# Development of Plateau Burning Composite Propellant for Ejection Seat CAD/PAD Systems

HELICON CHEMICAL COMPANY

David Reid, PhD
*President & CEO*

Dr. Eric L. Petersen
TEXAS A&M UNIVERSITY

Dr. Sudipta Seal
University of Central Florida

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# Introduction

# Introduction and Project Goals

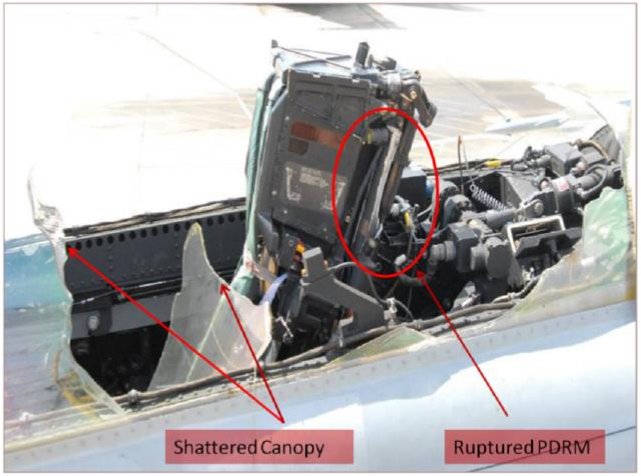
**Motivation:** **Eliminate the safety hazard associated with double base propellant nitrate ester (NE) stabilizer depletion from prolonged high-temperature exposure**

**Benefit:** **Longer installed life of affected CAD/PAD items, procurement cost savings, safety improvement**

**Project Goal:** **Develop an AP/HTPB composite propellant with equivalent performance to the double base propellant used in NACES ejection seat rocket motors and cartridges**

**Key Objectives:**

- Low temperature sensitivity ($\sigma_p < 0.1\%/K$)
- High burning rate: ≈1 in/s at 2000 psi
- Plateau burning from 2000-5000 psi
- Negative slope in burning rate curve through at least 4500 to 5000 psi
- Thermally stable / NE-free




2007 PDRM (MT29) auto-ignition incident

Source: Burchett, J., 5th International Nitrocellulose Symposium, 17-18 April 2012

# Background: AP/HTPB vs. Double Base Propellant

**Advantage of AP/HTPB: AP/HTPB propellants are nitrate-ester free and require no stabilizer → No high temperature aging degradation risk**

**Challenges: AP/HTPB propellants do not meet key performance requirements for use in some ejection seat CAD/PADs**

| | NE Double Base Propellant | AP/HTPB Composite Propellant |
|---|---|---|
| Burning rate | High | Low |
| Plateau burning | Yes | No |
| Burning rate temperature sensitivity | Low | High |
| High pressure operation | Yes | No |
| Thermal stability | Unstable | Stable |

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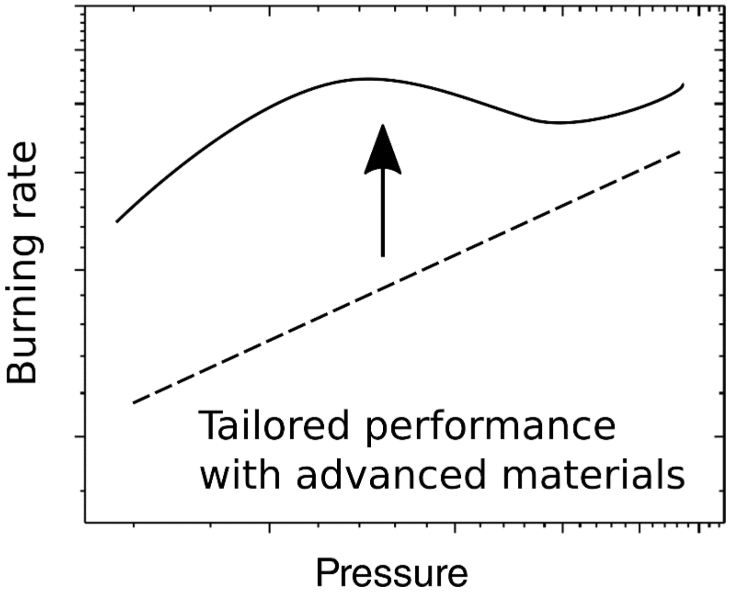
# Technology Overview

# Helicon's propellant technology

**Our approach: Incorporate latest research in burning rate modifiers and nanoparticle additives to produce a NE-free, AP/HTPB propellant with the performance characteristics of a NE double base propellant**

- → **Increase burning rate**
- → **Reduce temperature sensitivity**
- → **Create extended burning rate plateaus and mesas at the desired operating pressures**
- → **Match $I_{sp}$**
- → **Maintain thermal stability**



