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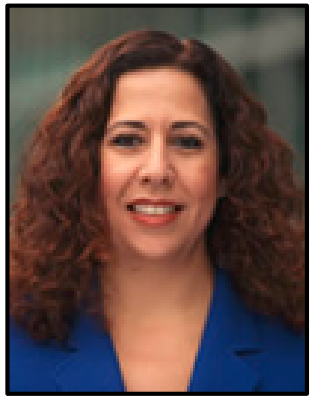
Advances in the Development of Environmentally Friendly Pyrotechnic and Propellant Formulations

February 27, 2020

SERDP DOD • EPA • DOE | ESTCP

Welcome and Introductions

Rula A. Deeb, Ph.D.
Webinar Coordinator



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Webinar Agenda

- **Webinar Logistics** (5 minutes)
  Dr. Rula Deeb, Geosyntec Consultants
- **Overview of SERDP and ESTCP** (5 minutes)
  Dr. Robin Nissan, SERDP and ESTCP
- **Environmentally Benign Multi-Component Delay System with Tunable Propagation Characteristics** (25 minutes + Q&A)
  Matthew Puszynski, Innovative Materials and Processes, LLC
- **Safer and Environmentally Conscious Continuous ResonantAcoustic® Production of Energetic Material** (25 minutes + Q&A)
  Mike Miller, Resodyn Corporation
- **Final Q&A session**

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- If material is not showing on your screen or if screen freezes
  - Key in Ctrl + F5 to do a hard refresh of your browser
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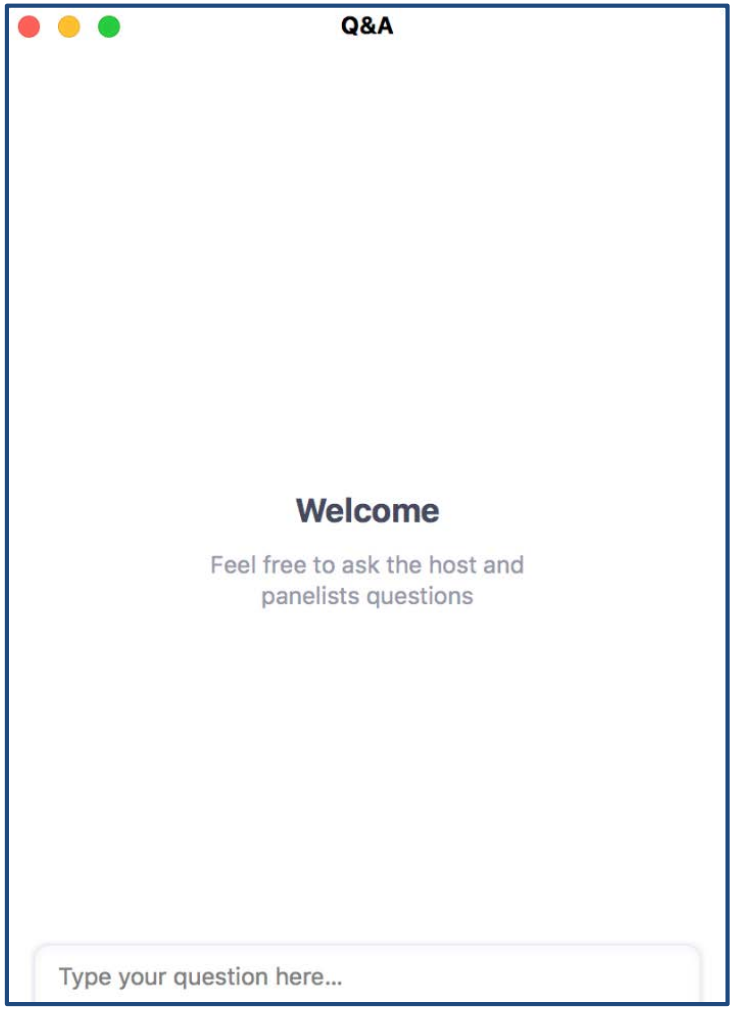


SERDP and ESTCP Overview

Robin Nissan, Ph.D.
SERDP and ESTCP

SERDP DOD ▪ EPA ▪ DOE | ESTCP

SERDP

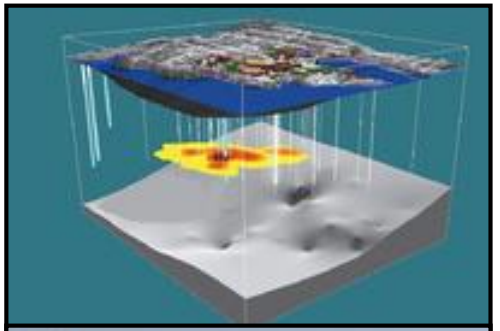
- Strategic Environmental Research and Development Program
- Established by Congress in FY 1991
  - DoD, DOE and EPA partnership
- SERDP is a requirements driven program which identifies high-priority environmental science and technology investment opportunities that address DoD requirements
  - Advanced technology development to address near term needs
  - Fundamental research to impact real world environmental management

ESTCP

- Environmental Security Technology Certification Program
- Demonstrate innovative cost-effective environmental and energy technologies
  - Capitalize on past investments
  - Transition technology out of the lab
- Promote implementation
  - Facilitate regulatory acceptance

Program Areas

- Environmental Restoration
- Installation Energy and Water
- Munitions Response
- Resource Conservation and Resiliency
- Weapons Systems and Platforms





Weapons Systems and Platforms

- Major focus areas
  - Surface engineering and structural materials
  - Energetic materials and munitions
  - Noise and emissions
  - Waste reduction and treatment in DoD operations
  - Lead free electronics

SERDP and ESTCP Webinar Series

Date	Topic
March 12, 2020	Applying Compound-Specific Isotope Analysis to Document Contaminant Degradation and Distinguish Sources
March 26, 2020	Long-Term Ecological Studies: Evaluating Responses to Ecosystem Restoration and Optimizing Recovery of Plant Communities
April 9, 2020	Ecological Risk Assessment Approaches at PFAS-Impacted Sites
April 23, 2020	Munitions Response Webinar: Project of the Year
May 7, 2020	Innovative Technologies for PFAS Destruction in Investigation Derived Wastes

For upcoming webinars, please visit

http://serdp-estcp.org/Tools-and-Training/Webinar-Series

Environmentally Benign Multi-Component Delay System with Tunable Propagation Characteristics

Matthew Puszynski
Innovative Materials and Processes, LLC

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Agenda

- Background
- Technical objectives
- Delay composition development and testing
- Conclusions
- Benefits to DoD

Background

- Elimination of chromates and perchlorates from military items
- Current delay systems contain chromium (VI) and potassium perchlorate
  - T-10 (B/$BaCrO_4$)
  - Tungsten delays (W/KClO4/$BaCrO_4$)
  - Zirconium-nickel delays (Zr-Ni/$BaCrO_4$/$KClO_4$)

