provide a predictive capability for the DoD acquisition community.
- The *goal* is to reduce development risk, acquisition costs & schedule for the design & evaluation of DoD systems in an environment of reduced testing and mandated safety & IM compliance.



Dept of Defense  
Joint Service Labs

Dept of Energy  
National Labs

*Collaborative Environment will aid the Safety & IM communities*

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*Weapons & Munitions M&S Initiative*



- **SBIRs & STTRs** are important components that supplement this government initiative
- Use the collaborative input from the small business + government/academia partners to meet the MSI goals by:
- Reducing acquisition cycle time and development costs
  - Integrating S&T State-of-Art into weapon acquisition
  - Reducing program risk
  - Reducing required testing (i.e., testing “smarter”)
- Fielding safe, IM compliant weapon systems
  - Maintaining performance goals
  - Understanding performance margins rather than point solutions

**Institutionalize M&S Advancements Into  
DoD Acquisition Culture**

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*M&S — an Enabling Capability*



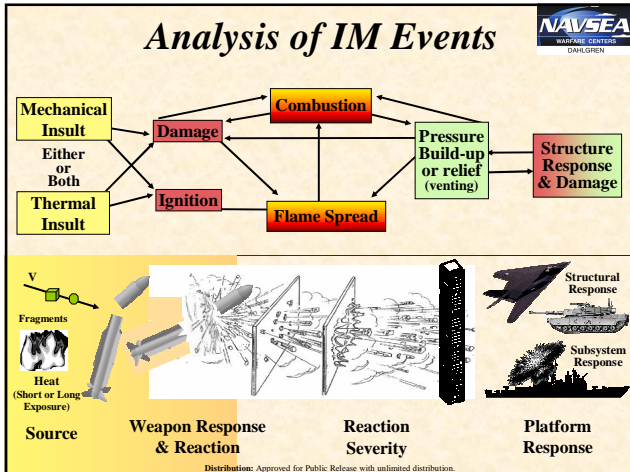
- Predictive modeling tools capable of assessing energetic response can be used to aid in the prevention & mitigation of IM hazards and threats
- M&S tools can enable the design of subscale tests that often predict the outcome of full-scale IM tests
- M&S tools are an aid in test data interpretation
- M&S tools can enable the quantification of statistical uncertainties and design margins, supplementing fewer number of tests
  - Aid in defining the response envelope rather than simple pass or fail — How close was munition to pass or fail?
  - Pass by chance or by design?
- M&S tools can enable performance & safety trade-off studies early in the design phase



*Improve Confidence in Safety Margins*

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### Weapons & Munitions M&S Initiative Philosophy for IM M&S

IM Tests Fastest Time Scales	BI 10 <sup>-3</sup> s	FI 10 <sup>-3</sup> s	SD 10 <sup>-3</sup> s	FCO 10 <sup>-2</sup> s	SCO 10 <sup>+5</sup> s	SCJ 10 <sup>+6</sup> s
Phenomenology						
Penetration	✓	✓				
Mechanical Damage & Ignition	✓	✓				
Thermal Ignition	✓	✓		✓ 2 <sup>nd</sup> Gen	✓	
Shock Initiation	✓	✓	✓			✓
Burn & Explosion	✓	✓	✓	✓ 2 <sup>nd</sup> Gen	✓	✓
Integrated violence of Response	✓	✓	✓	✓	✓	✓

**Code Gaps**

- Numerics Must Couple Across Disparate Time Scales
- Numerics Must Couple Multiple Physics

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### STTR for MDA — M&S Capability for IM Applications —

- **Topic:** “Expedited Transition of Propulsion Modeling & Simulation Capability”
- **Objective** — Facilitate making M&S capabilities more accessible to industry for IM related applications
- **Primary focus** — propulsion systems & selected potential hazards:
  - Bullet & fragment impact threats
  - Fast heating hazards (liquid fuel fires)
- **Scope** — areas of interest includes M&S tools for:
  - Propulsion systems analysis including propellants, confinement & integral mitigation methods for improved IM performance
  - System level design solutions for mitigation of threats & consequences

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### M&S Focus on Propulsion Systems

- Propulsion systems historically have been the “bad actor” for weapon system IM compliance
- This is especially true for very large rocket motors where:
  - IM and HC test costs are significantly higher
  - A lack of adequate test facilities limits options
  - There are too many combinations to test:
    - Multiple logistic and life-cycle configurations
    - Exposure to many potential hazards and threats
- Provide a sustainable validated toolkit for industry
- Improve our confidence in design safety margins

**Mass & length variation exceeds current scaling capability**

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## Current M&S related STTR for MDA

■ **Phase I: Summary conclusion for path forward** —>  
 “IM propulsion technology, including propellant formulations and M&S of propellant initiation & reaction growth, is immature and requires substantial continued investment. The current state-of-the-art technology is impeding the development of IM-compliant propulsion systems with the performance required for system applications.”  
**Solution:** overcome current limitations by developing and transitioning M&S technology enabling industry to design and develop mitigation systems meeting IM criteria.