# Nanomaterials for composite propellants

## Nanomaterials in propellants:

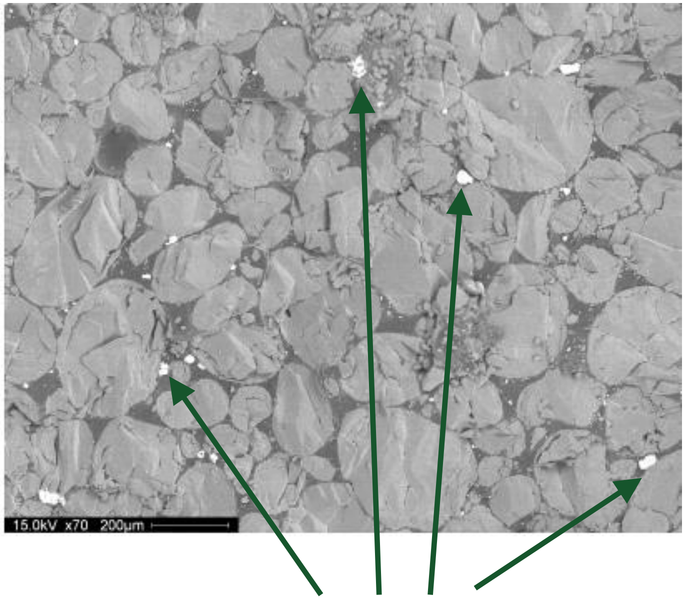
### Potential benefits:

- Nanofuels: fast burning, high combustion efficiency
- Nanocatalysts: higher activity, low catalyst loading required

### Challenges:

- Handling and safety
- Processability, high mix viscosity
- Poor dispersion, particle agglomeration
- Performance lower than anticipated

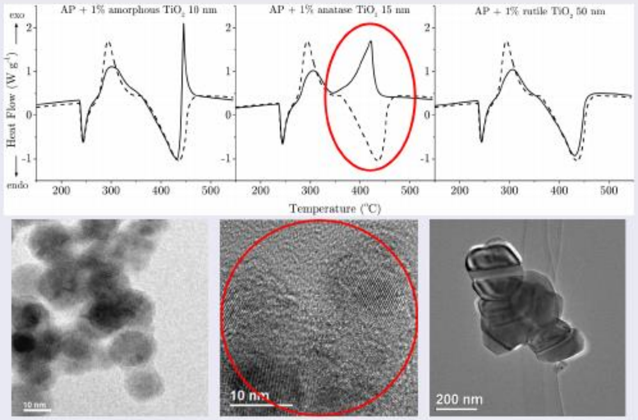
**AP/HTPB propellant containing nanopowder prepared by conventional mixing**



