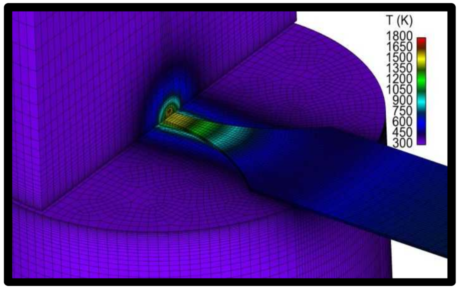
SAND2016-8459PE

Exceptional service in the national interest



Energetic Materials & Devices: Engineering Mastery through Science & Technology

Leanna Minier

Energetic Material Dynamic and Reactive Science

August 30, 2016

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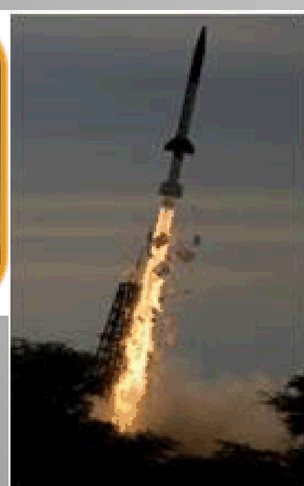
Environmental Testing Facilities

Asset Security and WMD Response



Integrated Military Systems

Nuclear Weapons and non-nuclear energetic components

nuclear weapons………

ALWAYS

NEVER

RELIABLY

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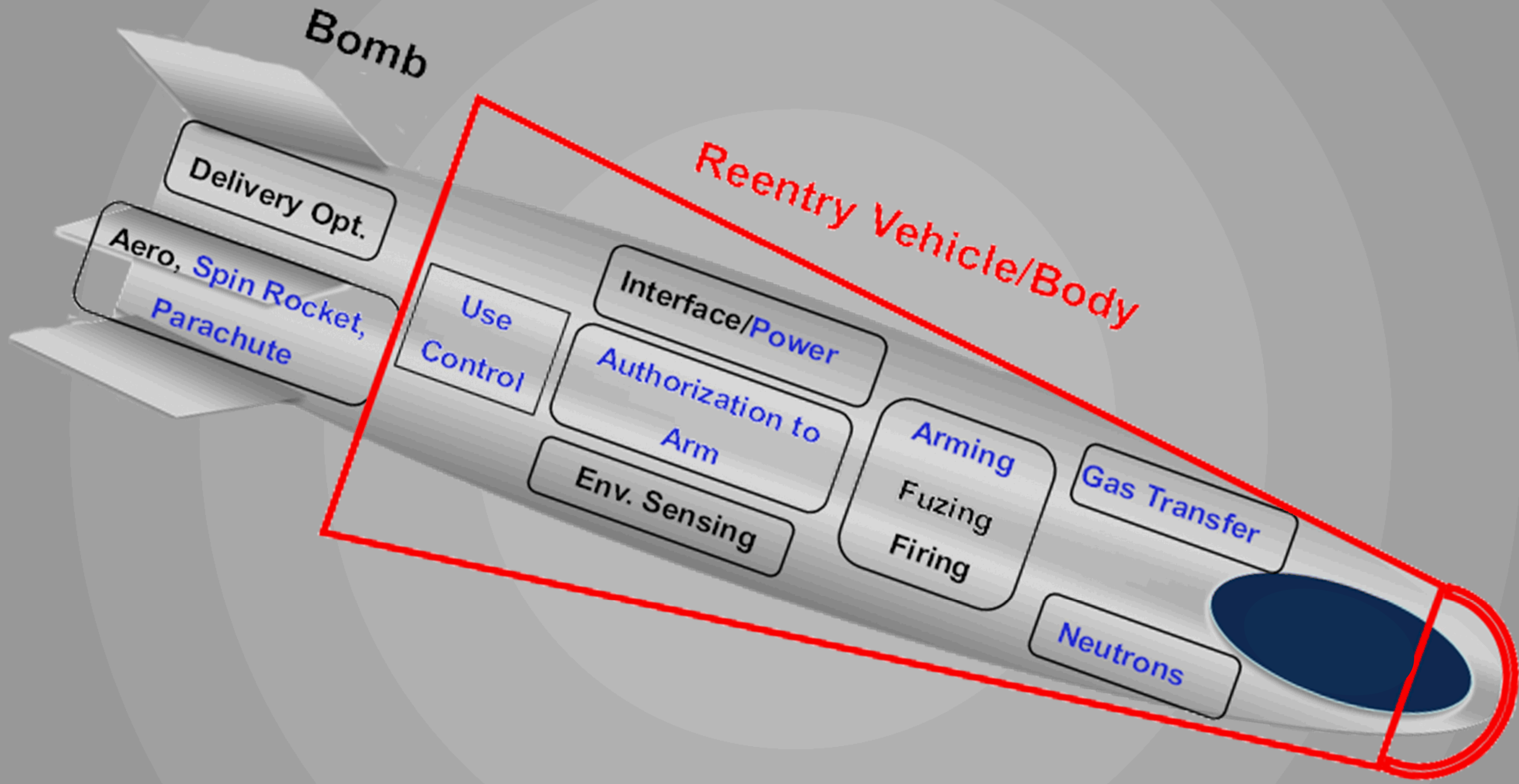
Sandia National Security Mission: Weaponization and Lifecycle



Contributing S&T to achieve engineering mastery:

- understanding underpinning science of multiple energetic technologies
- advancing theories, diagnostics, capabilities, and comp/sim tools
- integrating S&T into product life cycle