Technical Objectives

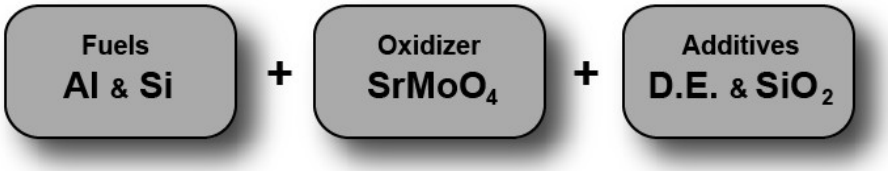
- Develop an environmentally benign pyrotechnic delay system
  - Tunable inverse burn rate (IBR) between 4 and 12 s/in
  - Proper function within the temperatures of -65ºF to 160ºF
  - All components to be environmentally benign
- Develop perchlorate-free input and output charges
- Manufacture and test fuze assemblies

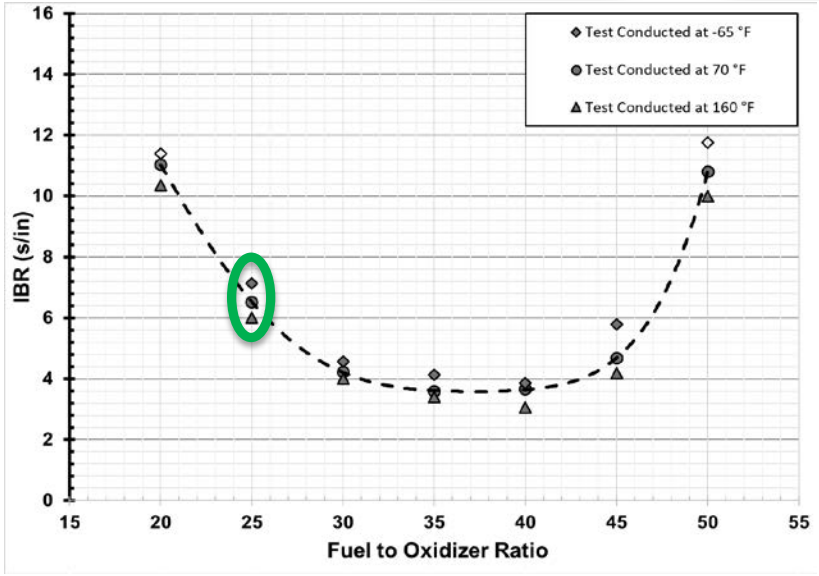
Pyrotechnic Green Delay Development

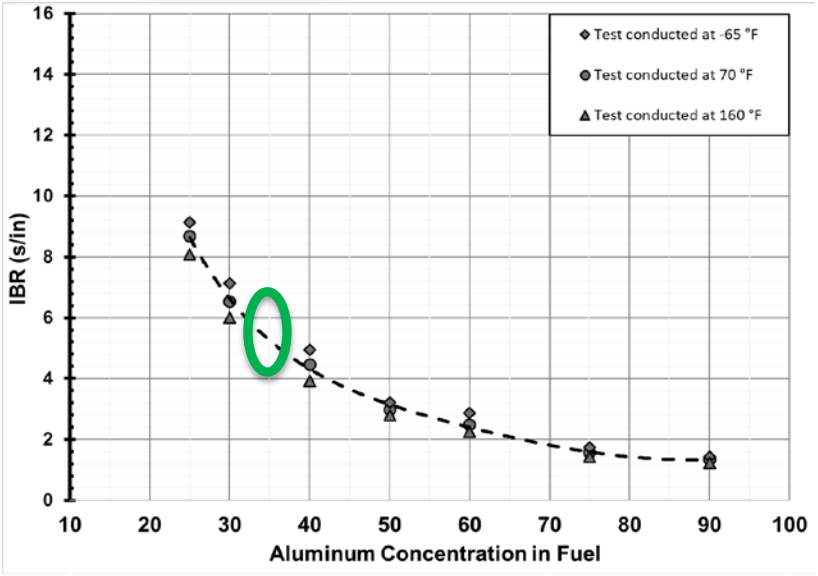
- Removal of environmental hazards
  - Aluminum and silicon as binary fuel system
  - Strontium molybdate as oxidizer
  - Silicon dioxide as burn rate modifier
- Burn rate tunability
  - Binary fuel ratio – aluminum to silicon
  - Fuel to oxidizer ratio
  - Concentration of burn rate modifier

Pyrotechnic Green Delay Optimization

- Inverse burn rate (IBR) can be tuned from approximately 1.3 to 11 s/in





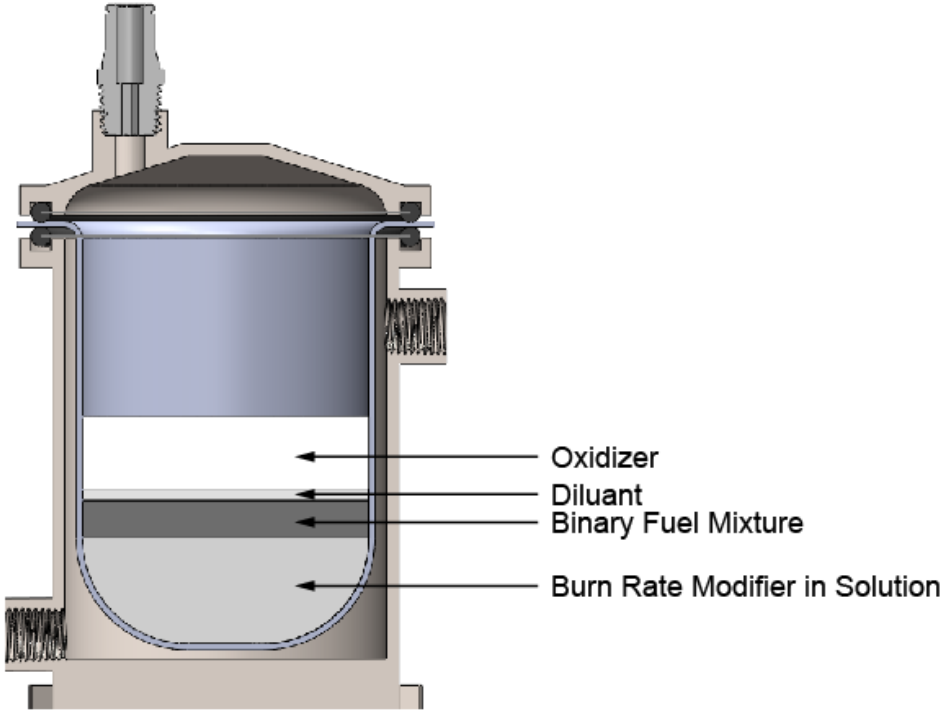


RAM Mixing Process

- Resonant Acoustic Mixing (RAM) technology as key aspect of project
  - Repeatable, accurate, and precise process
  - Short mixing times to achieve homogenous mixing
  - Wet mixing for safe processing of pyrotechnics