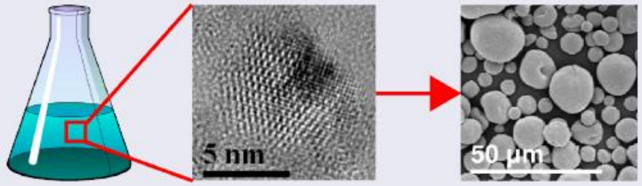

**Nanoparticle agglomerates**

# Nanomaterial properties investigations

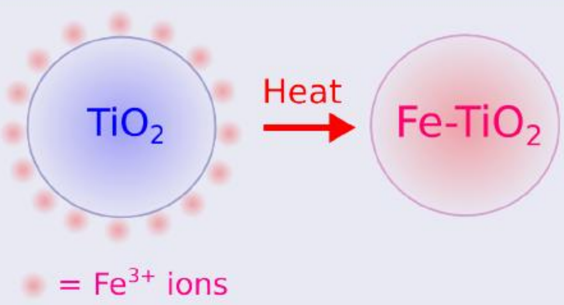
## Crystal phase



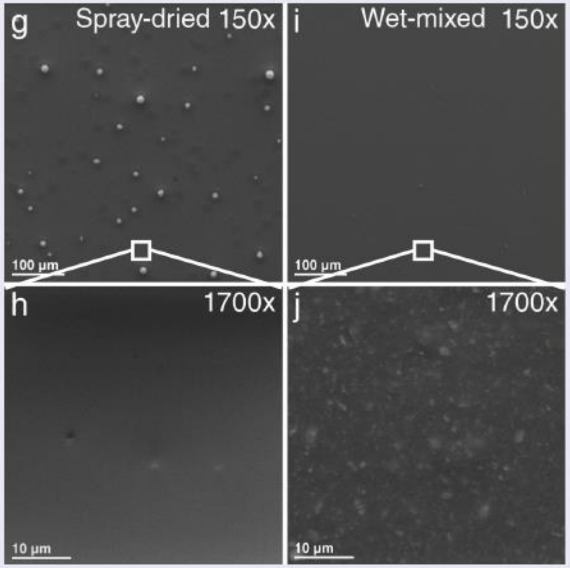

## Agglomeration



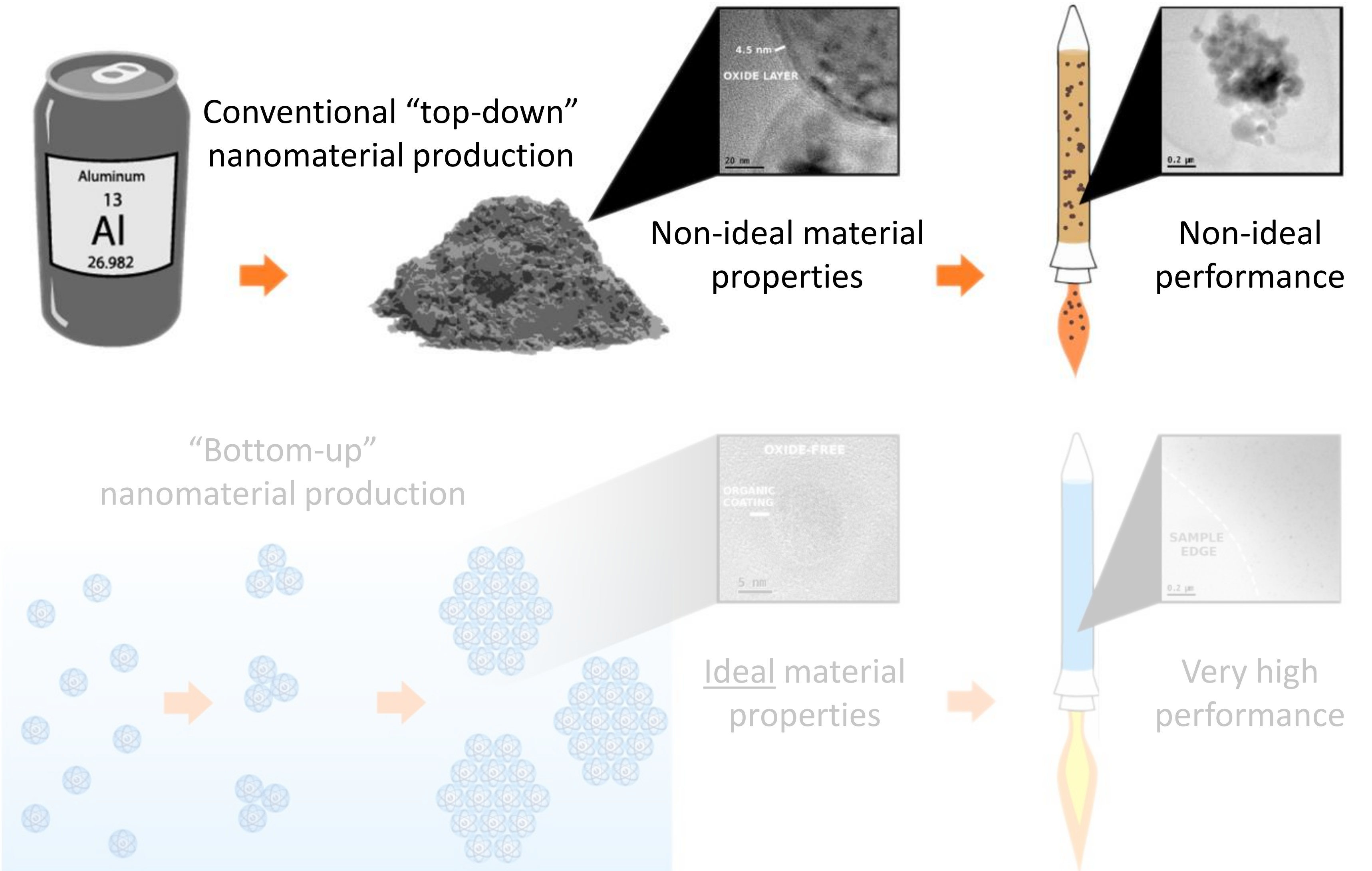