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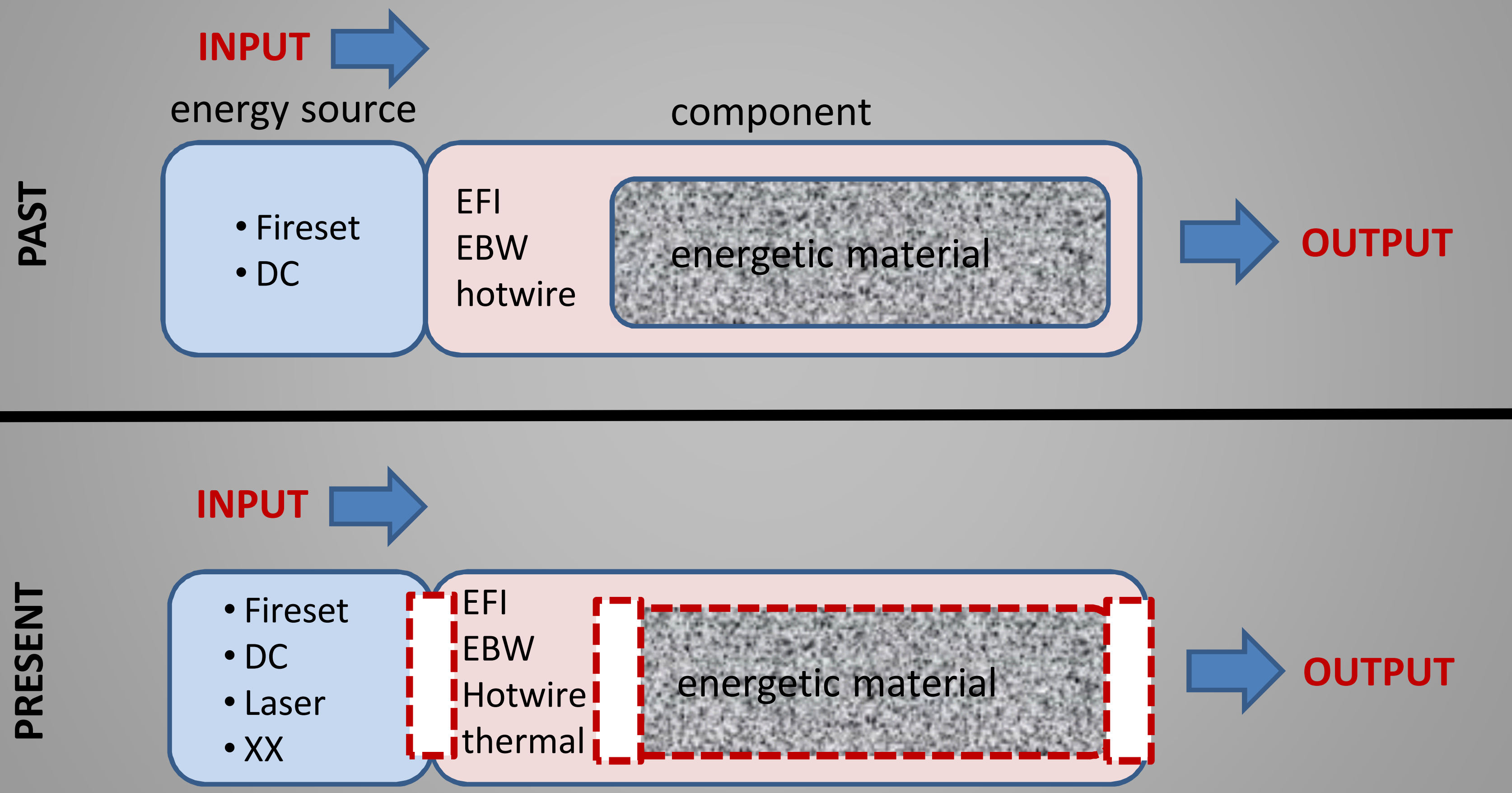
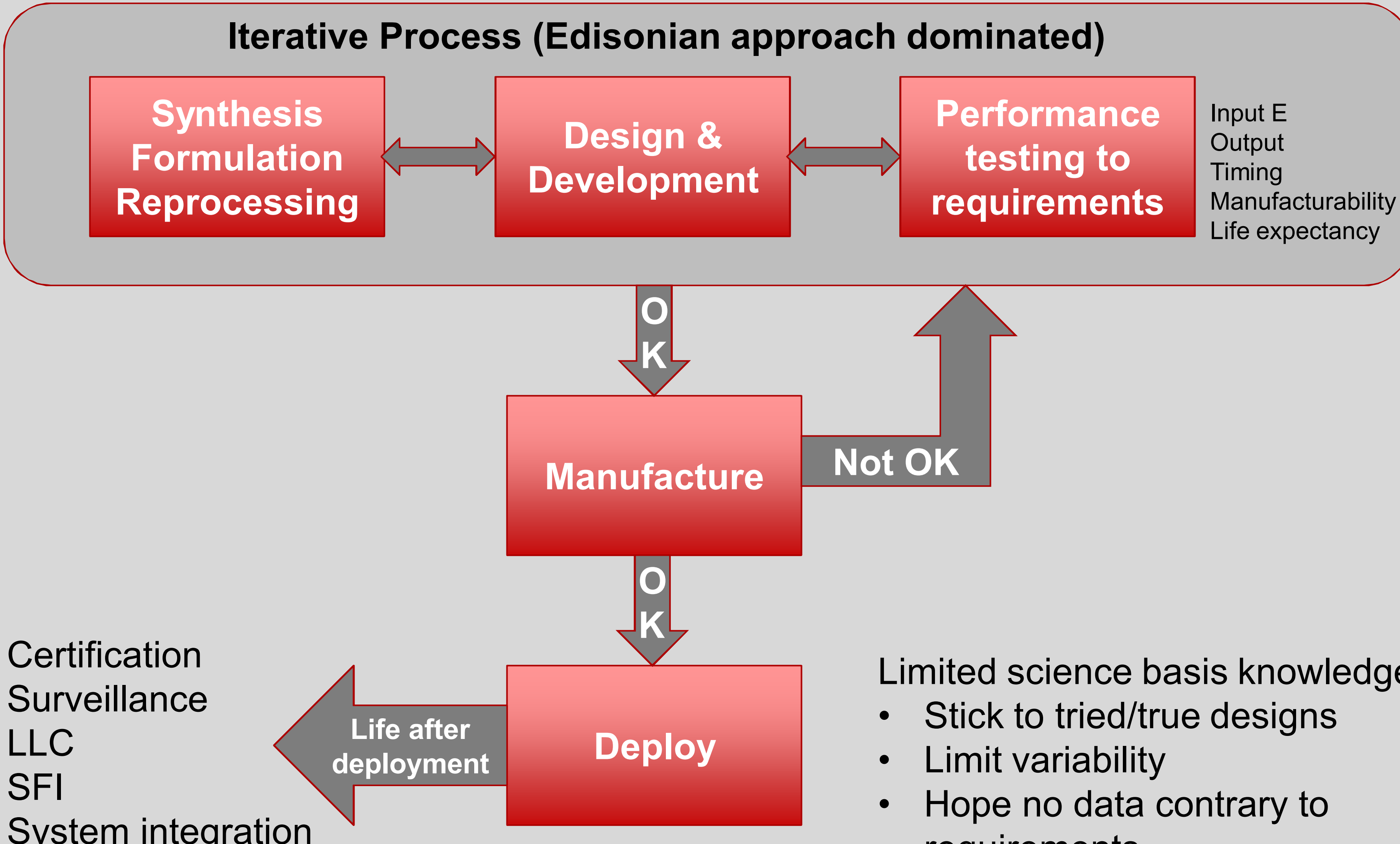
Goals:
model-based design and accelerated cycles of learning



