

# Switchable Reactives and Energetics (SeREne)

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Information Session Briefing

October 7<sup>th</sup>, 2024





## Clarification

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If there is any discrepancy between what is presented today and the anticipated Disruption Opportunity (DO) solicitation, the solicitation takes precedence. DARPA anticipates releasing the SeREne DO in October 2024.



## Opening Comments

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- The Information Session briefing is intended to provide an orientation to the anticipated SeREne Disruptioneering Opportunity Program Solicitation and is solely for information purposes
- The solicitation supersedes anything presented or said by DARPA at the Information Session
- Examples in this briefing (e.g., technologies, use cases) are chosen for ease of illustration only and do not constitute endorsement of any particular approach
- Interested performers are expected to be able to articulate a clear and compelling vision for their technology and proposed course of research
- We need your help to make this program a success!



# Issues with Current Energetics

## Opinion: The U.S. Needs A New Push In Energetic Materials

Mark Lewis July 22, 2024



Credit: U.S. Army Central Command

*"...much of U.S. technology associated with solid propellants and explosives—so-called energetic materials—has seen little advance since the end of World War II."*

Energetics must balance:

**SAFETY**

&

**PERFORMANCE**

+ High safety factor  
- Performance suffers

+ High yield  
- Too sensitive to field

**Energetics development is difficult due to balancing clashing priorities**



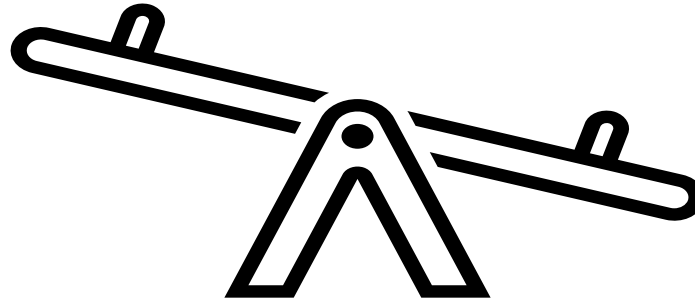
# Current Approaches to New Energetics

## Formulations to enhance **SAFETY**

Examples: Dynamite, IMX-101

- Binders/phlegmatizers
- Co-crystals
- Encapsulation (e.g., MOFs)

- Blending inert materials increases safety but reduces energy density, decreasing performance
- Formulation process is irreversible



## Materials discovery to enhance **PERFORMANCE**

Examples: CL-20, poly-CO

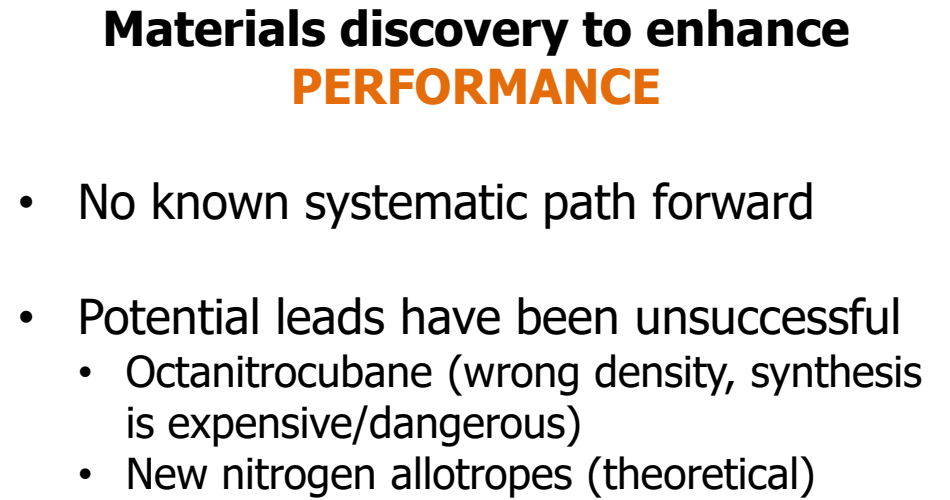
- Trigger linkages
- Detonation mechanisms

- Pure compounds give high performance but are too sensitive for use
- Compound properties are not inherently adjustable

↑ **DIAL-A-YIELD** ↓

Staged munitions systems:  
Currently only possible at system level, not formulation/material level