## Doping




## Microstructure



# Nanocomposite manufacturing methods



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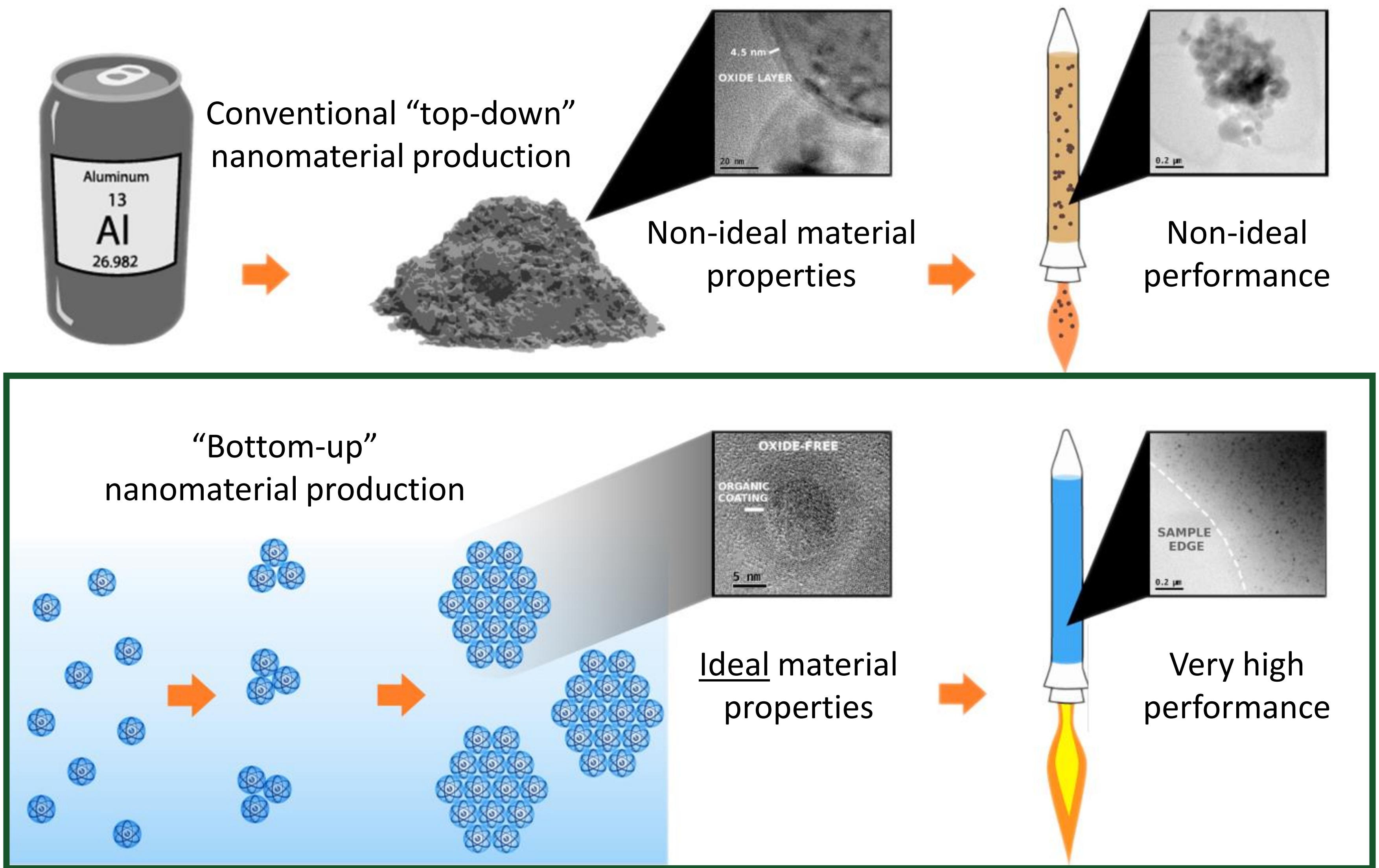
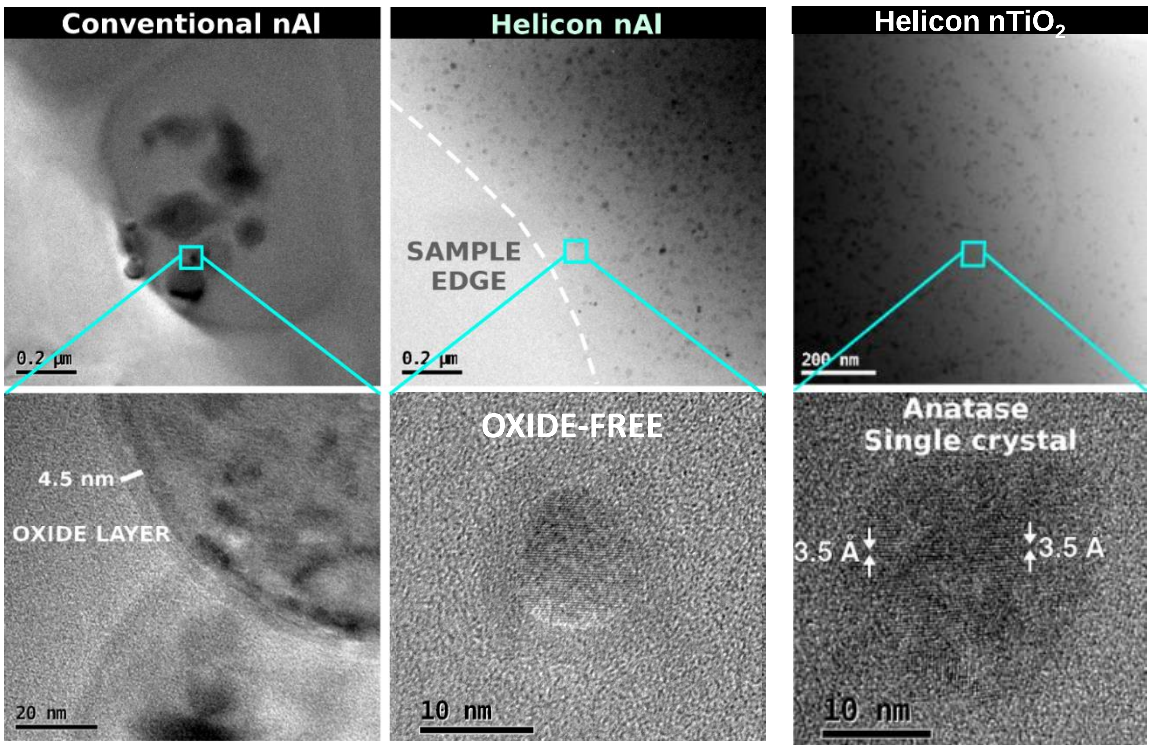
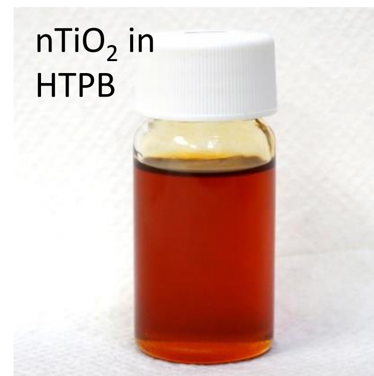
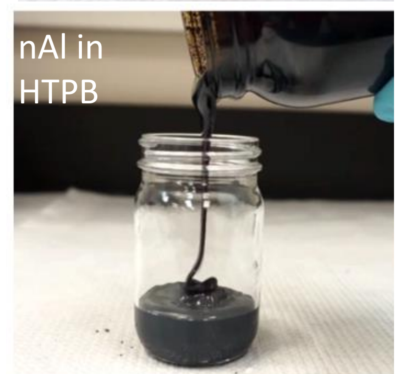


