Switchable Reactives and Energetics (SeREne)

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Information Session Briefing

October 7th, 2024

Clarification

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

- 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

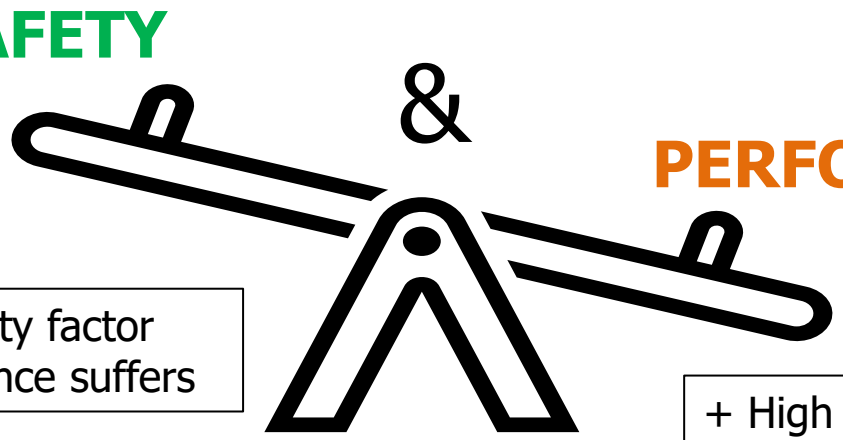
Opinion: The U.S. Needs A New Push In Energetic Materials

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:



+ High safety factor
- Performance suffers

+ High yield
- Too sensitive to field

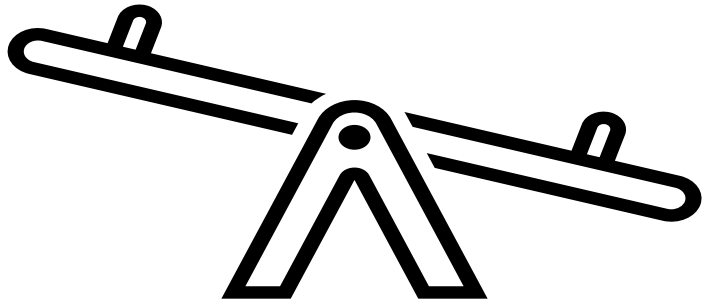
Energetics development is difficult due to balancing clashing priorities