**Need: Energetics with sensitivities and explosive yields that are predictable and controllable**



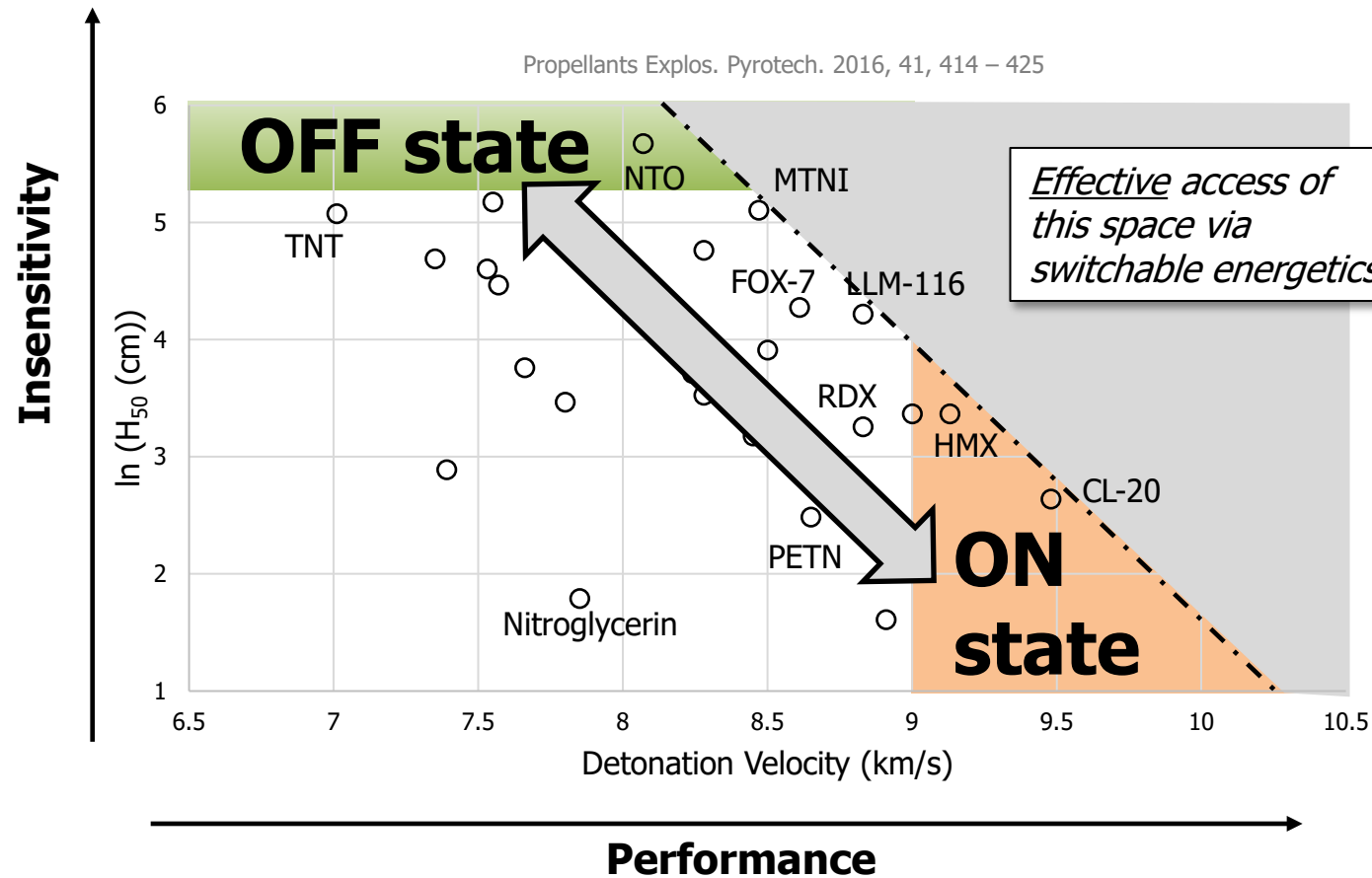
- Sacrifice performance for safety
- No easy way to restore performance