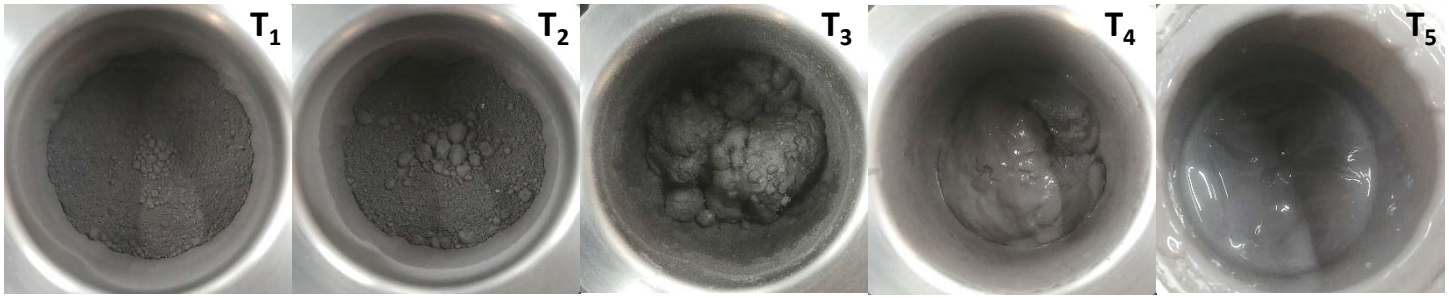
RAM Mixing Process

- RAM vessel loading order
  - Dispersion of burn rate modifier
  - Separation of fuels and oxidizers
  - Enhancing powder wetting during mixing



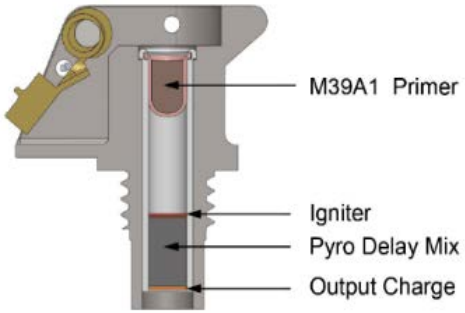
RAM Mixing Process

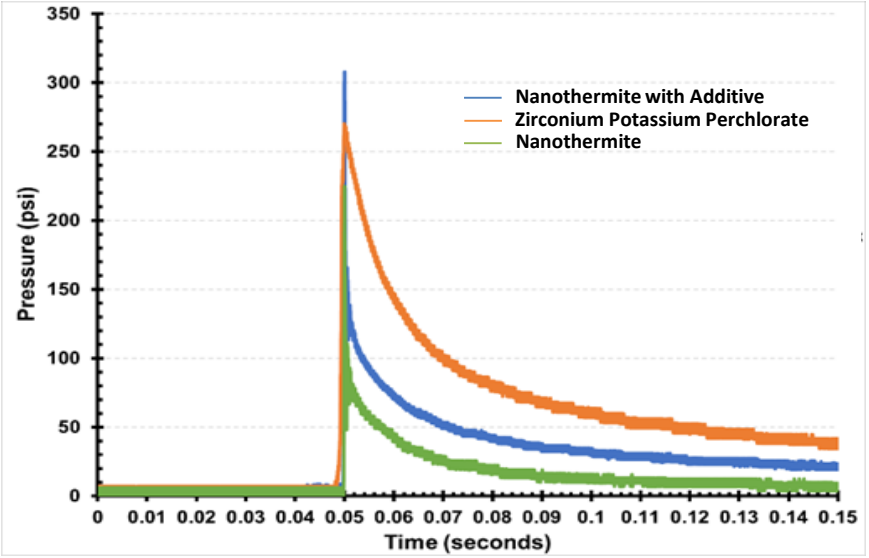
- RAM Process
  - Powder wetting
  - Incorporation
  - High intensity mixing
  - Use of jacketed cooling system



Output Charge Development

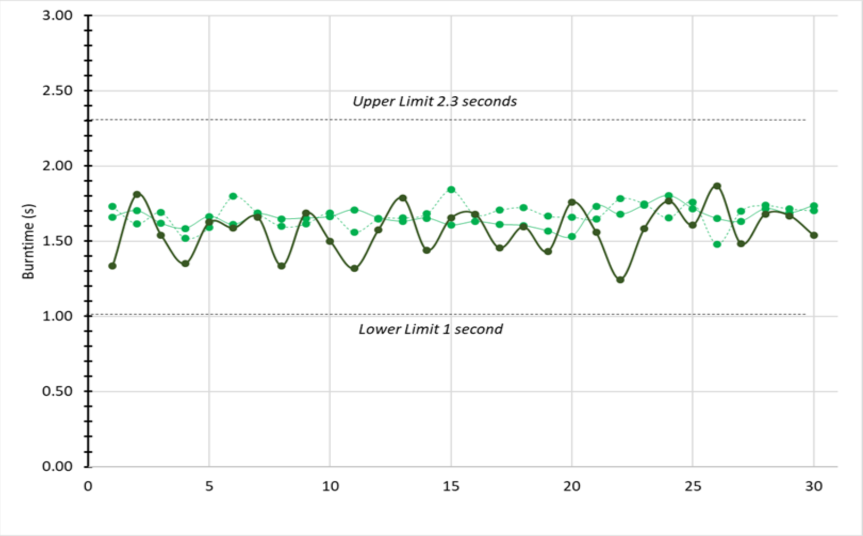
- Environmentally acceptable formulation
  - Eliminates perchlorates
  - Nanothermite based material
  - Tunable output characteristics

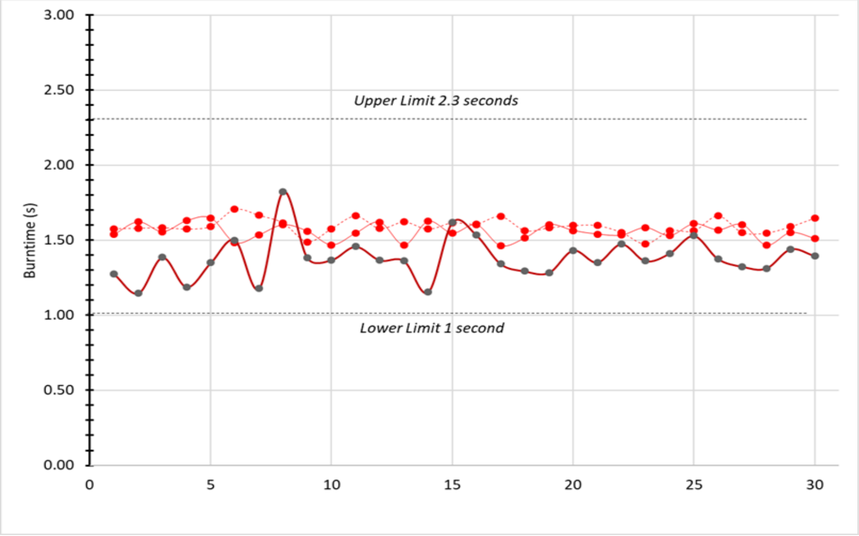


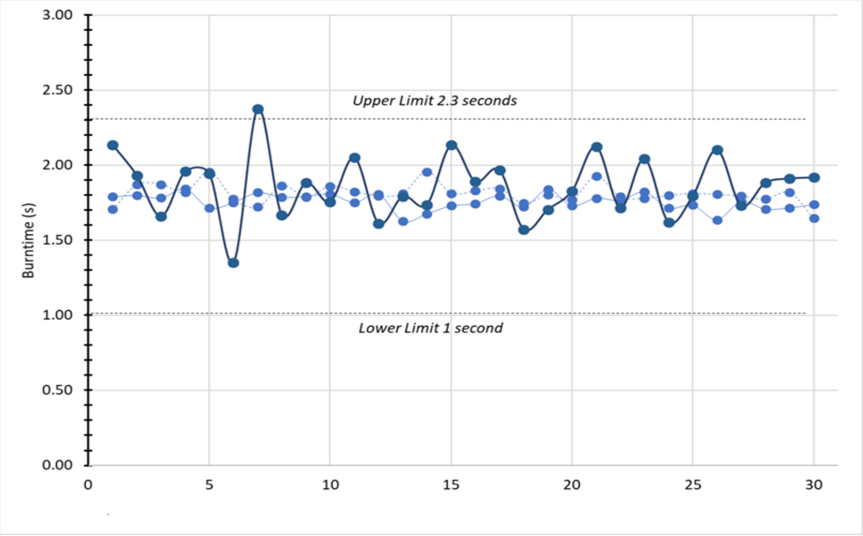


M201A1 Fuze Testing

- Burn time data from testing of AMTEC and IMP M201A1 fuzes at three different temperatures
  - -65ºF: blue
  - 70ºF: green
  - 165ºF: red