S&T is basis for achieving goals!

Point design process demonstrates need for science-based understanding

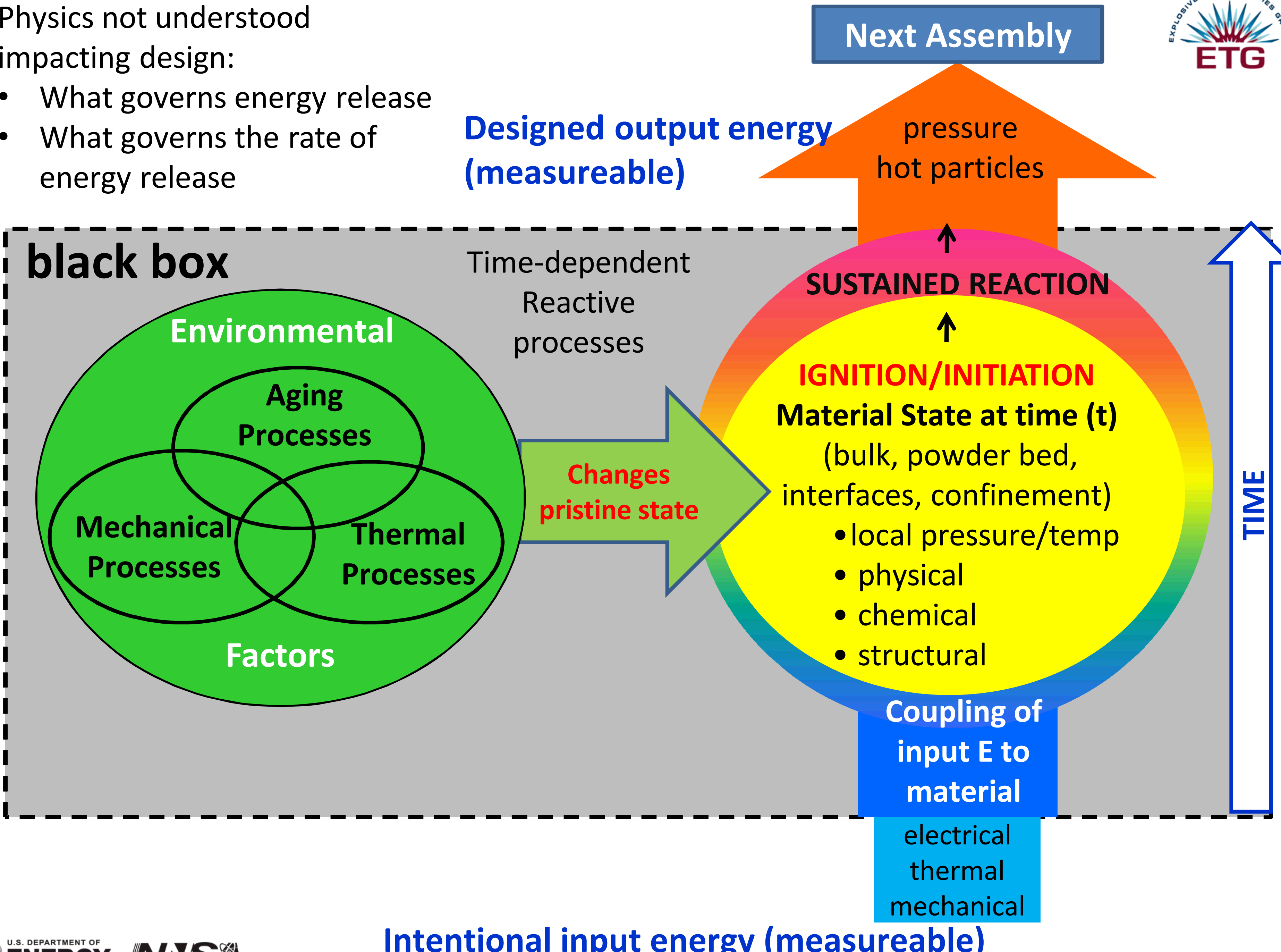


Limited science basis knowledge

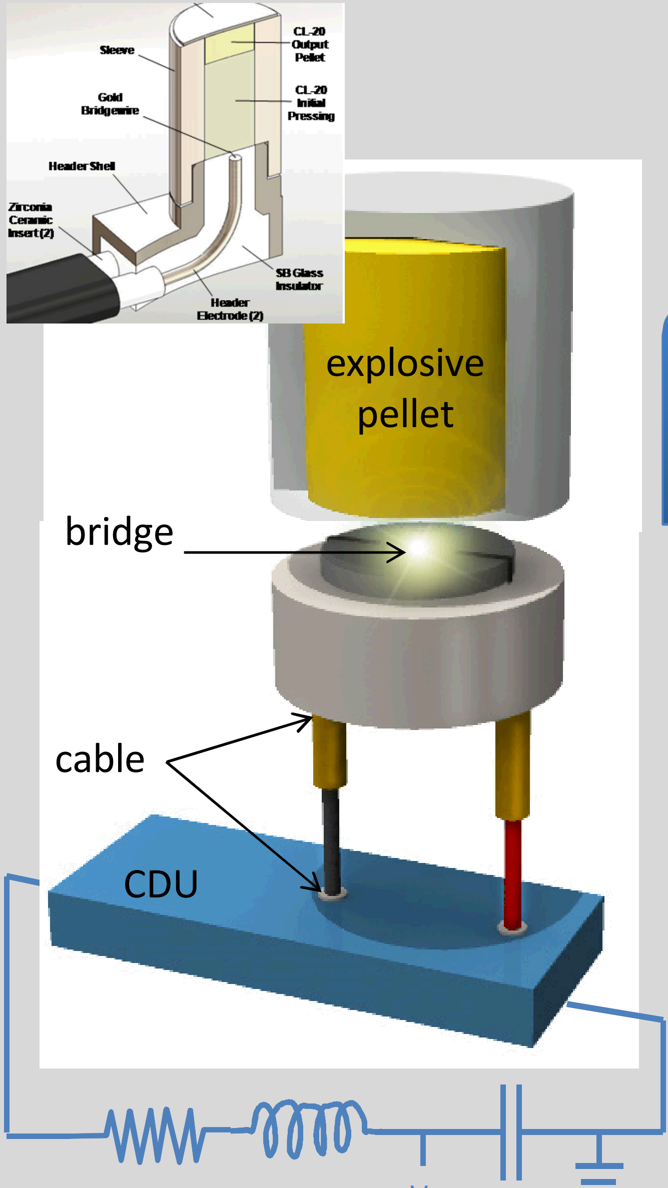
- Stick to tried/true designs
- Limit variability
- Hope no data contrary to requirements

Physics not understood impacting design:

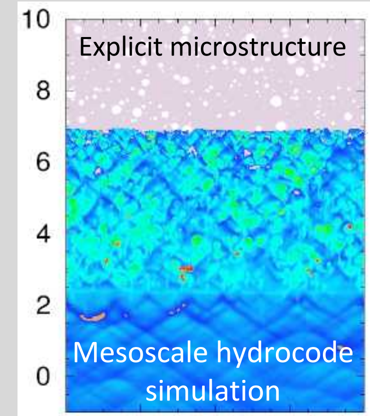
- What governs energy release
- What governs the rate of energy release



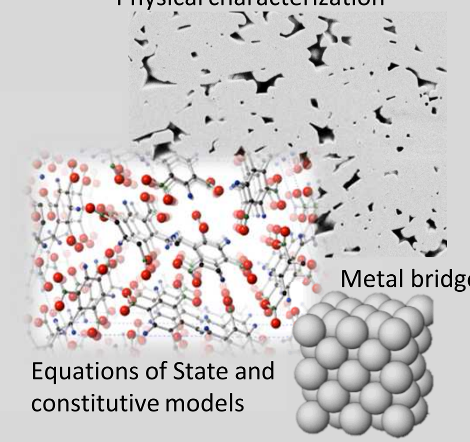
EBW Detonator Technology / Engineering / Science

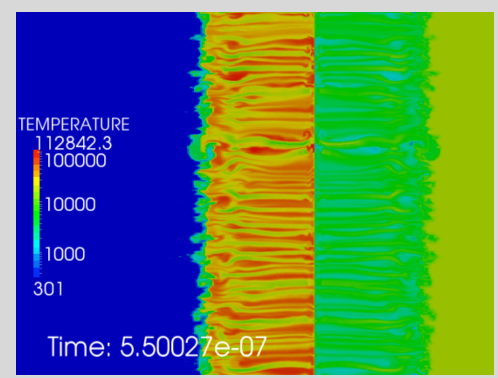


Chemical energy is released and the shock transitions to detonation	Reaction mechanisms and rates. Computational burn-model framework.
Shockwave energy is localized by heterogeneities creating hot-spots	Microstructural characterization Constitutive models Explicit computational representation
Bursting wire imparts a stimulus into explosive pellet	First-principles equations of state for energetic molecular crystals
Metal bridge rapidly expands (burst)	Wire expansion predictions and measurements
CDU: Energy in the capacitor is delivered to the bridge	First-principles electrical conductivity models and equations of state for metals