# Helicon’s nanocomposite technology

- Helicon has developed new materials synthesis and processing technology to create **homogeneous nanoparticle/polymer composites**
- HTPB binders containing Helicon’s homogeneous nAl and $nTiO_2$ produce composite propellants with unique performance characteristics

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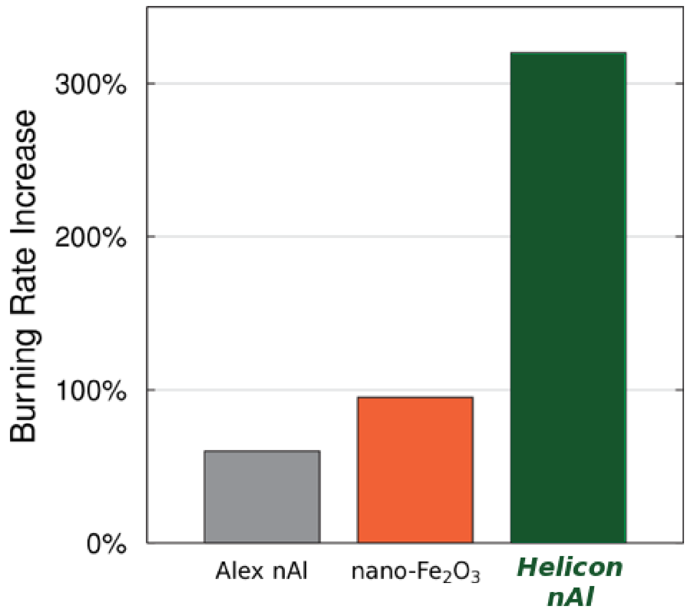
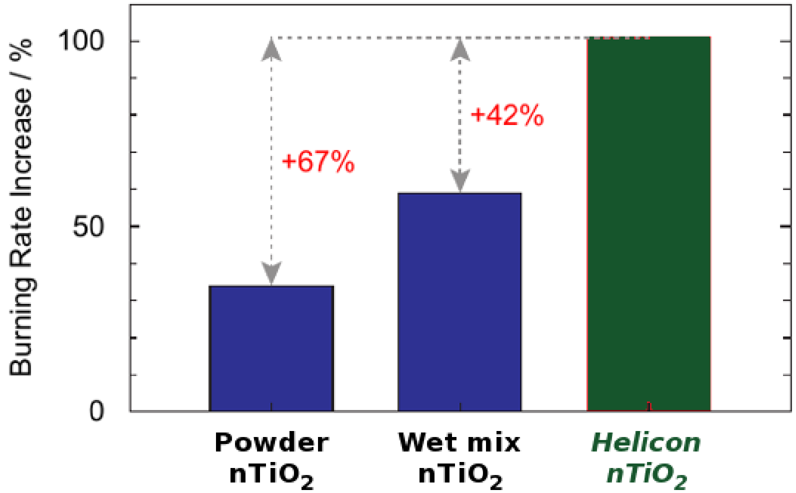
# nAl and $nTiO_2$ propellant performance




**Helicon nAl dispersed in HTPB**

- Oxide-free
- Homogeneous dispersion in the binder
- Extremely rapid ignition
- Complete combustion
- Not catalytic toward AP decomposition
- High burning rates due to heat feedback mechanism




**Helicon $nTiO_2$ dispersed in HTPB**

- Highly active anatase crystal structure
- Homogeneous dispersion in the binder
- Effective at low concentration (≈0.1%)
- High burning rates due to AP reaction catalysis

# Propellant Development Progress

# Helicon's propellant additive technology

- Increase burning rate
- Reduce temperature sensitivity
- Create extended burning rate plateaus and mesas at the desired operating pressures
- Match $I_{sp}$
- Maintain thermal stability