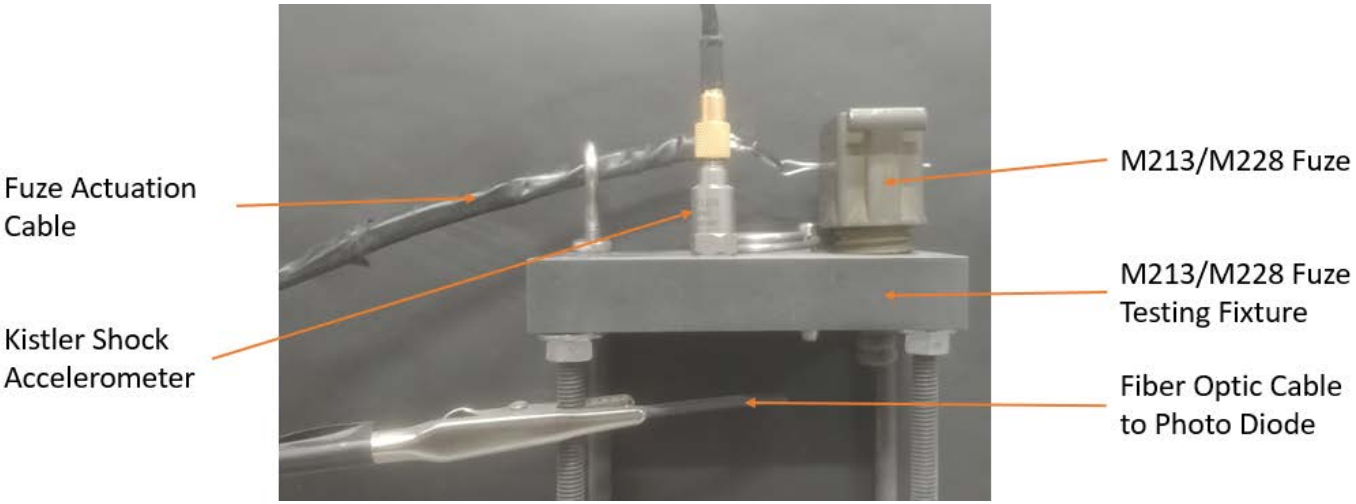






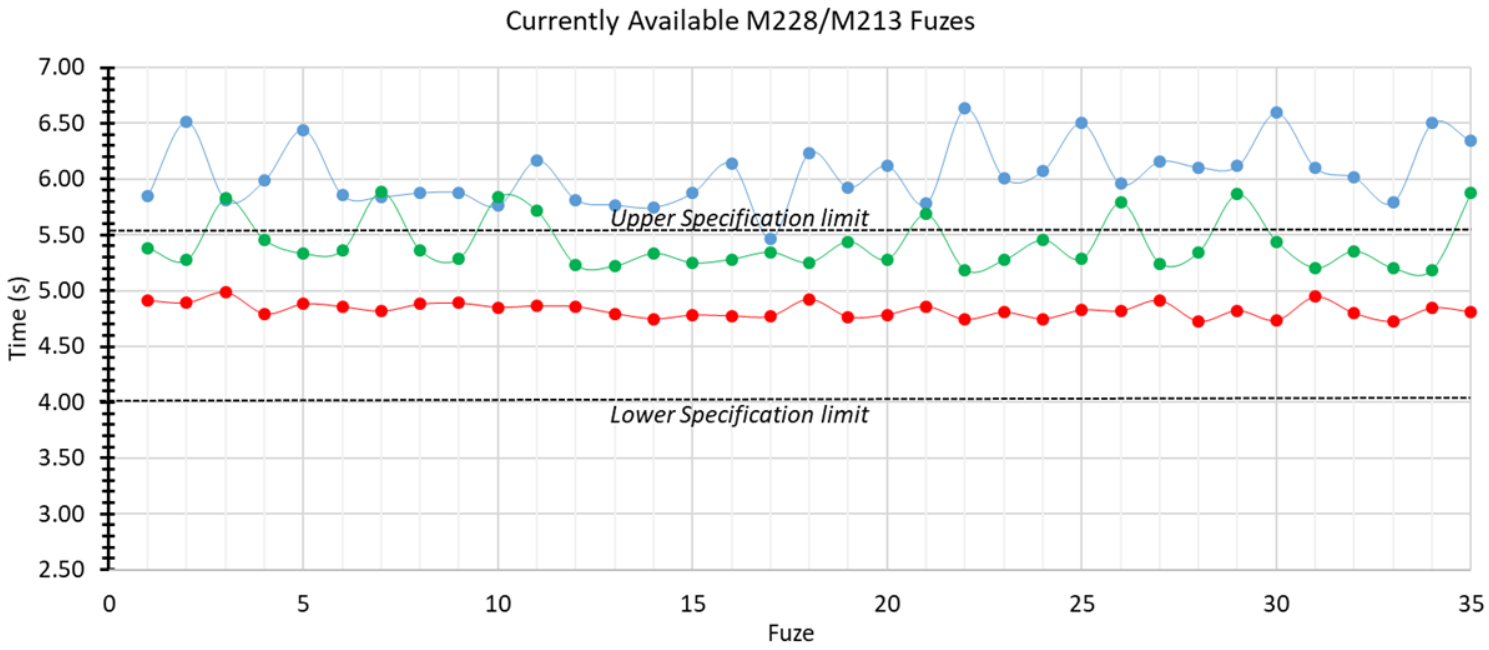
M213/M228 Fuze Testing

- M213/M228 Fuze burn time testing method
  - T=Initial determined with shock accelerometer
  - T=Final determined with photodiode
  - Data captured and analyzed using oscilliscope