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

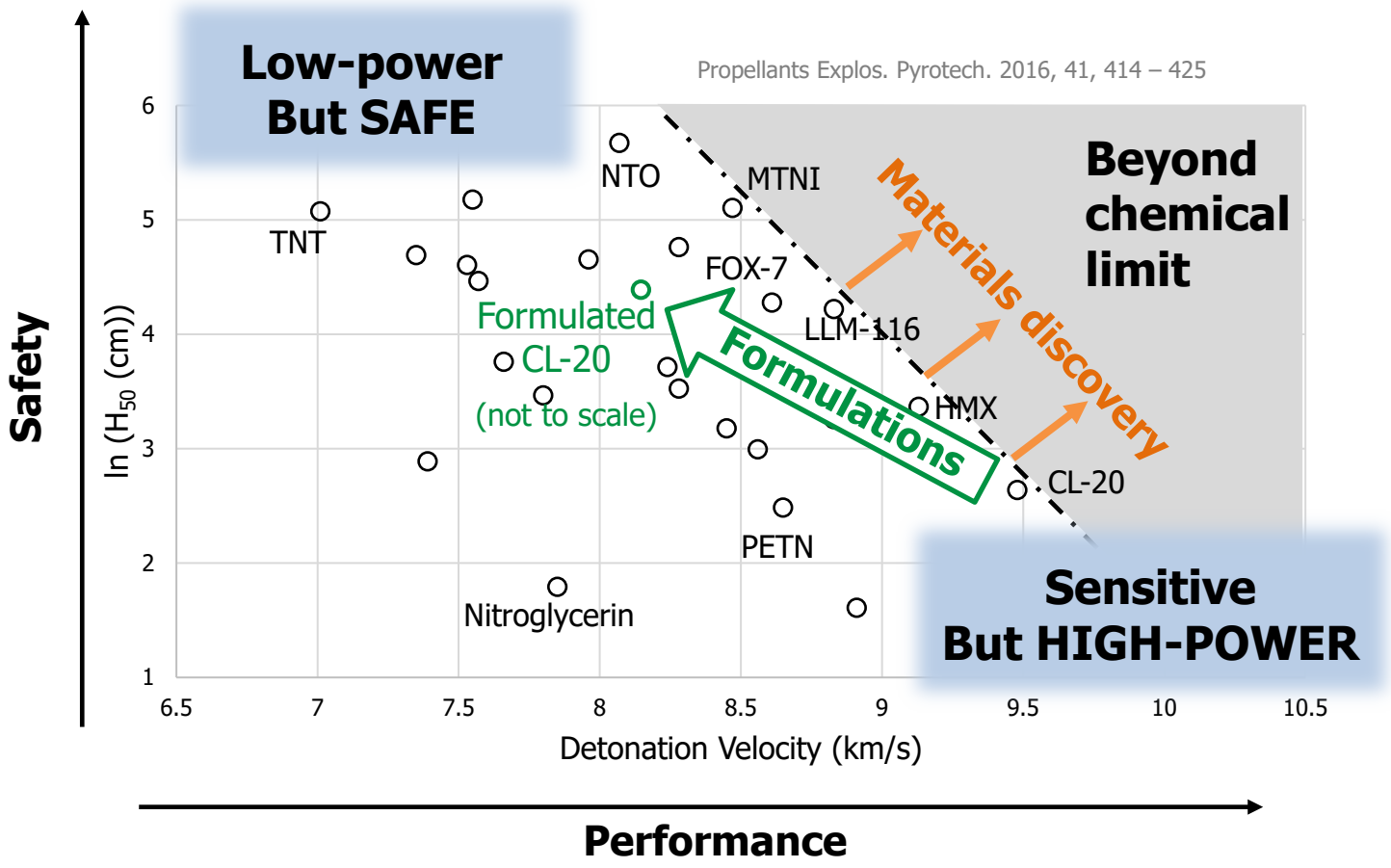
DIAL-A-YIELD

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

IMX: Insensitive munition explosive
CL-20: Hexanitrohexaazaisowurtzitane
MOF: Metal-organic framework

Energetics Development is at an Impasse



Materials discovery to enhance PERFORMANCE

- No known systematic path forward
- Potential leads have been unsuccessful
  - Octanitrocubane (wrong density, synthesis is expensive/dangerous)
  - New nitrogen allotropes (theoretical)