→ Nanocomposite ballistic modifiers

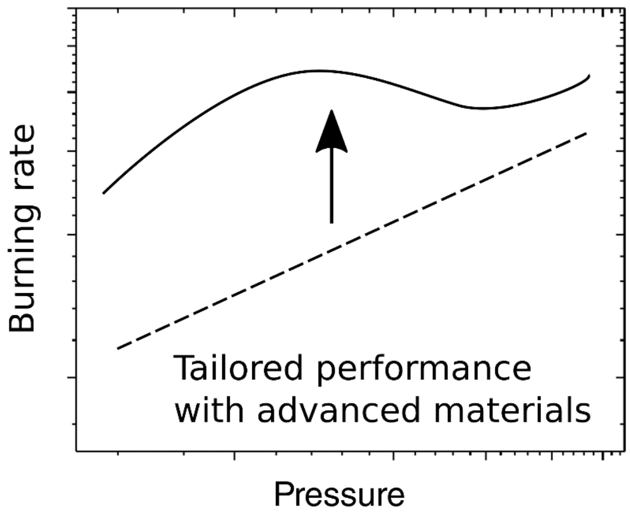
→ Nano-Al with heat feedback mechanism

→ Modify binder melt layer rheology using additives

→ Optimize overall composition

→ Formulation tailoring, thermochemical calculation

→ No sensitizing ingredients

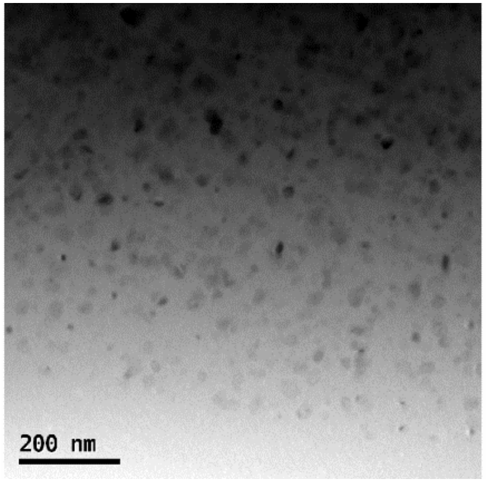



***This propellant development effort combines multiple materials & technologies to achieve the desired effects***

# Helicon's propellant additive technology

- **Increase burning rate** → **Nanocomposite ballistic modifiers**
- **Reduce temperature sensitivity** → **Nano-Al with heat feedback mechanism**
- Create extended burning rate plateaus and mesas at the desired operating pressures → Modify binder melt layer rheology using additives
- Match $I_{sp}$ → Optimize overall composition
- Maintain thermal stability → Formulation tailoring, thermochemical calculation

→ No sensitizing ingredients




- Nanomaterial ballistic modifiers accelerate the burning rate to meet CAD/PAD device requirements
- Rapid fuel combustion heat feedback mechanism reduces $\sigma_p$ to 0.1-0.2%

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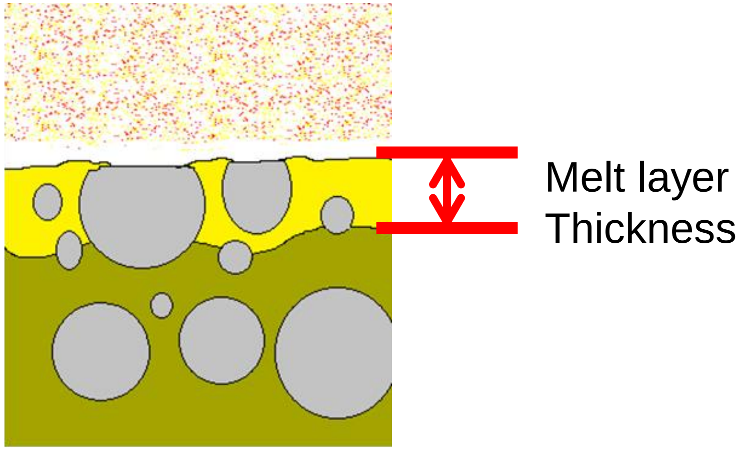


- Additives modify binder melt layer thickness and viscosity
- Produces burning rate plateaus spanning 1000s of psi

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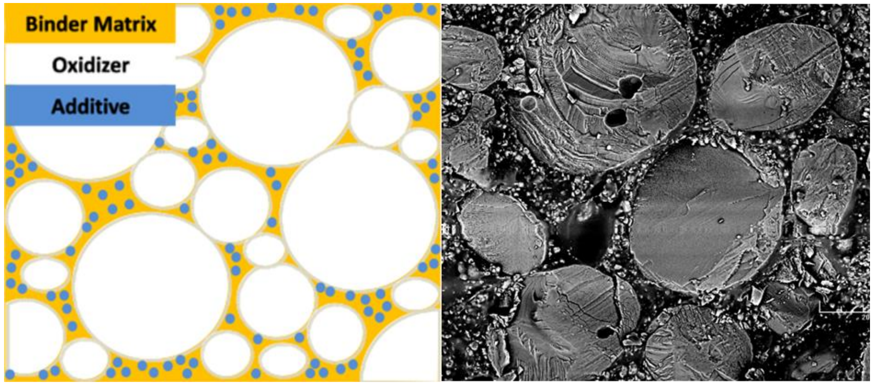


Overall performance is matched by tailoring the propellant formulation

- % AP
- % Al
- Other ingredients

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- Create extended burning rate plateaus and mesas at the desired operating pressures
- Match $I_{sp}$
- **Maintain thermal stability**