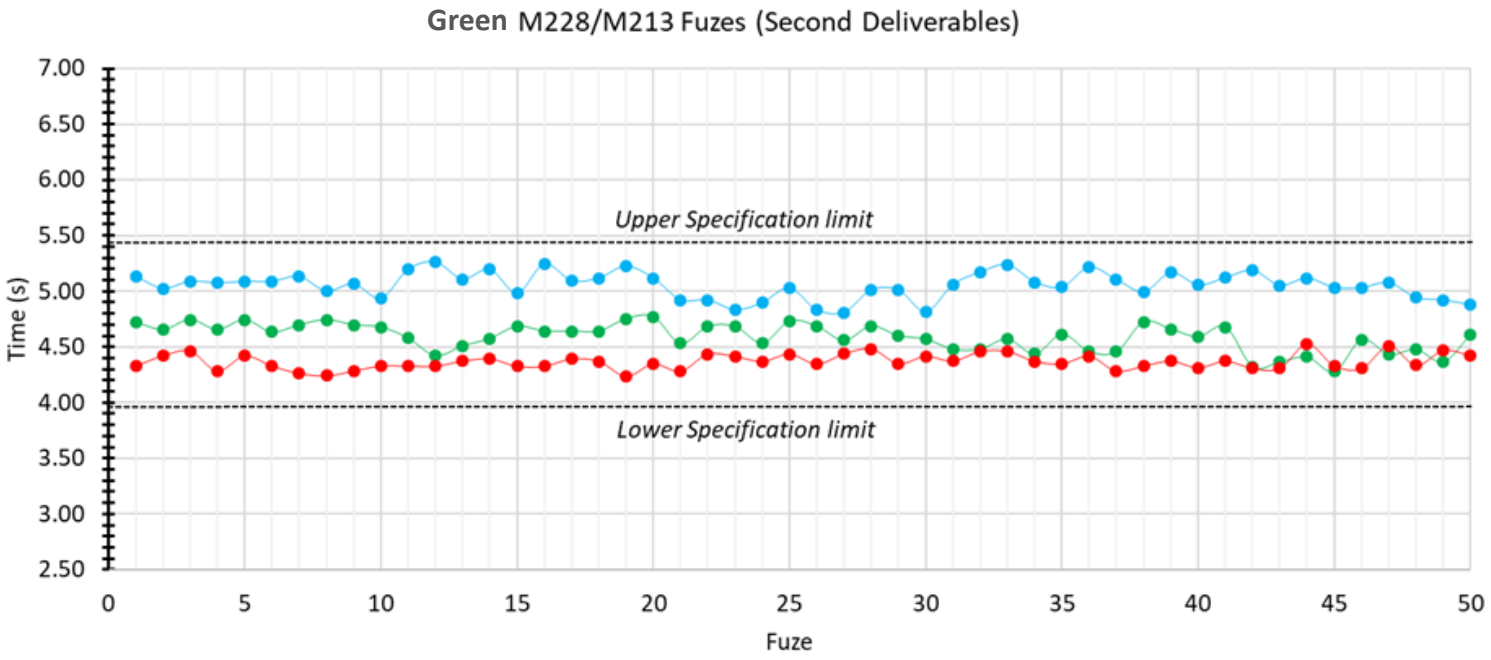
M213/M228 Fuze Testing

- Burn time data from testing of commercial fuzes with lead based primers
  - -65ºF: blue, 70ºF: green, 165ºF: red



M213/M228 Fuze Testing

- Burn time data from testing of fuzes with green delay and lead-free primers
  - -65ºF: blue, 70ºF: green, 165ºF: red



Conclusions

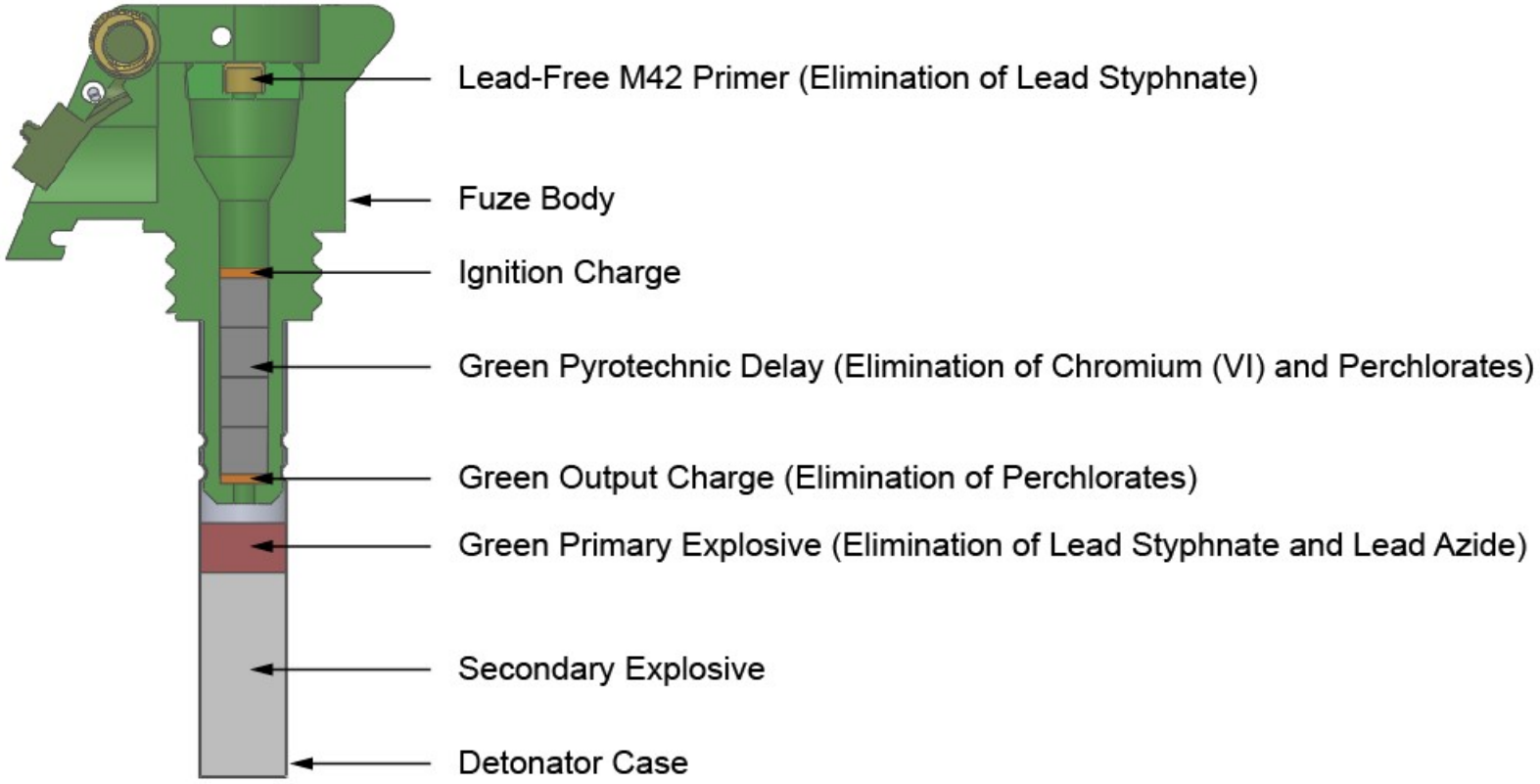
- All constituents are environmentally benign
  - Reduction in occupational and environmental hazards
  - Evaluated by US Army Public Health Center
- RAM mixing process was demonstrated
  - Process is repeatable, accurate and precise
  - Significant reduction in mixing time
  - Less waste generated
- Reproducible coefficient of variation percentage

Benefits to DoD

- Lead-free primer and detonator technologies were incorporated with the green pyrotechnic delay
  - Elimination of chromium (VI) and perchlorates from delay compositions
  - Elimination of perchlorates from output charge
  - Elimination of lead from primer and detonator components
- Fully environmentally benign M67 grenade firing train
- Increased accuracy, precision and reliability in fuze performance
- Green delay is viable for use in additional end items
  - MK4 Mod 2 Cartridge
  - CCU-47/A Cartridge
  - Other CAD/PAD Cartridge

