In Situ Nano-Aluminum Composites for Energetic Materials

David Reid, Ph.D.

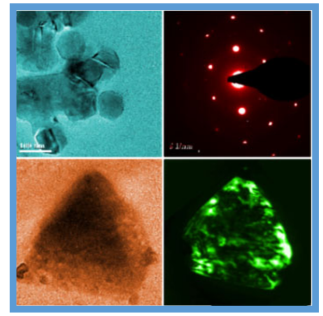
CAD/PAD Technical Exchange Workshop
2022

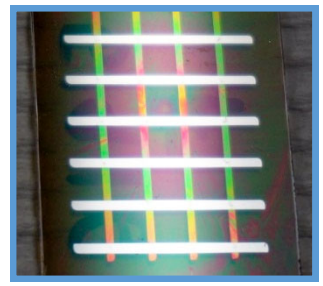
Helicon Chemical Company

Chemistry-Focused

Nano-energetic Product Development

- **Reactive & energetic materials**
  - **Solid & liquid fuels and propellants**
  - **Explosives**
  - **Catalysts**
  - **Structural reactive materials**
  - **Energetics additive manufacturing**
- **Patented nanocomposite production technology**
- **Grams to kilograms laboratory & scale-up**
- **Functional polymers**
- **Films and coatings**





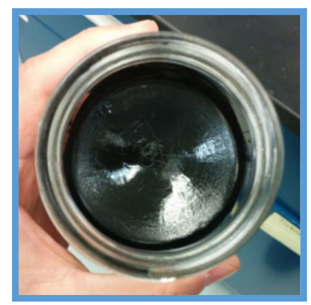


Photo credit: Helicon

Technology Introduction:
In Situ Reactive Aluminum Composites

Helicon's Reactive Aluminum Composites

Helicon's reactive composites enable advanced aluminum performance in energetic materials