■ **Phase II** \*:
 

- Develop “Knowledge Structure” for weapon PMs to support integration & transition of M&S tools.
- Develop & demonstrate M&S tools to address specific IM hazard mitigation analyses for propulsion systems.

■ **Phase III** \*:
 

- Demonstrate M&S tools to address IM hazard mitigation analyses for application to a specific weapon propulsion system.

\* Technical partners Lawrence Livermore National Laboratory and Sandia National Laboratories are assisting the knowledge structure and providing specific hazards mitigation analyses.

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## Violence of Reaction is Uncertain (1 of 3)

**SINGLE TEST: no reaction or burn or explosion (phenomena not well understood)**

The graph plots Reaction (y-axis) against Delivered Energy (x-axis). A solid black curve labeled "Damage" starts at the origin and rises. A legend in the bottom right shows a red square for "Energy Applied" and a yellow circle for "Energy Delivered".

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## Violence of Reaction is Uncertain (1 of 3)

**SINGLE TEST: no reaction or burn or explosion (phenomena not well understood)**

The graph is similar to slide 10, but includes a dashed purple circle around the "Damage" curve labeled "Ignition?". The legend remains the same.

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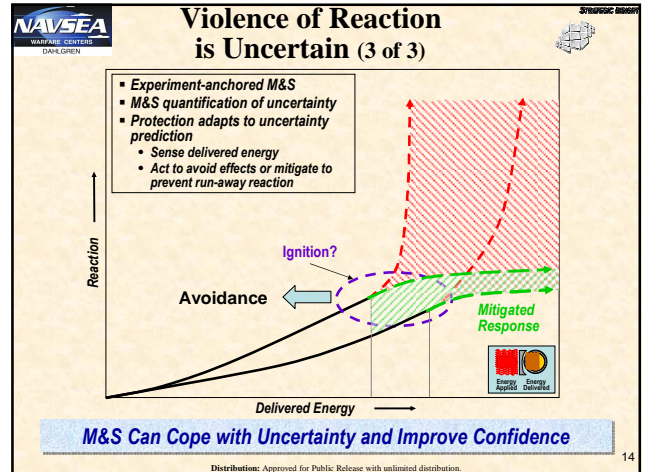
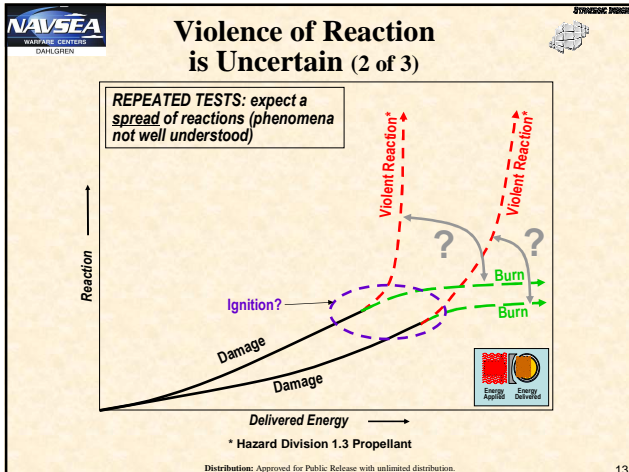
## Violence of Reaction is Uncertain (1 of 3)

**SINGLE TEST: no reaction or burn or explosion (phenomena not well understood)**

The graph adds a dashed red curve labeled "Violent Reaction\*" and a dashed green curve labeled "Burn". A question mark is placed above the "Burn" curve. The legend remains the same.

\* Hazard Division 1.3 Propellant

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### Utility of M&S in the Weapon Development Process

- Quantify the region of “uncertainty” associated with single or multiple trials to establish the weapon level of response to the IM stimulus
- This is a cornerstone approach in MDA’s STTR process where a M&S tool set is evolving for industry use in propulsion system development.

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### Summary

- DoD is engaged in a phased development of M&S tools to assist IM design & evaluation efforts for propulsion systems.
- Technical integration via STTR contracts (knowledge structure + future model demonstrations) supports the DoD initiative.
- Benefits of propulsion M&S capability:
  - Earlier evaluation of performance-safety tradeoffs
  - Safer designs without sacrificing performance (avoidance & mitigation strategies are key)
  - Better knowledge of design boundaries & margins

... A Win for Propulsion System Developers where System Safety, IM and System Performance Must Be Balanced!

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***Other M&S Related STTR Activities***  
(endorsed by NAVSEA)

- **Topic: “*Lightweight Layered Protection Systems for Missile Launchers & Canisters*”**
  - **3 Phase I contracts underway**
  
- **Topic: “*Small-Scale Experimental Rationale for Solid Rocket Propellant Hazard Response*”**
  - **Anticipate Phase I awards soon**

*Additional government / industry collaborations are continuing to assist in the formulation of system solutions for IM*