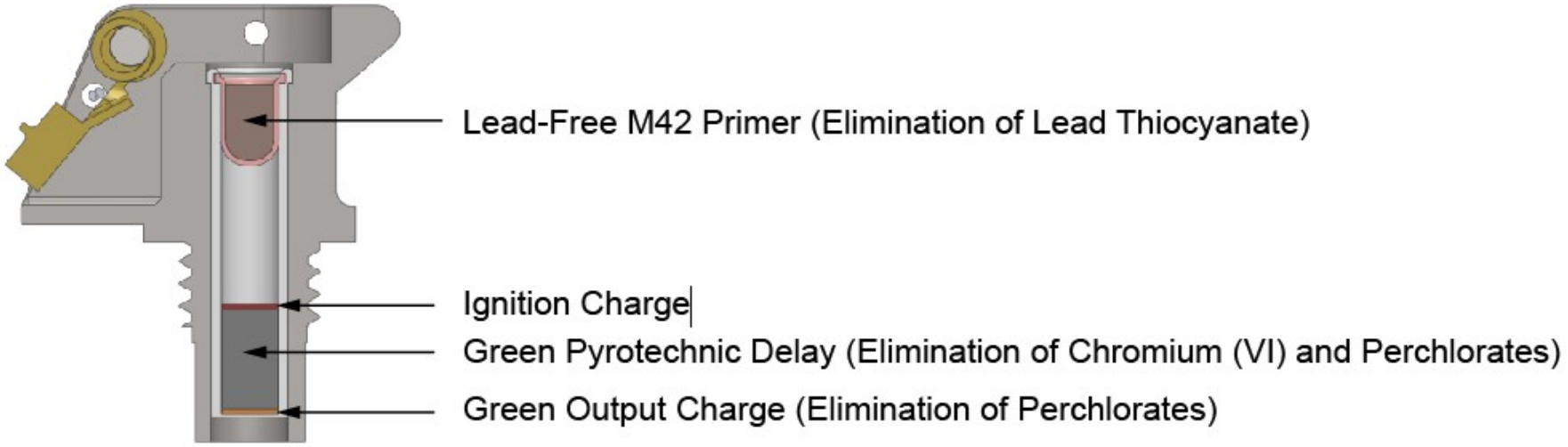
Benefits to DoD

- Fully green M213 fuze system for the M67 grenade



Benefits to DoD

- Fully green M201A1 fuze system



Technology Path Forward

- **WP18-5262**: Demonstration of this technology is being conducted on Navy CAD/PAD items
  - Mk 4 Mod 2 Cartridge
  - CCU-47/A Cartridge
- **WP20-D4-5106**: This technology was proposed for demonstration in Navy CAD/PAD applications using additive manufacturing techniques
- **WP20-D4-5045**: Demonstration of the green delay material in the US Army M213 fuze and a fully green M67 grenade firing train (primer and detonator)
- Qualification of green delay material
- Qualification of demonstrated cartridges and fuzes
- Implementation of technology at industry partners for item manufacturing

For additional information, please visit

www.serdp-estcp.org/Program-Areas/Weapons-Systems-and-Platforms/Energetic-Materials-and-Munitions/Pyrotechnics/WP-2519

Speaker Contact Information
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Q&A Session 1

Safer and Environmentally Conscious Continuous ResonantAcoustic® Production of Energetic Material

Mike Miller, P.E.
Resodyn Corporation

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Agenda

- Fundamentals of ResonantAcoustic® Mixing (RAM) and Continuous Acoustic Mixing (CAM)
- The CAM-Clean-In-Place (CIP) system
- Characterization of the mixing
- Clean-In-Place review
- CAM system development for energetics

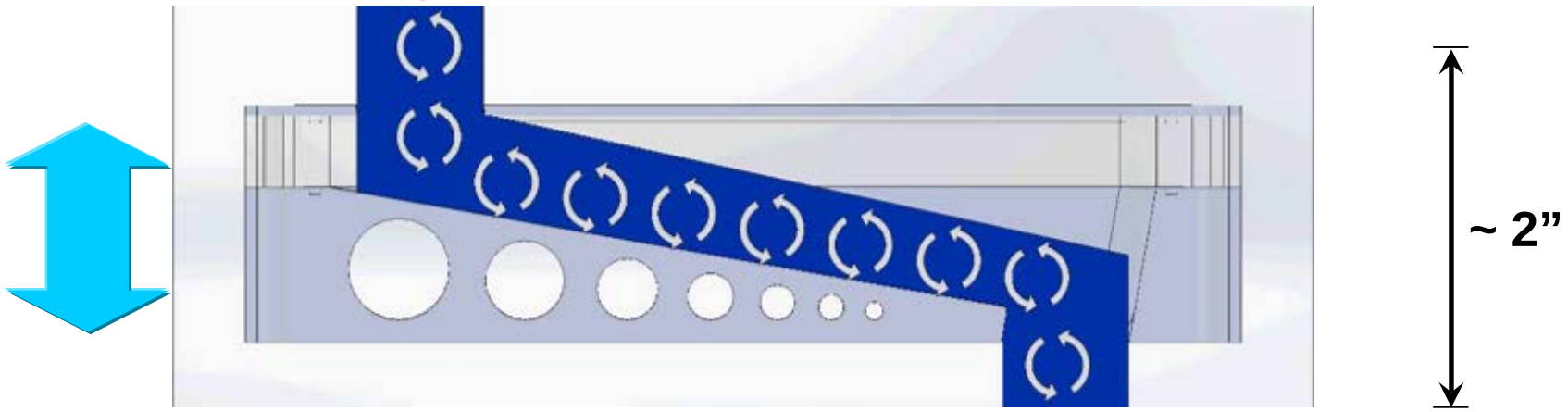
Basics of RAM Mixing

- ResonantAcoustic® mixers create up to 0.55-inch oscillating displacements at ~60 Hz (up to 100 g of acceleration)

Continuous Acoustic Mixer - Paste

- Upper and lower acoustic transducers continuously work on the materials being mixed