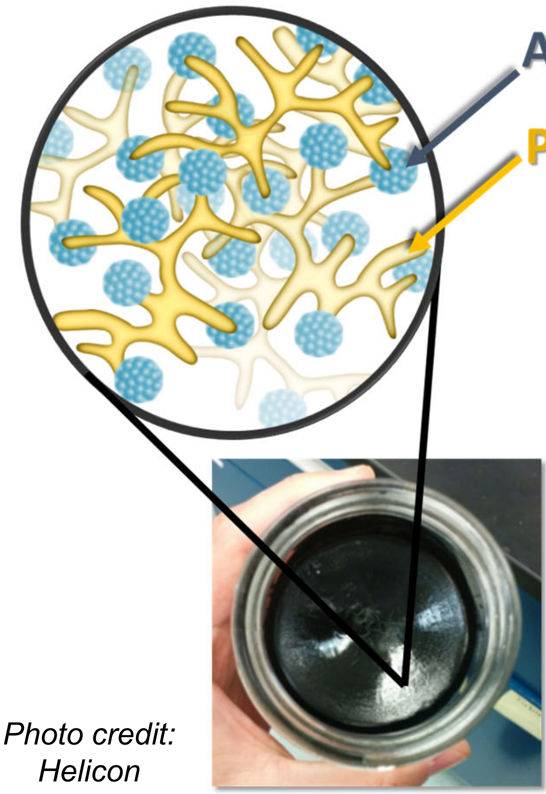


Photo credit: Helicon

Aluminum nanocomposite solid fuel

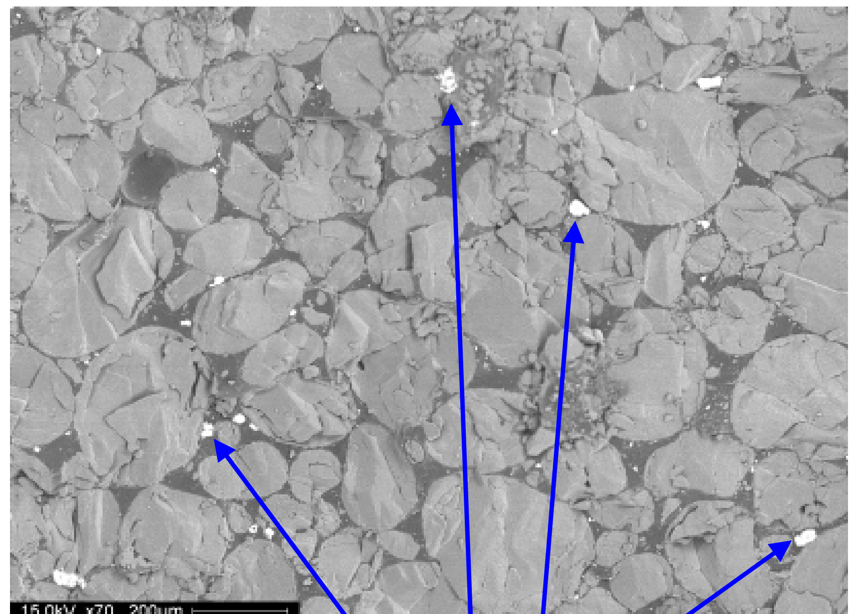
- **Produced using Helicon's patented process**
- ***Molecular-level mixing* of nano-aluminum fuel and polymer binder**
- **Extremely rapid nanoparticle combustion**
- **Maximum energy release from aluminum fuel**
- **Safe to handle, store, use**
- **Replacement for conventional fuel ingredients that have unwanted behavior such as sensitivity, toxicity, aging, poor performance**

Solving the "Nanoparticle" Problem

SEM cross-section of AP/HTPB propellant containing conventional nanopowder

Problems of conventional nanoparticles are eliminated:

- **Handling and safety**
- **High mix viscosity**
- **Poor dispersion**
- **Particle agglomeration**
- **Lower than ideal performance**



Nanoparticle agglomerates

Photo credit: Helicon

Helicon's Metallized HTPB R45M Binder

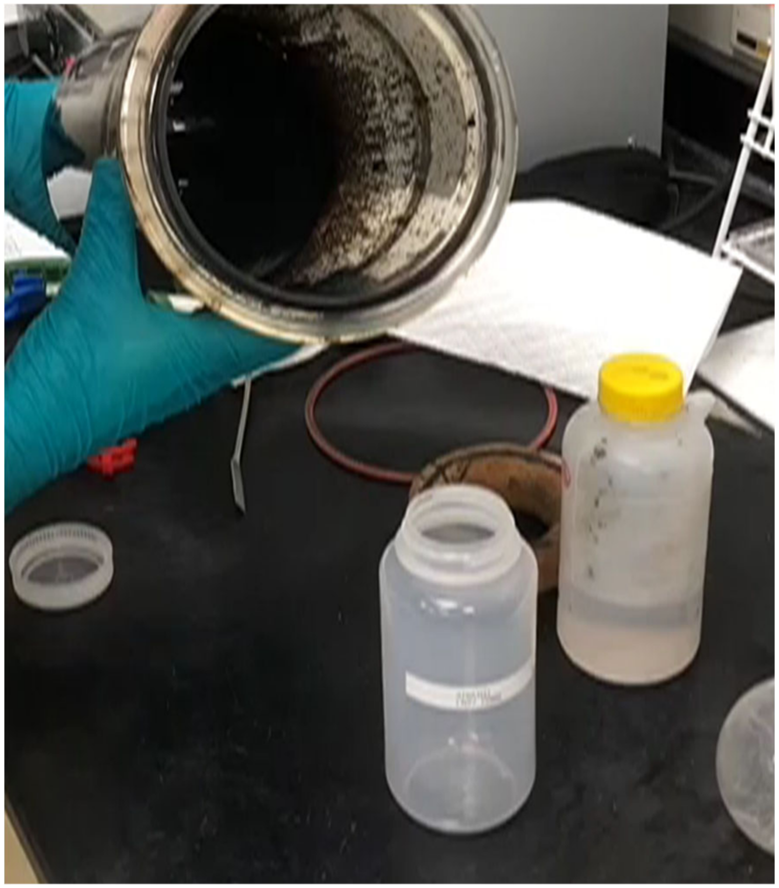
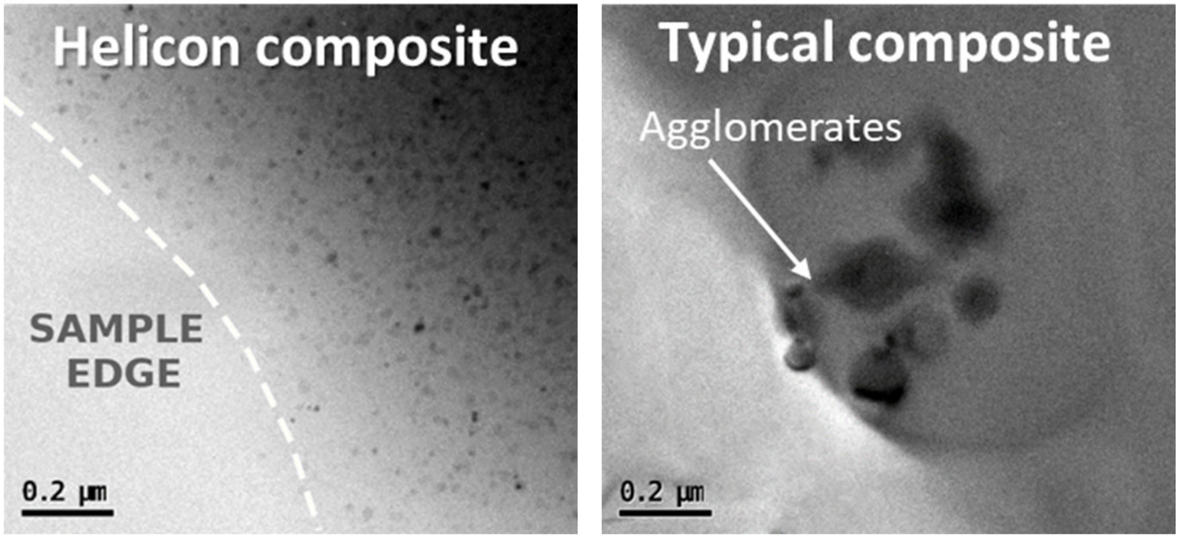