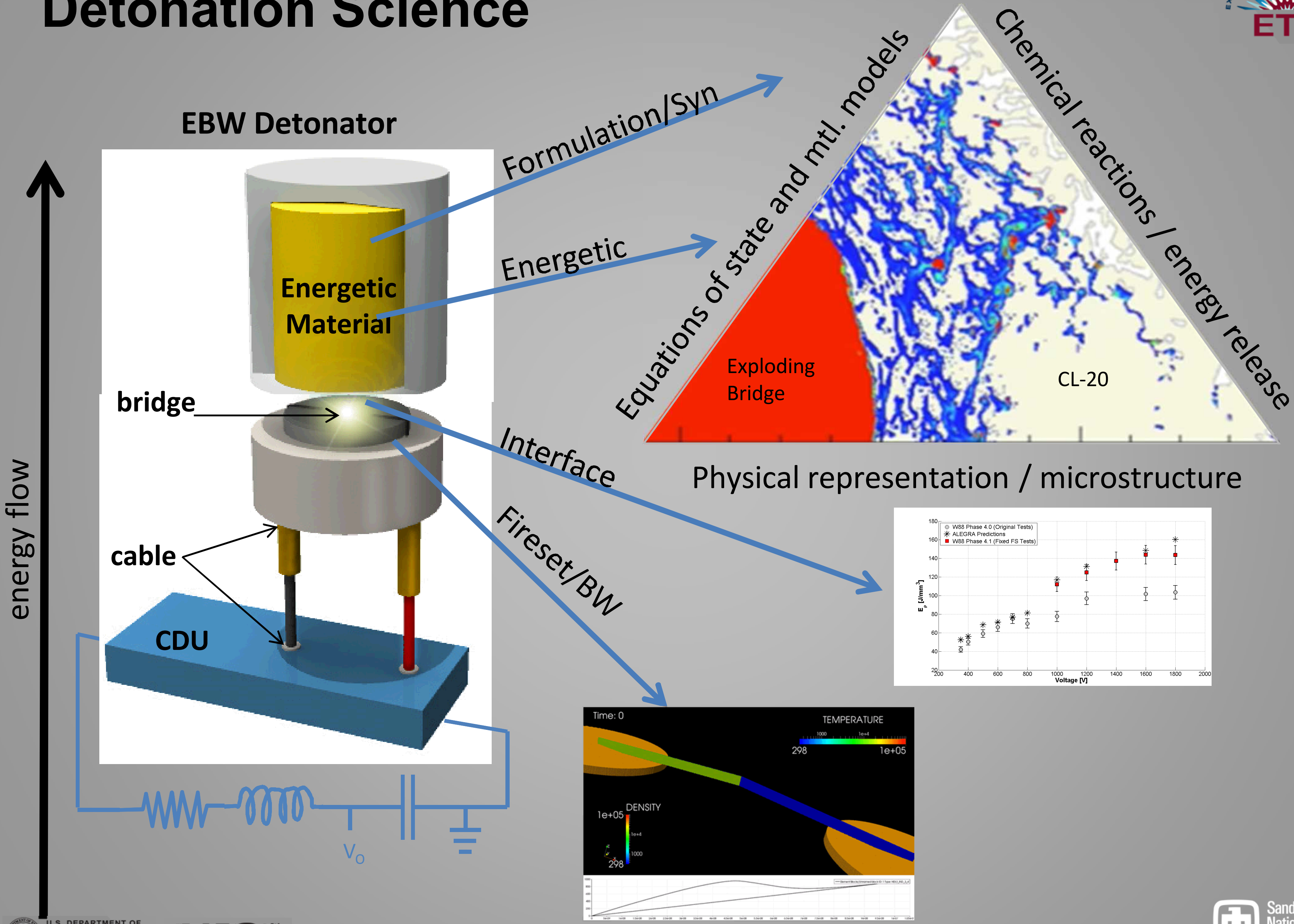
Physical characterization



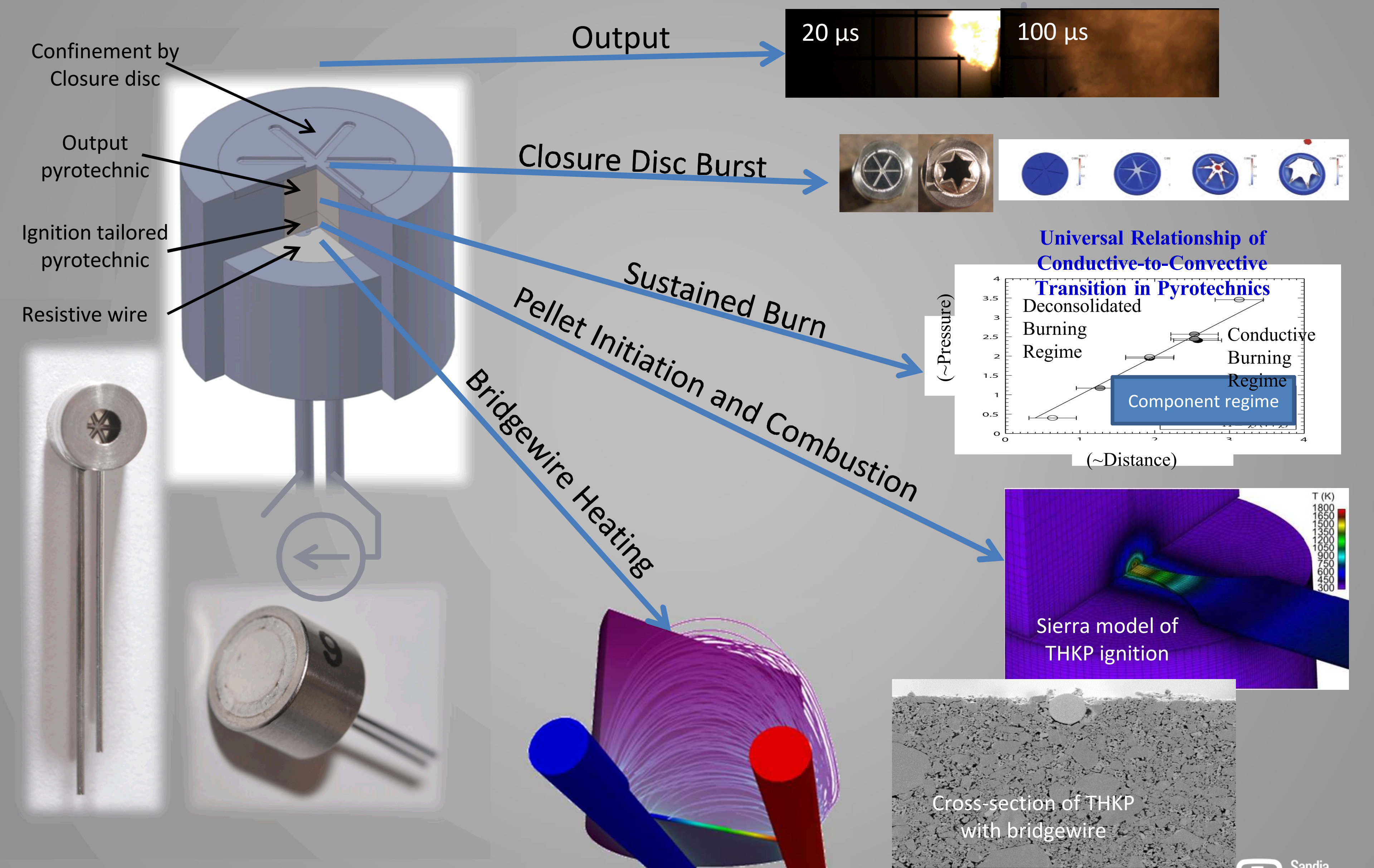


Complex physics underpins component performance, safety, reliability

Detonation Science



Pyrotechnic (Propellant) Combustion Science



Reactive Process in Subsonic Combustion and Detonation

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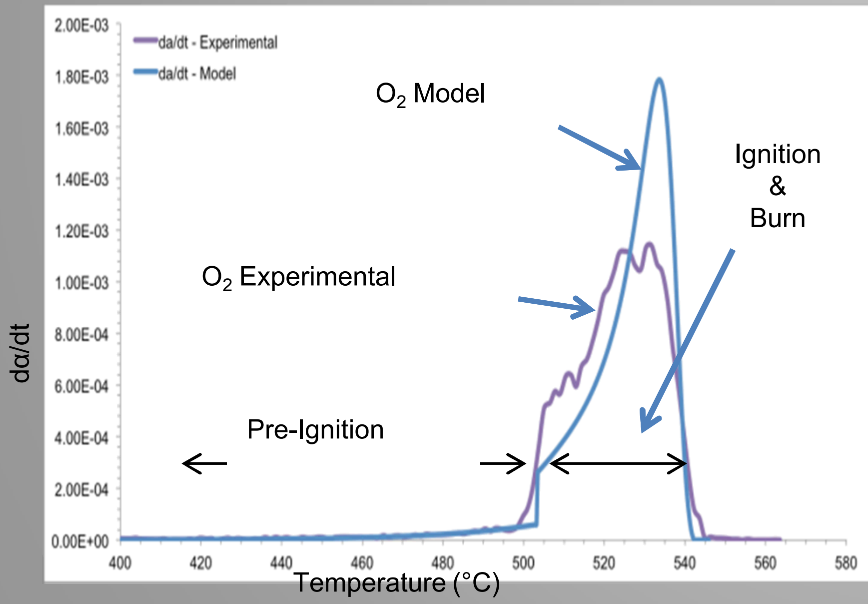
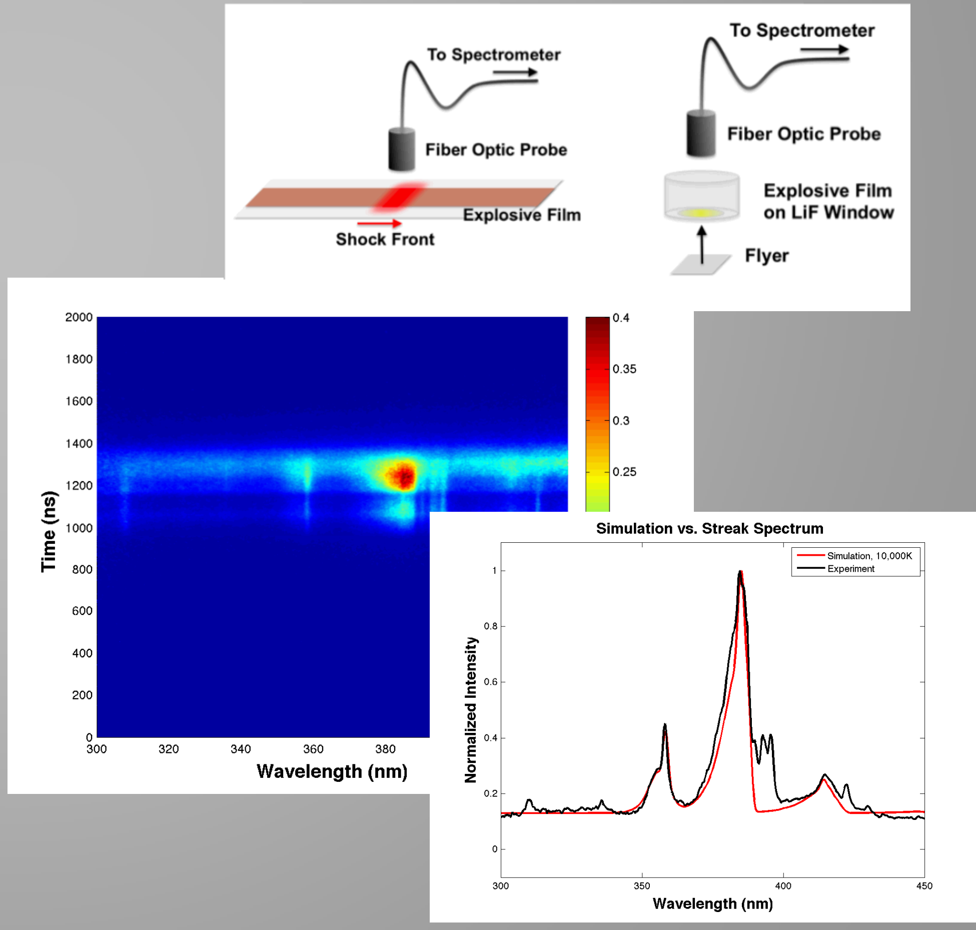
THKP Ignition/Combustion Behavior

- Identified and reduced a complex multi-phase reaction process pyro oxidizer to a 3-step reaction process for kinetic model.