## Current approaches have not achieved safe, high-performance energetics

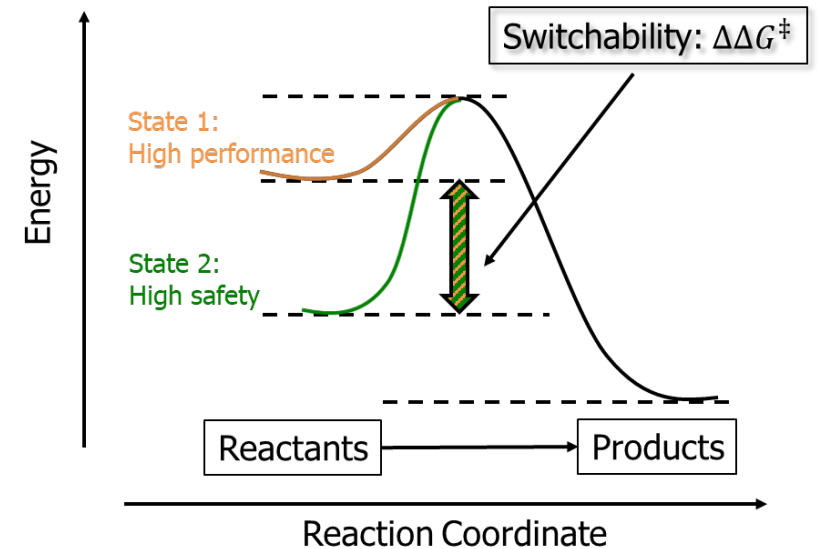
MTNI: 1-methyl-2,4,5-trinitroimidazole  
FOX-7: 1,1-diamino-2,2-dinitroethylene  
LLM-116: 4-amino-3,5-dinitro-1H-pyrazole  
CL-20: Hexanitrohexaazaisowurtzitane  
 $H_{50}$ : impact height 50% detonation probability



# There is Another Way: Switchable Reactives and Energetics



## Molecular Switch Energy Profile



Problems to solve:

- Switchability energy is large ( $\sim 100$  kJ/mol)
- Limited on number of states

**Need: Engineer reversible switchability into *known* energetic materials**

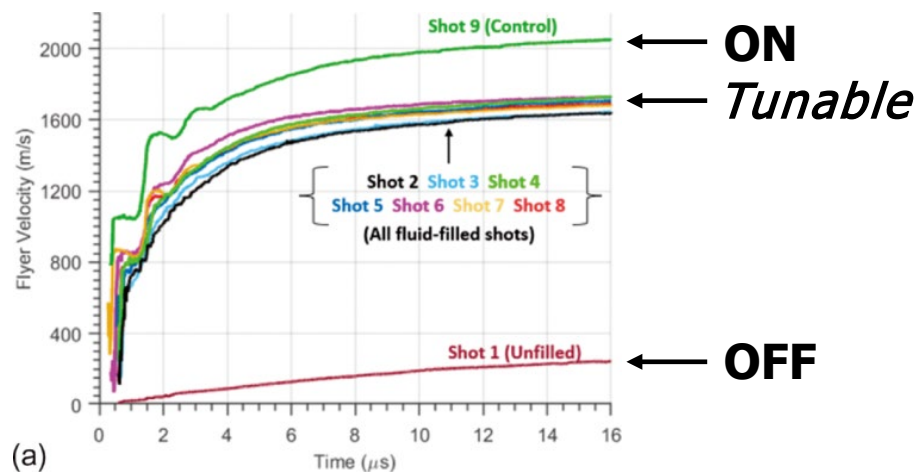
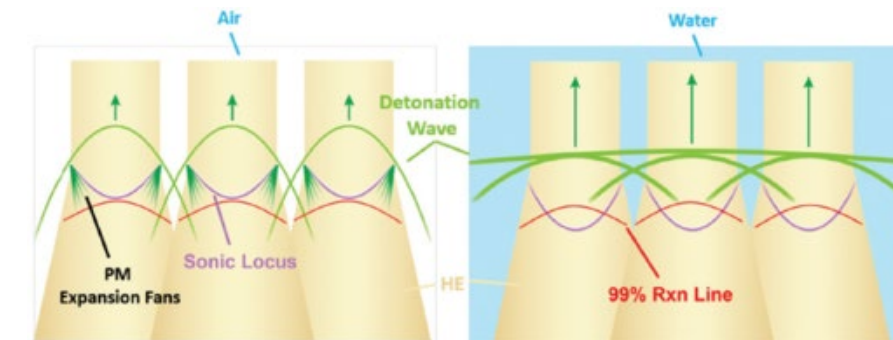
HMX: High Melting Explosive  
RDX: Royal Demolition Explosive  
TNT: Trinitrotoluene  
NTO: Nitrotriazolone  
PETN: Pentaerythritol tetranitrate