Photo credit: Helicon

- **HTPB R45M binder / nano-aluminum composite**
- **Drop-in replacement for conventional HTPB R45M**

Cured binder cross-sections @ 50,000X magnification:



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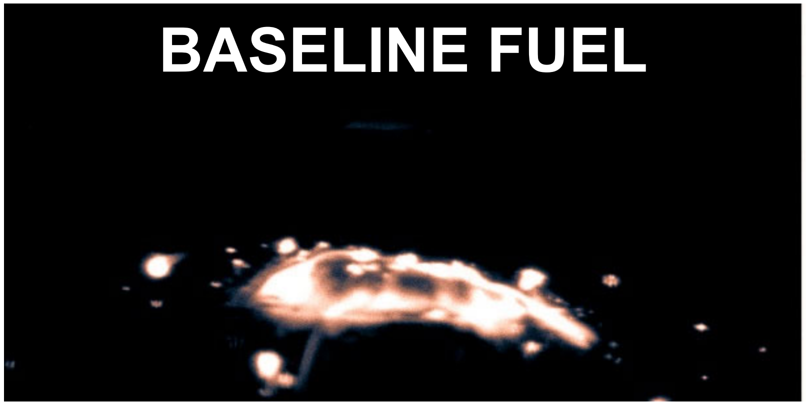
How It Works



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Conventional Al combustion:

- **Large molten aluminum droplets (LMDs) form on the propellant surface**

Helicon technology:

- **Reduces LMDs and improves combustion efficiency**

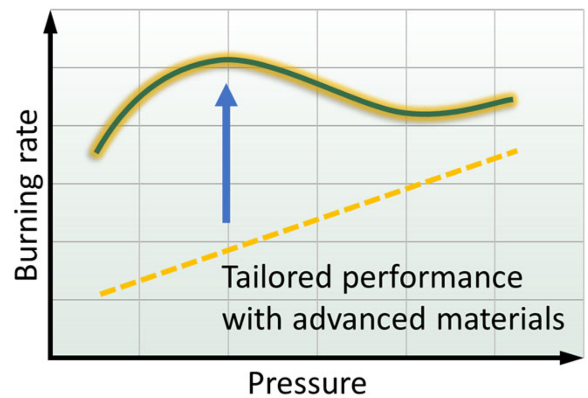
Plateau Propellant Development

SBIR Goal: **Develop a new composite propellant with equivalent performance to be a drop-in replacement for a current propellant used in CAD/PAD rocket motors and cartridges.**