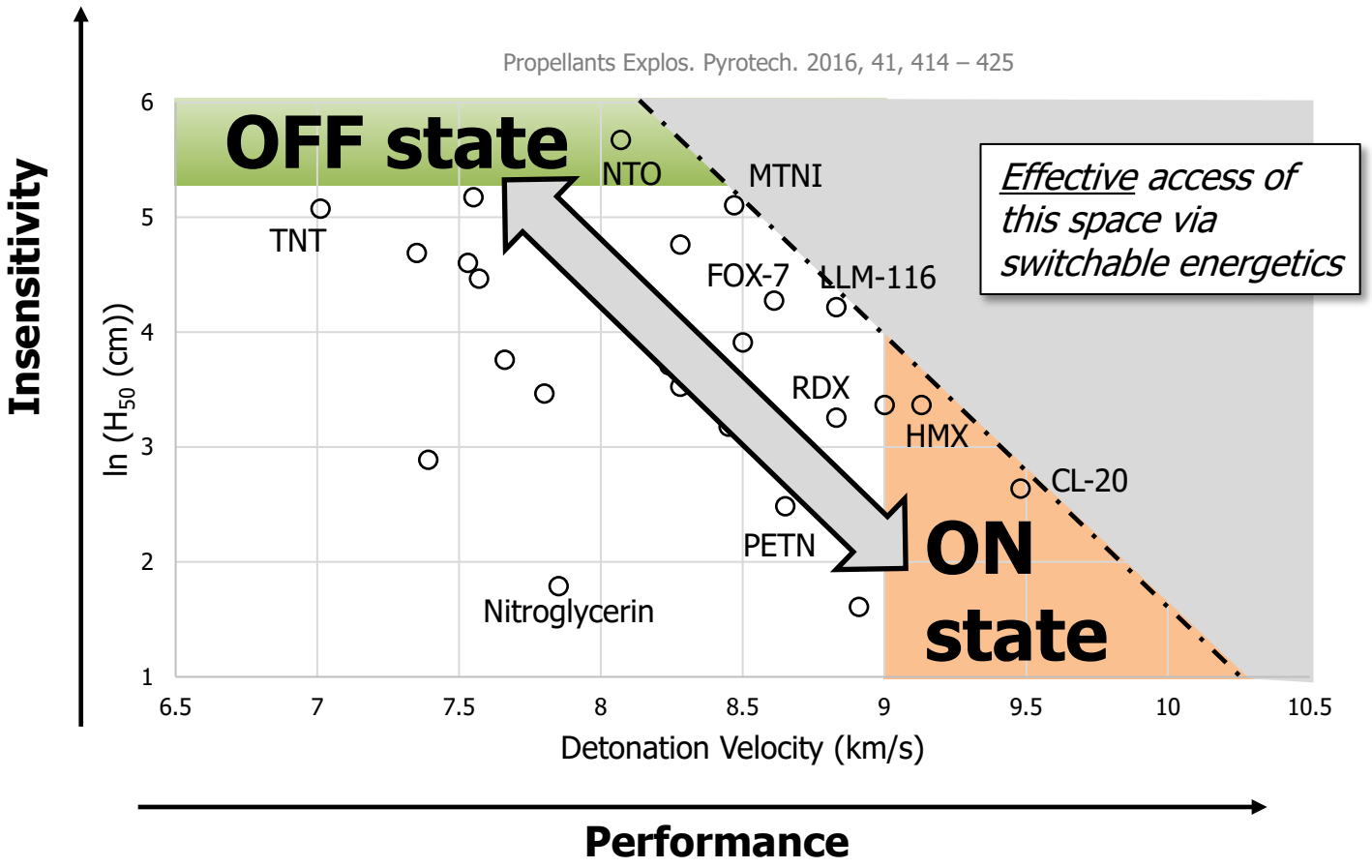
Formulations to enhance SAFETY

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

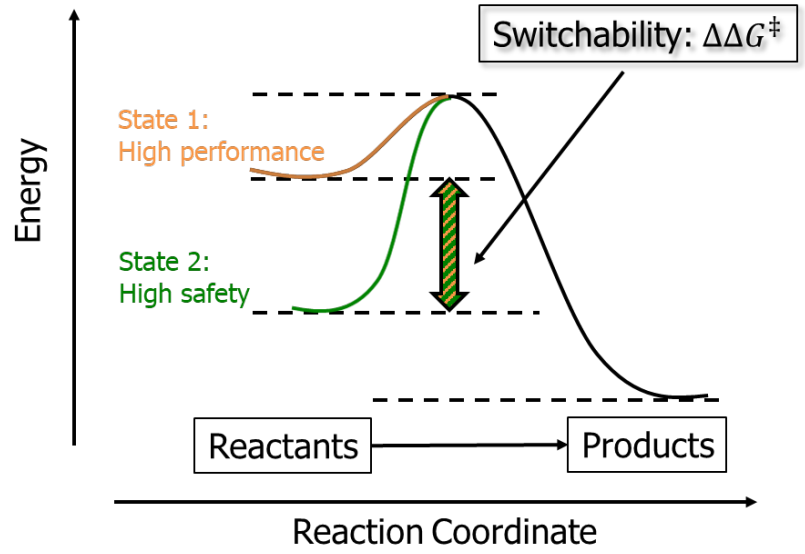
Current approaches have not achieved safe, high-performance energetics

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
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 (~100 kJ/mol)
- Limited on number of states