→ Nanocomposite ballistic modifiers

→ Nano-Al with heat feedback mechanism

→ Modify binder melt layer rheology using additives

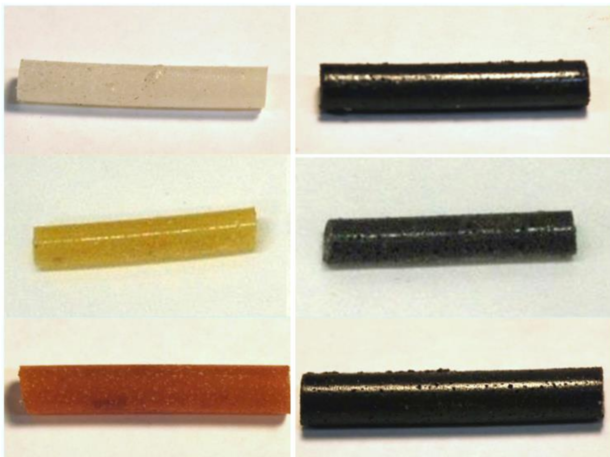
→ Optimize overall composition

→ Formulation tailoring, thermochemical calculation

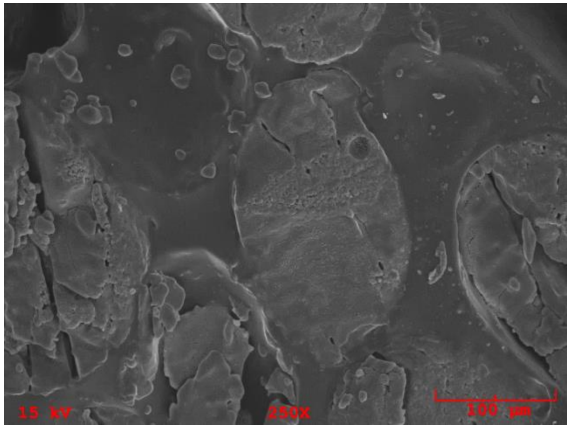
→ **No sensitizing ingredients**

# High humidity thermal stability testing

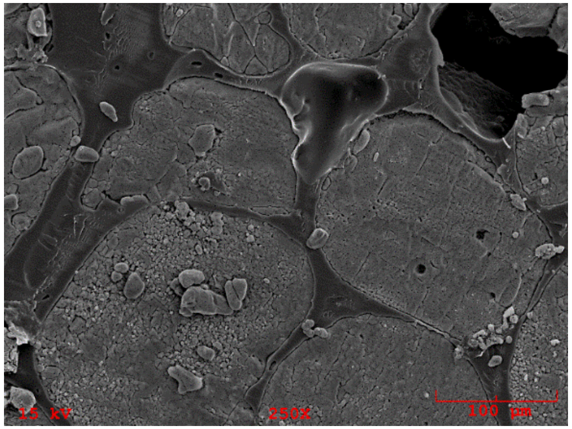
| | Baseline (no additives) | Test Propellant |
|---|---|---|
| Time = 0 days | | |
| Time = 30 days | | |
| Time = 60 days | | |



- Evidence of HTPB oxidation around AP crystals – typical of AP/HTPB propellants
- No performance change
- No thermally sensitive ingredients present




Zero time




60 days at +200 °F, 85% R.H.

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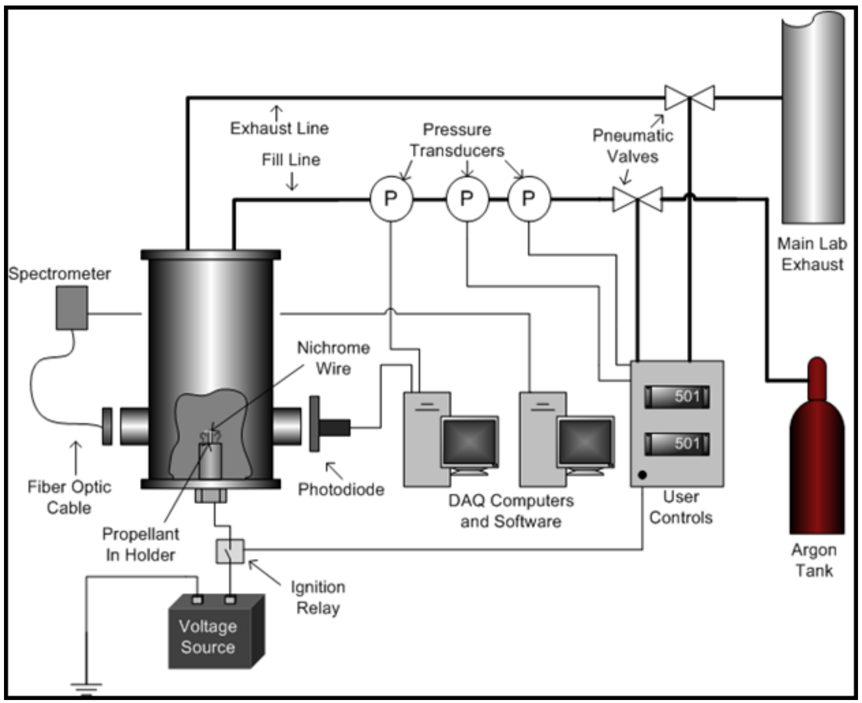
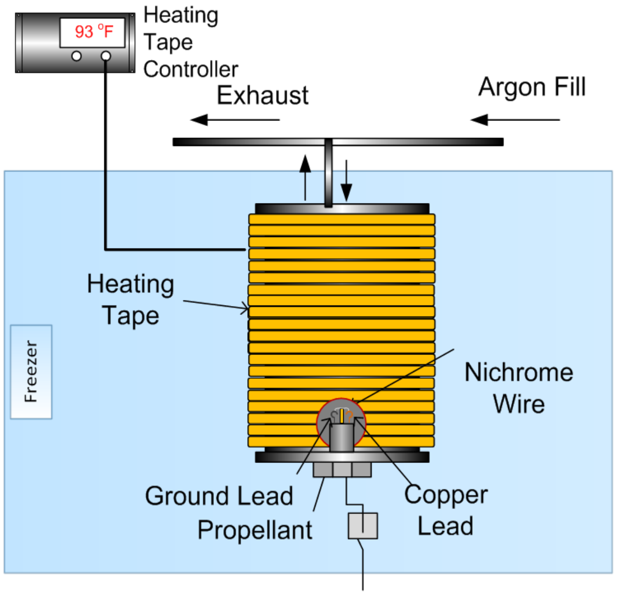
# Propellant testing at Texas A&M