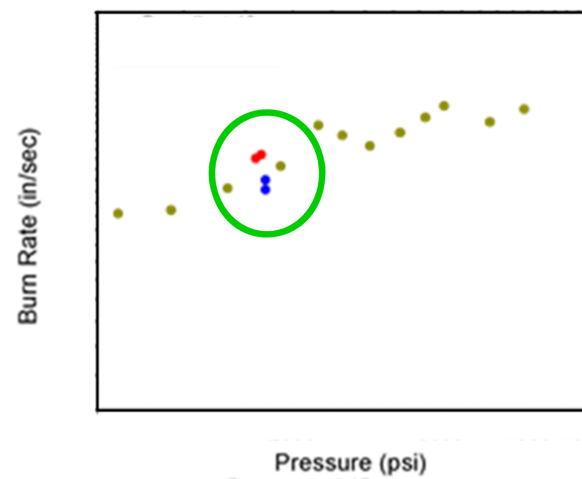
Benefit: **Composite propellant will extend the service life of affected CAD/PAD items, lower procurement cost, reduce maintenance and impact to warfighting capability**

We modified a composite propellant to:

- → **Increase burning rate**
- → **Reduce temperature sensitivity**
- → **Create extended burning rate plateaus at the desired operating pressures**
- → **Match specific impulse to target**
- → **Maintain thermally stable aging of all ingredients**



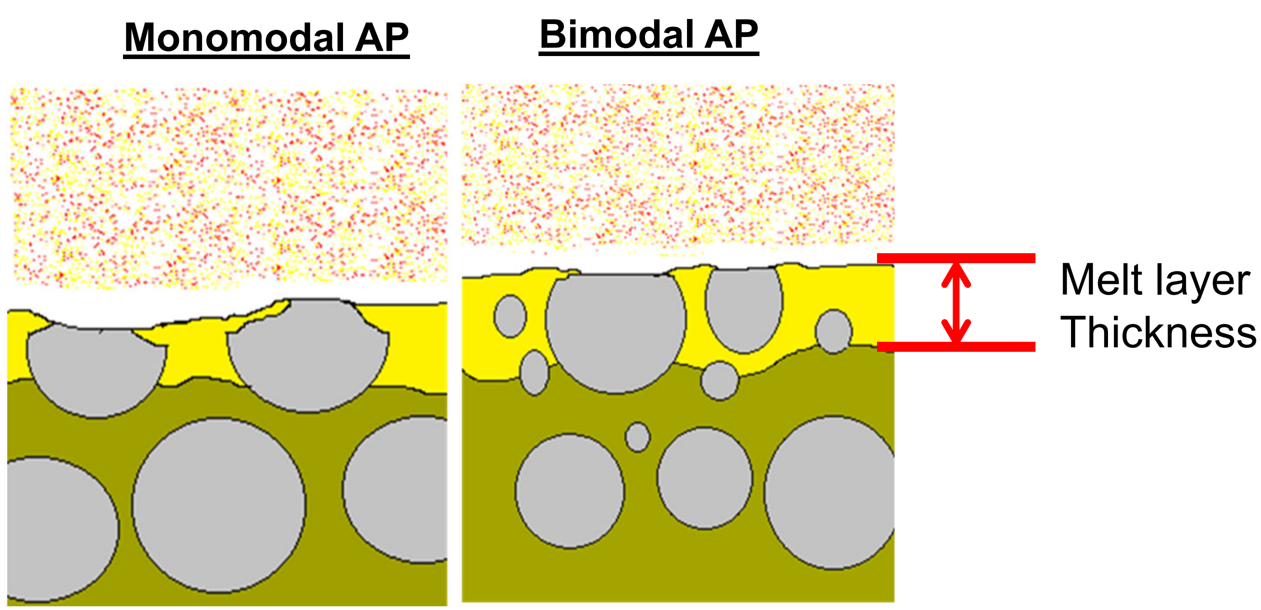
Example of minimized temperature sensitivity of propellant made with nAl-HTPB binder:



Binder Melt Layer Phenomena

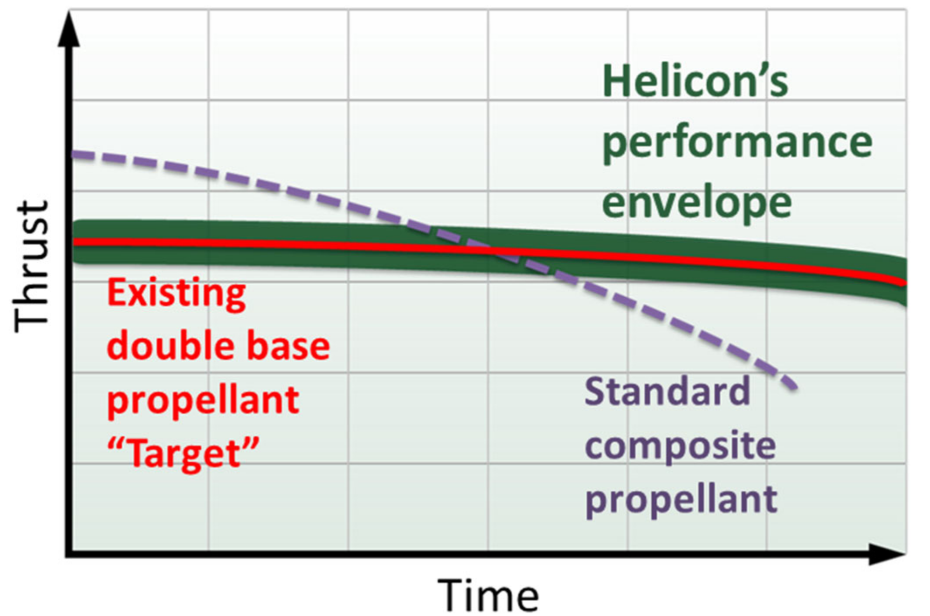
Exploiting Melt Layer Effects for Plateau Burning Propellants

- **Larger AP particles protrude through melt layer; smaller particles are smothered**
- **Melt layer becomes thinner as pressure increases**
- **Effects can be tuned to produce plateau burning over various pressure ranges**



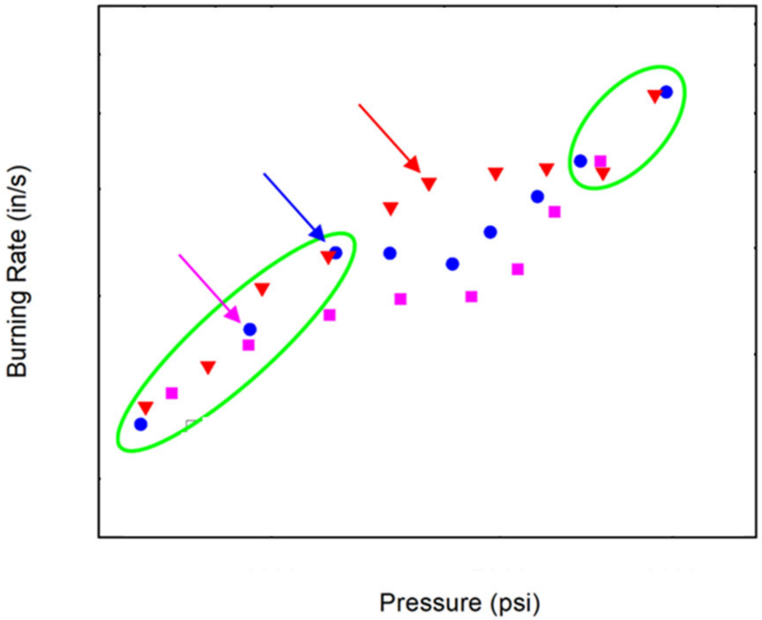
Ballistic Modeling of CAD/PAD Device

- Ballistic model was based on propellant strand data, thermochemical calculations, and CAD/PAD device design and original test data
- Ballistic model with Helicon's optimized propellant matched the target performance
- Ballistic model confirmed the importance of the plateau region in stabilizing thrust over time