Need: Engineer reversible switchability into *known* energetic materials

HMX: High Melting Explosive
RDX: Royal Demolition Explosive
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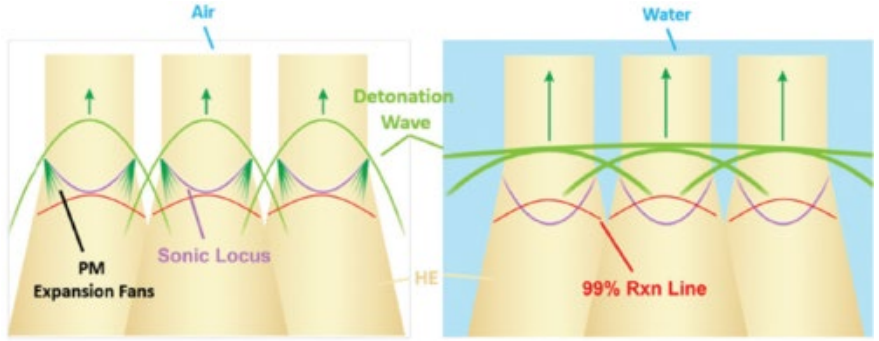
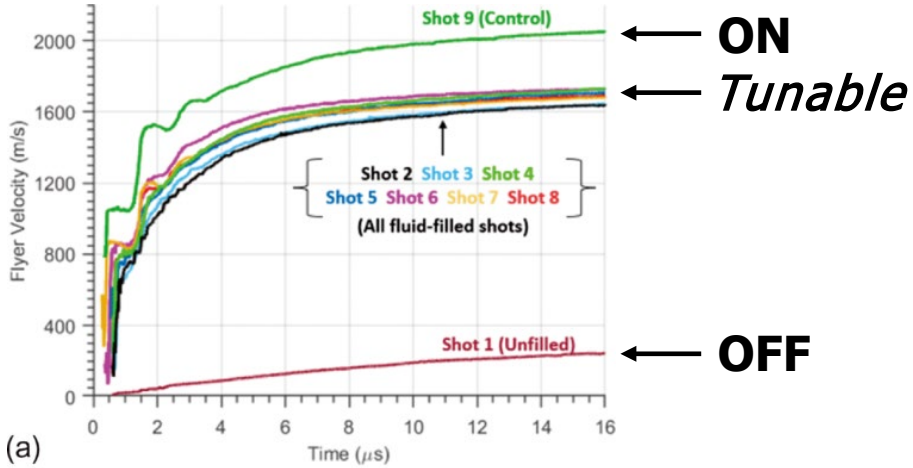
Engineering Switchability into Energetics

"Structural" Switch

Switch: Thermal, mechanical, chemical

Critical diameter manipulation





ON

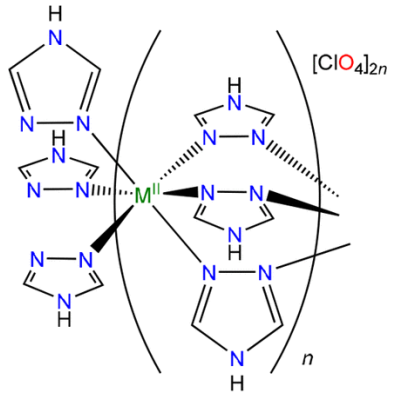
Tunable

OFF

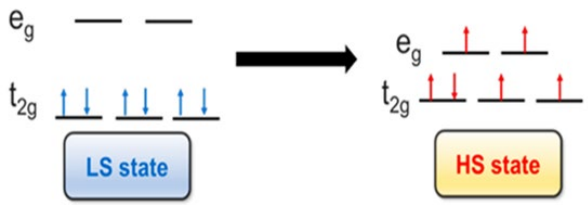
Phys. Rev. Lett. 130, 116105 **2023**

"Atomic" Switch

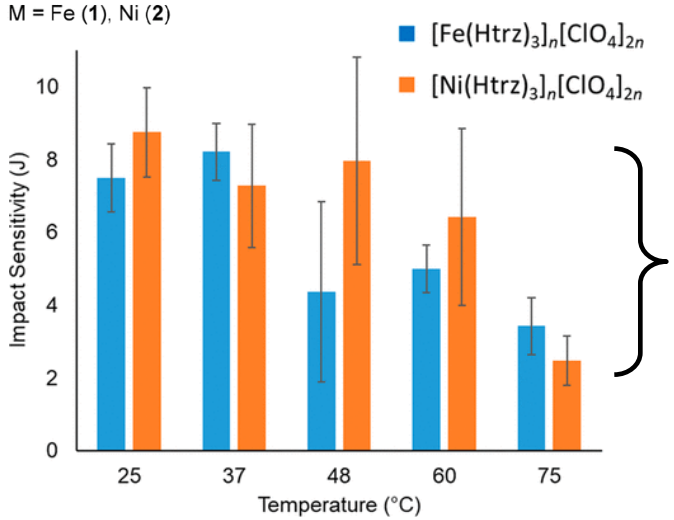
Switch: Thermal, pressure, chemical, magnetic



Nanomaterials **2022**, *12*(10), 1742



M = Fe (**1**), Ni (**2**)



4x impact sensitivity change!

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

LS: Low-spin
HS: High-spin

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	$J/g_{energetic}$	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

Gov't: Government
IV&V: Independent Verification and Validation
TA: Technical Area

Phase 1 Milestones

- 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…

- 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

- 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

Security

- 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

- Please submit any questions to **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