HNS Detonation Chemistry

- Time-resolved streak spectroscopy coupled to molecular modeling



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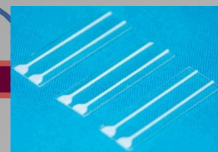
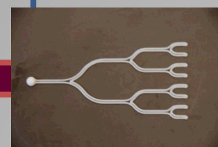
MicroEnergetics: Advanced Concepts

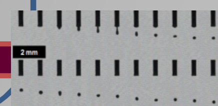
Physical Vapor Deposition



Robocasting Direct Write



Inkjet



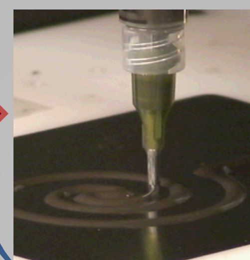
Fundamental Energetics Research

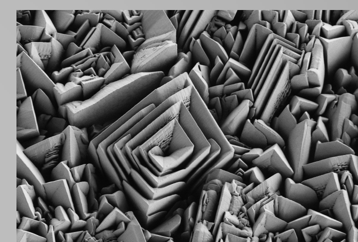
Preparation-Structure-Property Relationships

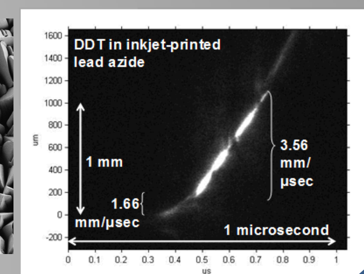
Temperature Porosity Output

Rate Grain size Velocity

Composition Crystal structure Initiation threshold







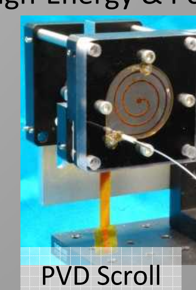
Initiation Mechanisms

Tailoring and Exploiting Phenomenology

Advanced Component Development

Low-Energy & Power

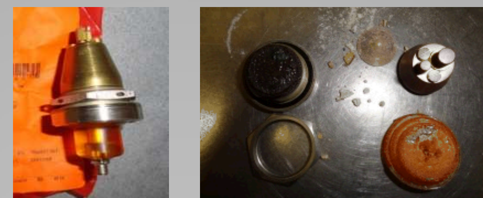
High-Energy & Power



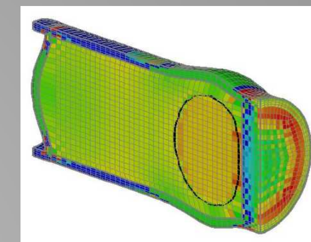
- **Tailoring material properties.**
- **Understanding complex physics underpinning performance, safety, reliability**
- **Enabled new frontiers in R&D**
- **Enabled new concepts in components**