Continuous Module Inlet



60 Hz Vertical Motion

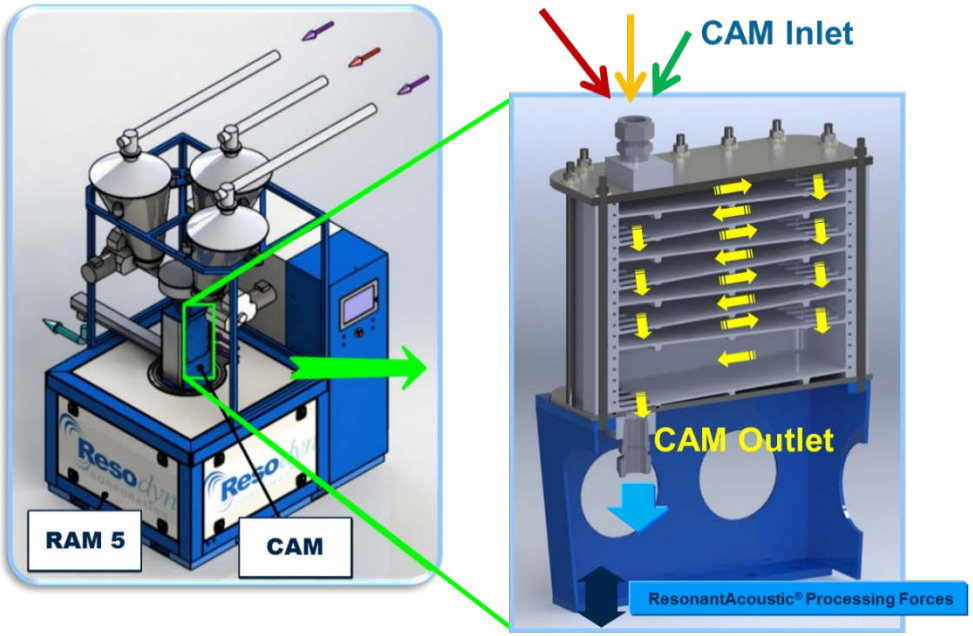
Continuous Module Outlet

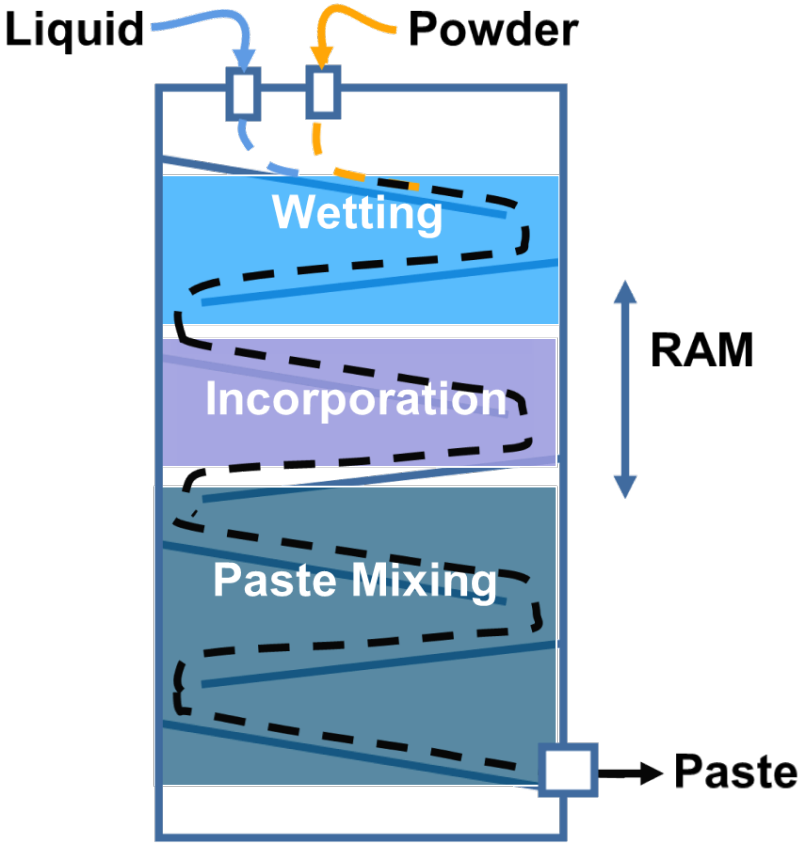
Mixing Pastes Continuously

- CAM-CIP for RAM 5
  - Paste viscosities >1,000,000 cP at room temperature
  - Tested at 3.0 kg/min or 180 kg/hr

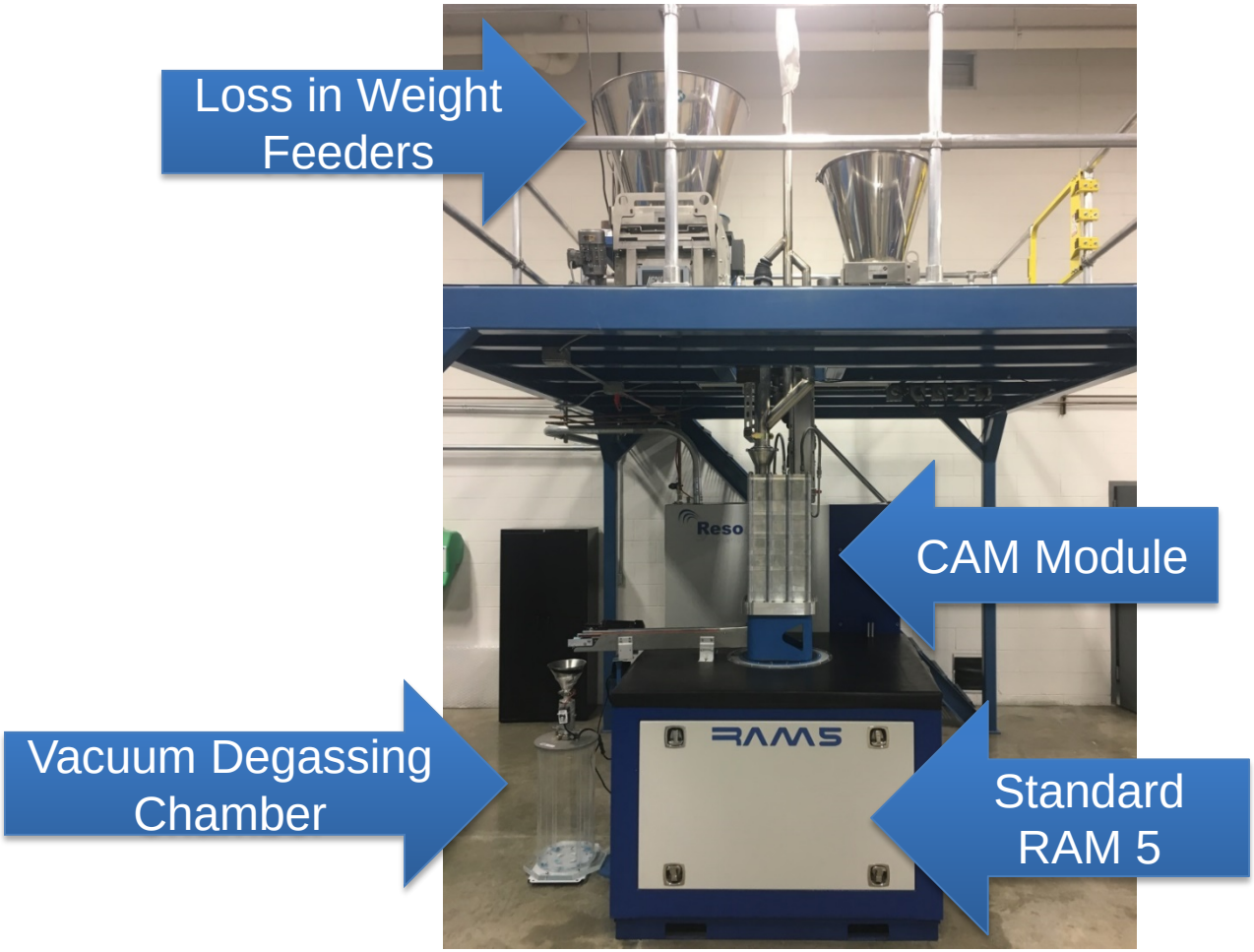
Continuous Schematics

Continuous Acoustic Mixer (CAM)