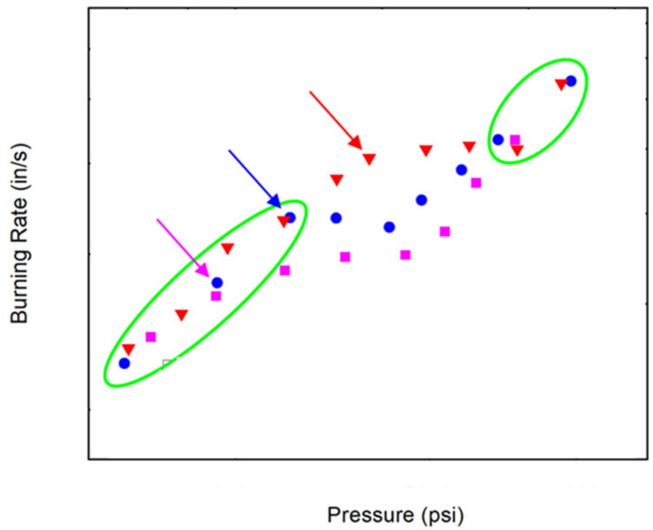
Propellant Scale Up Issues Encountered

Photo credit: *Helicon*

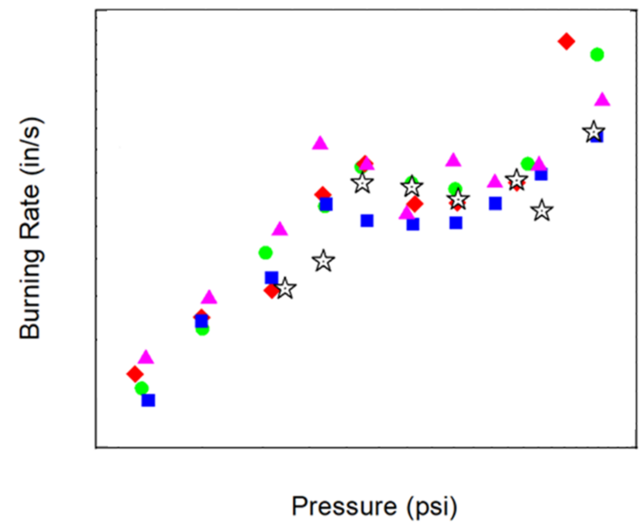


- **Propellant mixes were too viscous due to the narrow AP size distribution used**
- **Plateau effects began to vary based on mix size and material lots used**

Improving Plateau Consistency



Improved control of nAl-HTPB cure chemistry



- **Plateau burning behavior is controlled by the binder melt layer properties**
- **Tighter control of HTPB cure chemistry was achieved through binder synthesis optimizations**
- **Propellant mix viscosity was improved by introducing micron Al powder to create a bimodal particle distribution (in combination with AP)**

Solid Fuel Ramjet Technology Development

Operational Need & Improvement

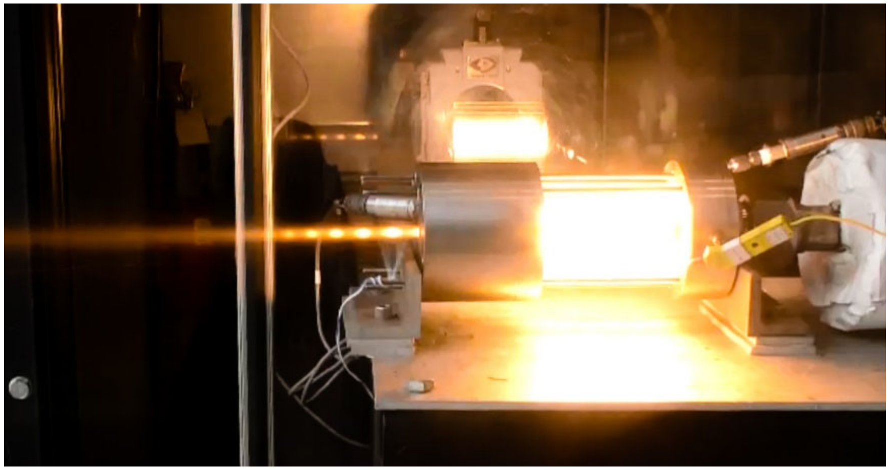
SBIR Goal: Develop high-performance solid ramjet fuel having a high regression rate with stable combustion in airbreathing rocket configurations, and high combustion efficiency over a wide range of operating conditions.

Benefit: Helicon's advanced, high-performance, insensitive fuels will meet the challenging performance goals for future Naval weapons platforms, providing the improved range and reduced time to target required to defeat evolving threats.

Helicon's revolutionary nanocomposite manufacturing process provides this performance advantage

- Scalable, cost-effective approach
- Compatible with current production methods
- High performance without hazardous or sensitive ingredients

Photo credit: Helicon



Test of Helicon fuel at Purdue University

DoD & Commercial Markets

DoD focus areas in energetics

- 3D printable propellants and warheads
- Airbreathing propulsion
- Liquid fuels & propellants
- Insensitive munitions
- Industrial base obsolescence
- Next-generation chemical propulsion systems

Photo courtesy of US Navy

Commercial applications

- Fuel & propellant for commercial space launch
- Explosives and propellants for oil/gas/mining
- High-strength, lightweight composites
- Thin film technology for electronic systems
- Pulsed power, capacitors, and photovoltaics
- Fuel cells nanocomposite membranes & catalysts
- Multi-functional coatings

Photo courtesy of US Navy

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Thank you

Questions?