Abnormal Thermal Environments

Fuel fire accident simulation



Before and after exposure to ATE



cook-off simulation

Thermal and Mechanical Boundary Conditions
- Hermeticity
- Confinement
- Temperatures
- Heating Rates

Thermal Decomposition → Ignition Time

Semi-Empirical Correlation → Violence

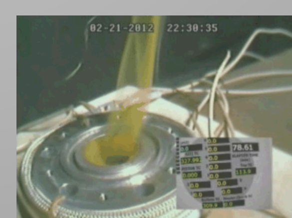
Evolution → Damage → Combustion → Violence

Damage
- Porosity
- Permeability
- Plastic work
- Phase separation
- Extent of rxn
- Binder cross-linking

Violence
- P(t)
- Wall/frag velocity
- Blast impulse

Complex physics Underpins performance, safety, reliability

Thermally damaged explosive



Mild post-ignition burn

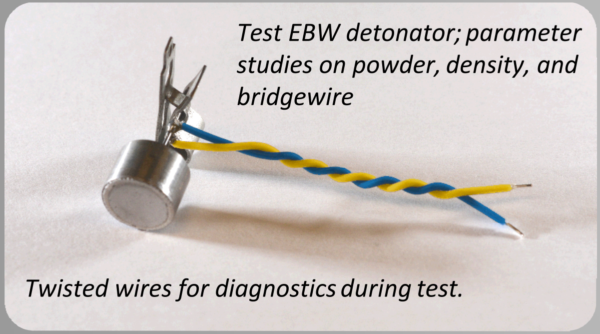
Debris from violent cook-off reaction

Rapid Prototype Facility: Accelerated Cycles of Learning

- RPF is responsible for assembly of energetic components:
  - Design and Development
  - Diagnostic integration
  - Failure investigation
  - Fundamental R&D
  - Work For Others

Use indicator

Battery ignitor showing energetic ignition increment.

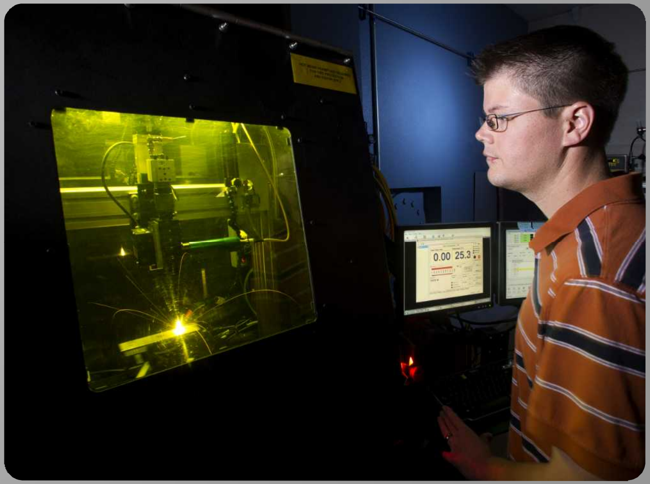


Test EBW detonator; parameter studies on powder, density, and bridgewire

Twisted wires for diagnostics during test.

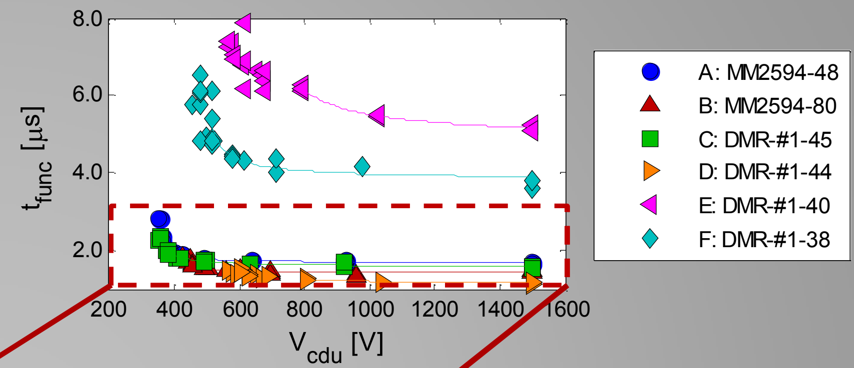
Power cartridge replicator: low cost output replicator designed and produced for WFO development (modified bolt to match mechanical interface).

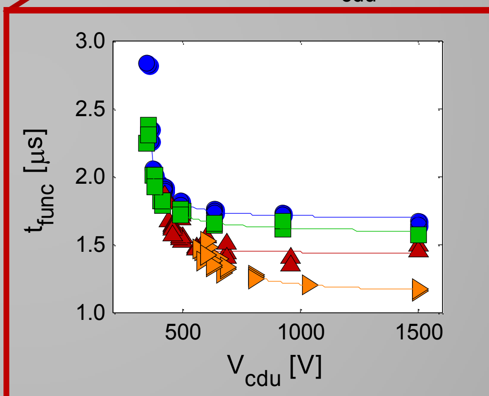
- Provides capabilities of our external production partners, enabling SNL to maintain expertise as production agency for non-nuclear explosive components.
  - Bridgewire welding
  - Laser welding
  - Epoxy encapsulation
  - Header glassing
  - Explosive powder pressing
  - Process inspection
  - Header prototyping