MTNI: 1-methyl-2,4,5-trinitroimidazole  
FOX-7: 1,1-diamino-2,2-dinitroethylene  
LLM-116: 4-amino-3,5-dinitro-1H-pyrazole  
CL-20: Hexanitrohexaazaisowurtzitane  
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## "Structural" Switch

Switch: Thermal, mechanical, chemical

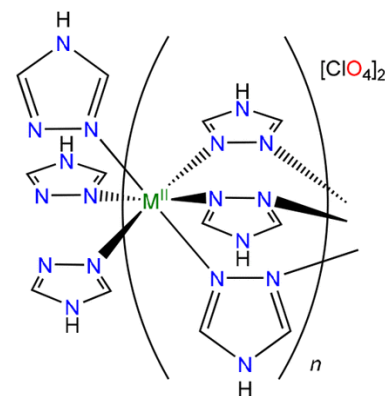
### Critical diameter manipulation



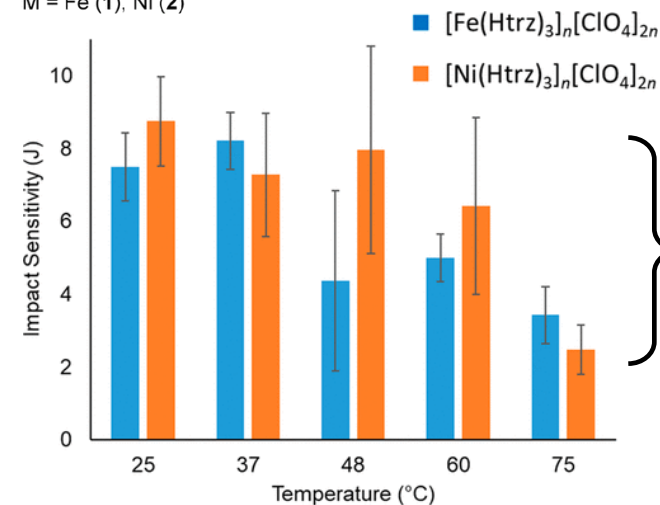
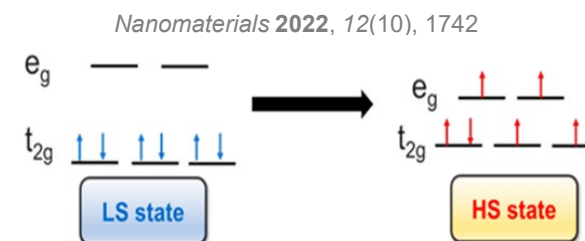
*Phys. Rev. Lett.* 130, 116105 2023

## "Atomic" Switch

Switch: Thermal, pressure, chemical, magnetic



M = Fe (1), Ni (2)



*4x impact sensitivity change!*

*J. Am. Chem. Soc.* 2020, 142, 10, 4842–4851





## Program Structure

**TA1 Explosives:**  
detonating energetic materials

**TA2 Propellants (solid or liquid):**  
deflagrating energetic materials

### **Phase I – Switchability**

- Length: 12 months
- Budget: Not to exceed \$1M
- Goal: Prove robust on-off switchability between high-performance and high-safety is feasible

### **Phase II - Tunability**

- Length: 12 months
- Budget: Not to exceed \$1M
- Goal: Proof of concept for broadly tunable energetics

### **Government Independent Verification and Validation (IV&V) Team**

- Measure performance of developed energetic material
- Assist in scale-up of material to for testing
- Performers are expected to work openly and regularly with Gov't Team