- Burning rate and temperature sensitivity characterized by strand burners at Texas A&M University
  - Measurements at -65°F, ambient, +200°F
  - Zero time and aged (60 day +200°F) samples




High Pressure Window Bomb / Strand Burner



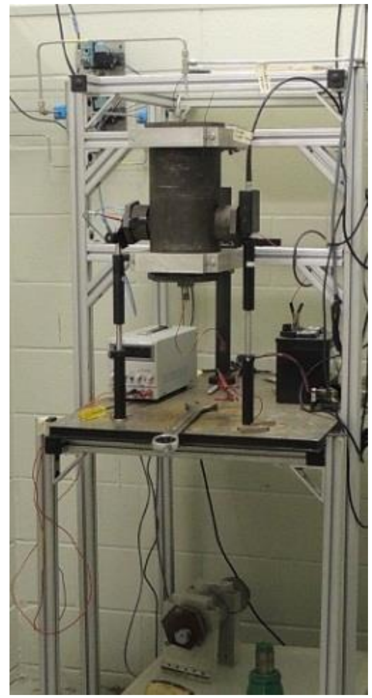

Strand burner for low and high temperature testing

# Texas A&M facility photographs

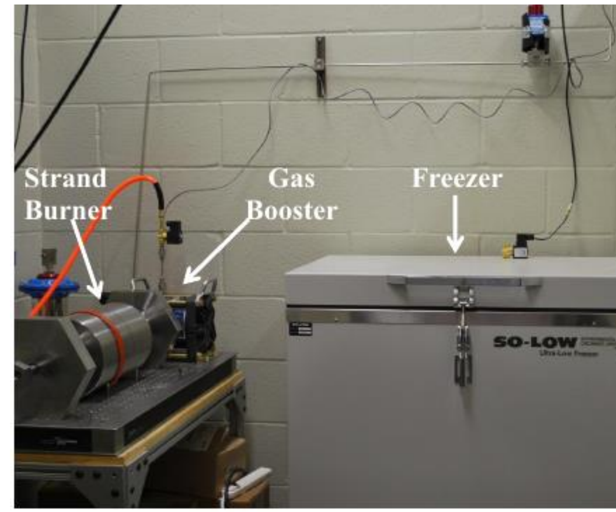
Fume hood

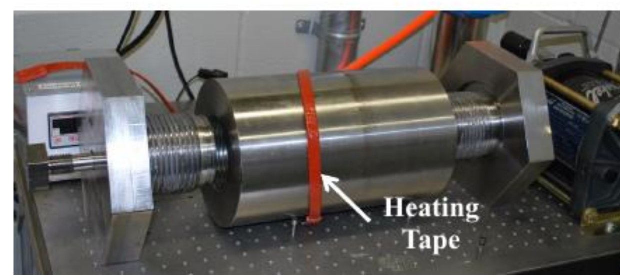
Cast and vacuum

ESD floor



Strand bomb




Variable temperature strand burner

# Propellant development: current status

- **Formulations matching $I_{sp}$, burning rate, plateau, $\sigma_p$, and thermal stability goals have been developed and tested via strand burner**
- **Current formulation effort focuses on extending the burning rate plateau to higher pressure region**
- **AP decomposition/deflagration rate becomes problematic at high pressure**

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| Burning rate | High | **High ✔** |
| Plateau burning | Yes | **Yes ✔** |
| Burning rate temperature sensitivity | Low | **Low ✔** |
| High pressure operation | Yes | **In Progress** |
| High-temperature aging | Unstable | **Stable ✔** |

# Acknowledgements


<u>Texas A&M University</u>

- Dr. Eric Petersen
- Andrew Demko
- Catherine Dillier

<u>University of Central Florida</u>

- Dr. Sudpita Seal
- Kevin Grossman

<u>NSWC IHEODTD</u>

- Engineering Team

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# *Advanced Fuels and Propellants*

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