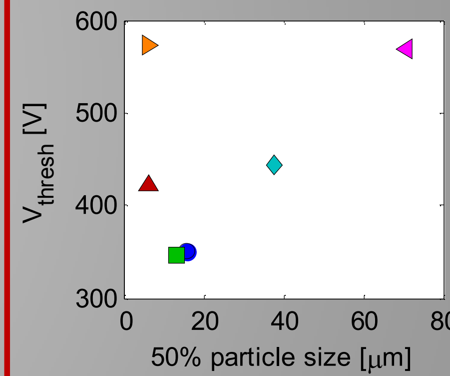


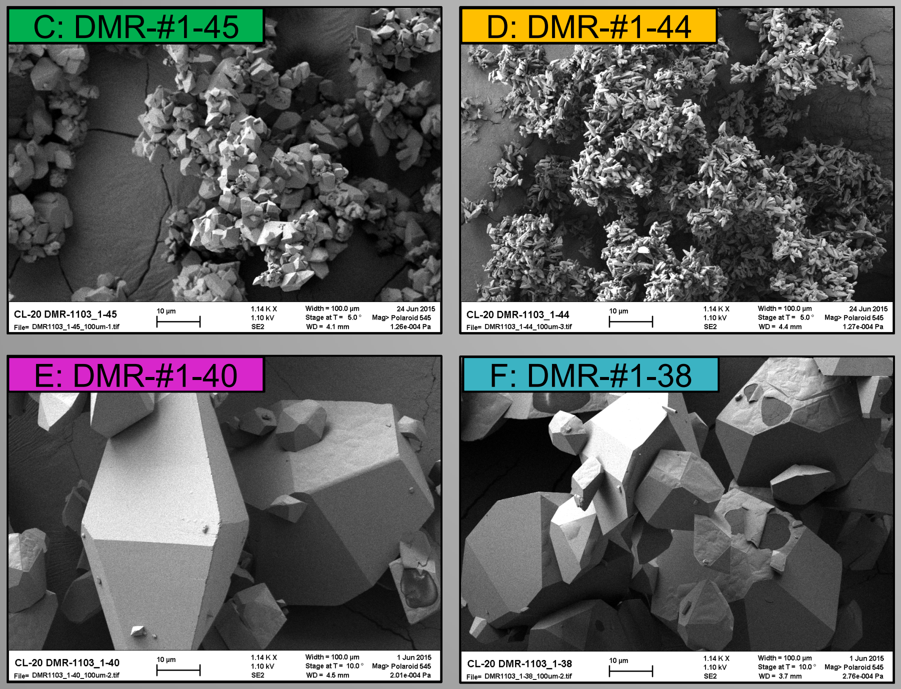
Identifying critical relationships between material properties and performance

- CL-20 was recrystallized to study effect of morphology on performance in a component geometry
  - Four distinctly different morphologies produced within several weeks, including β-CL-20
  - Assembled into EBW detonators by RPF for component level performance characterization





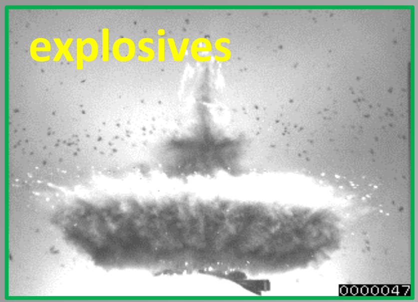




All images are of same magnification! (100 µm width)

- Results compared to vendor-produced powders baselined in prototyped detonators
  - Effect of particle size on performance (threshold shown) is obtained in a weeks

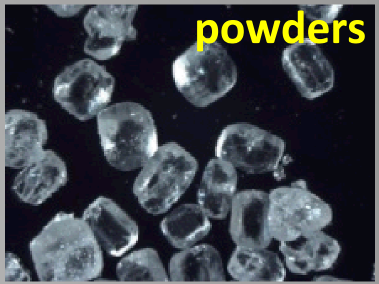
S&T critical for engineering mastery



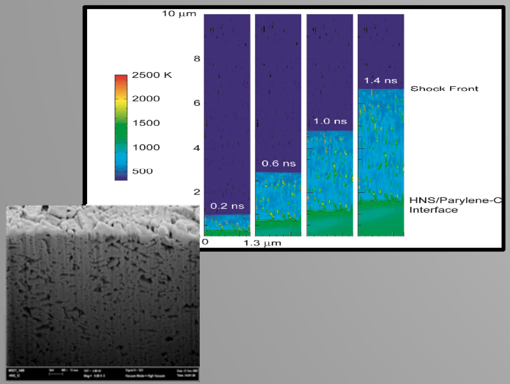
EBW/EFI detonators
Timer/drivers

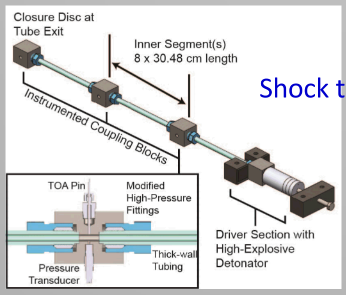
Ignitors
Latch indicator
Actuators
Valves

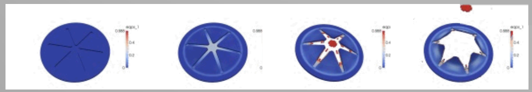
Motors
Primers
Actuators



HMX
TKP
THKP

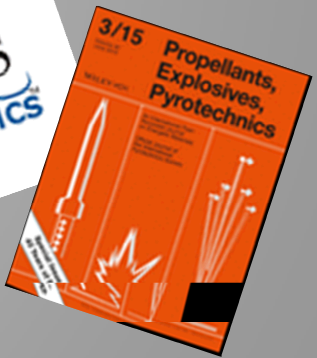






RPF

APS physics



Laboratory Directed Research & Development

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Closing Thoughts in Support of S&T

Why bother with energetic materials?

Why the use of energetic materials in the main charge – because…
want to weaponize substantial energy in spatially-limited configurations:

- Volume: Energy/power delivered per volume (potential to kinetic) is HUGE
- Time delivery
- Reliability

Same principle applies for non-nuclear energetic components.

No technology to date can compete with EM!

Why bother with EM S&T?

What we know:

- How much energy comes out of an energetic material

What we can engineer:

- Energy input into a given component geometry
- Desired output of the energy
- Desired function time

What we don't know:

- **What controls the rate-of-release of the energy in the EM**
- **Governing processes for the energy rate-of-release in a component design**