*IV&V testing will be conducted at a Government provided facility.*

**Proposers may submit to one or both TAs; however, separate proposals are required for each TA**



# Program Metrics

Metric	Applicable TA	Unit	Phase I	Phase II
Switchability Metrics				
Tunability of Performance	All	N/A	Reversibly switchable	Reversibly tunable to 5 points
Energy of switching: maximum energy required to switch between two states	All	J/g <sub>energetic</sub>	Scalable to < 1	Scalable to < 0.1
Performance Metric				
Minimum detonation velocity of full "on" state	TA1: Explosives	m/s	> 9000 (modeled)	> 9000 (measured by Gov't IV&V)
Minimum specific impulse of full "on" state	TA2: Solid and liquid propellants	s	> 270 (modeled)	> 270 (measured by Gov't IV&V)
Sensitivity Metrics				
Minimum impact insensitivity of "off" state	TA1: Explosives TA2: Solid propellants	J	> 49	> 49
Minimum stability of "off" state	TA2: Liquid propellants	days	>7	>30



# Phase 1 Milestones

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- Month 1:
  - Attend an in-person kick-off meeting and present initial concept from proposal and path for development.
  - Assign personnel to all supporting positions identified in the proposal and provide their names to the Government.
- Month 3:
  - Deliver an intermediate report detailing the switchable energetic method identification process and the plan towards predicting performance and measuring sensitivity.
- Month 6:
  - Deliver an intermediate report detailing the final choice of switchable energetic method and its anticipated performance and sensitivity properties.
- Month 9:
  - Deliver sufficient energetic material to the Government IV&V team for Phase 1 evaluation.
  - Deliver an intermediate report outlining the plan towards enabling tunability of the switchable energetic method, including an outline of the tunability mechanism and the predicted performance of the tunable states. This report should address any anticipated challenges and present mitigation strategies.
- Month 11:
  - Present an end-of-phase brief detailing:
    - The results and lessons learned on demonstrating switchability of an energetic material between a high-performance "on" state and a high insensitivity "off" state.
    - A detailed description of how performance was modeled, and sensitivity was measured.
    - A path forward for advancements that will allow the Phase 2 metrics to be realized, including any testing or references to show viability of the path.



## Phase 2 Milestones

- Month 13:
  - Attend a Phase 2 kick-off meeting. Present detailed Phase 2 technical approach and initial experimentation. Efforts towards scale-up of the energetic material should be included as well.
- Month 15:
  - Present progress towards tuning the performance of the switchable material and include progress on collaborative efforts with the IV&V team for material scale-up. Include the predicted performance and sensitivity of the different states.
- Month 21:
  - Deliver sufficient energetic material for Government IV&V Phase 2 evaluation.
- Month 23:
  - Present an end-of-phase brief detailing:
    - The results of demonstrating tunability of reversible switchability of an energetic material between 5 points.
    - An evaluation of key insights, development risks, challenges, and mitigation strategies.
    - An assessment of energetic material performance against program metrics with supporting evidence.
    - Lessons learned from the program and consideration for technology transition.
- Month 24:
  - Deliver a program final report detailing demonstration of a tunable energetic that can switch between an "on" and "off" state as well as 5 additional points with intermediate performance characteristics.

**Proposer should address the schedule of fixed milestones in proposal submissions**



## SeREne is NOT interested in...

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- Proposals centered on materials discovery without a switchability component
- Approaches that do not focus on material-scale development of switchability
  - Examples: Proposals focused on switchability at the full munition or system level
- Liquid propellant proposals that focus on non-hypergolics or cryogenics
- Evolutionary or iterative approaches



## Federally Funded Research and Development Centers (FFRDC) and University Affiliated Research Centers (UARC) Eligibility

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- May serve as technical advisers and IV&V partners throughout the program
  - Provide assessment of performer capabilities and validating experimental data and material performance
- This Disruption Opportunity does not solicit IV&V participation

**U.S. Government, FFRDC, or UARC personnel interested in learning more about SeREne or potentially participating in program activities should contact DARPA at [SeREne@darpa.mil](mailto:SeREne@darpa.mil)**



- Both TAs may generate information subject to CUI controls
- Proposers should review DARPA-PA-24-04 Section 8.2.2 regarding DoD requirements related to protection of CUI and Controlled Technical Information (CTI)
- Review the CONTROLLED UNCLASSIFIED INFORMATION (CUI) GUIDE attached to the solicitation to assist in proposal preparation



# Questions

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- Please submit any questions to [SeREne@darpa.mil](mailto:SeREne@darpa.mil)
- Answers to the questions will be provided later and posted to DARPA Opportunities page
  - <https://www.darpa.mil/work-with-us/opportunities>
- Select presentation materials will be made available after clearing public release





[www.darpa.mil](http://www.darpa.mil)