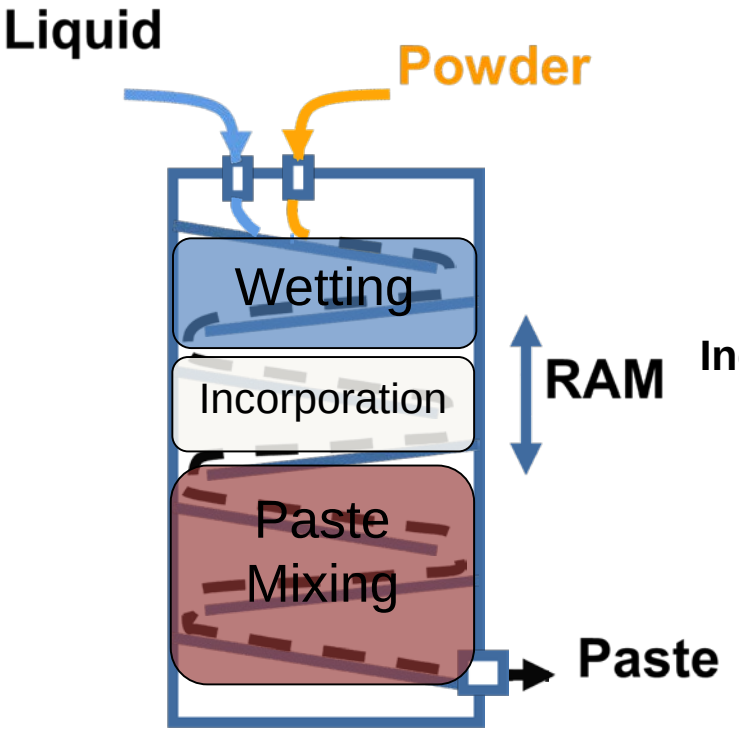
The Overall Process

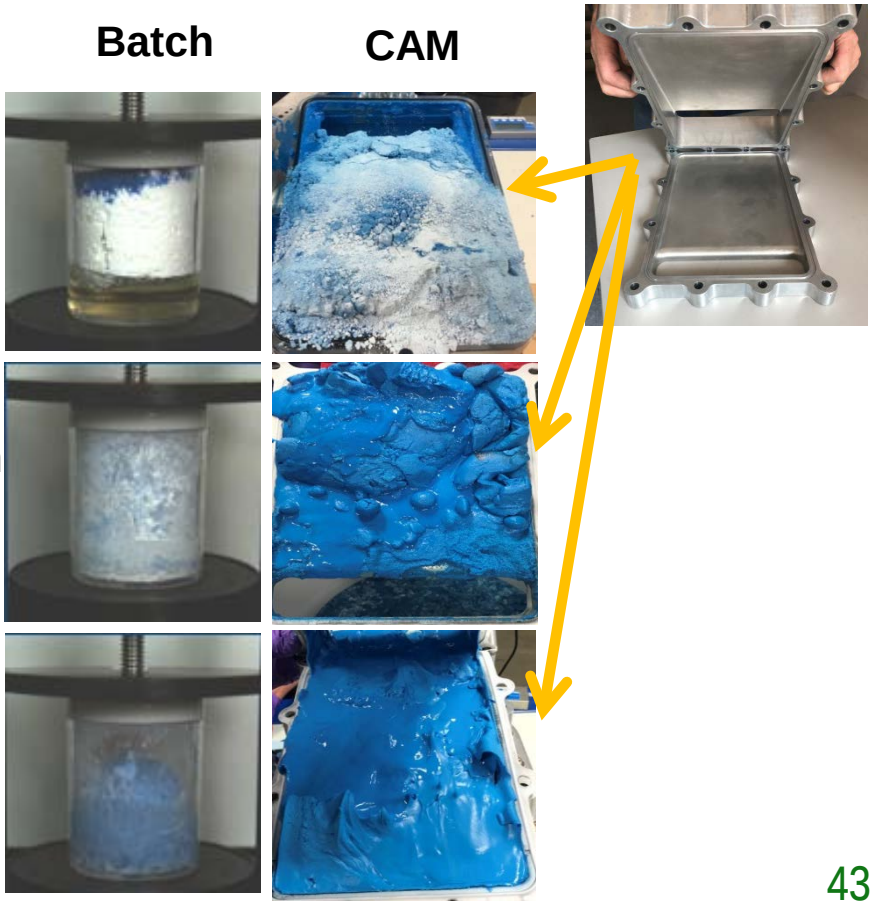


Continuous Mixing System

Continuous Module Mix Regimes

- Mix regimes are the same within the CAM as in batch

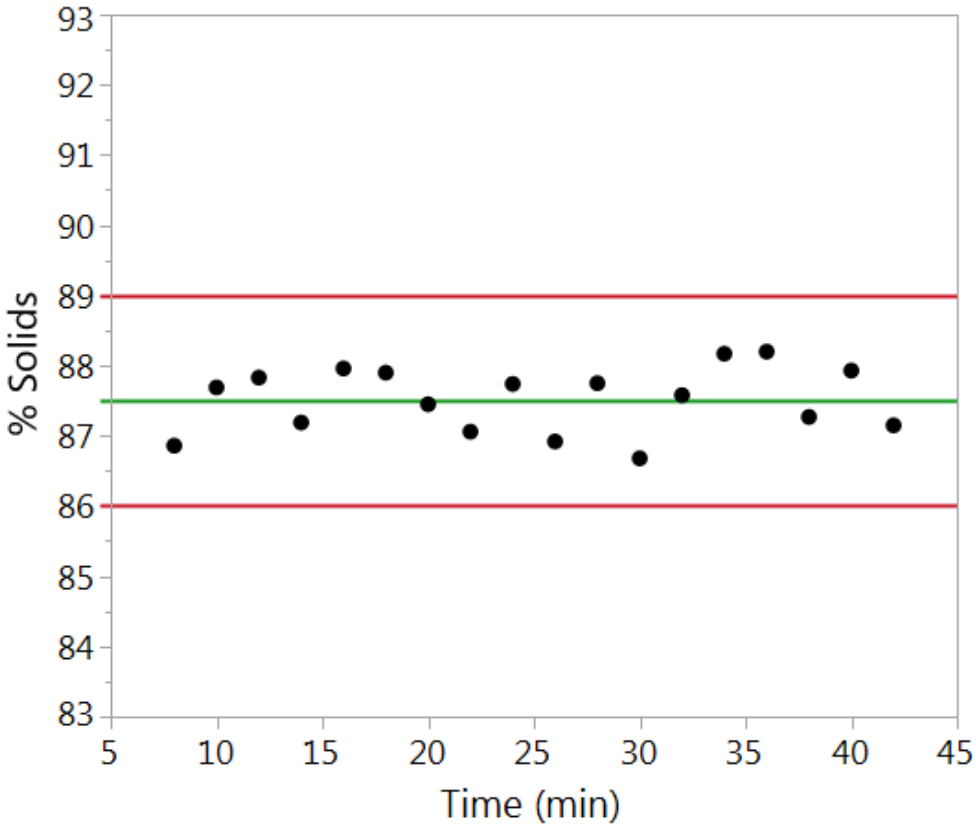




Plastic Bonded Surrogate Explosive Paste

- Thermal Gravimetric Analysis (TGA) provides a reliable and reproducible measure of solids loading consistency

Produced material solids loading is well controlled to within ±3 standard deviations



Operational Parameters

- Solids loading (viscosity) has a negative effect on homogeneity and consistency
- Solids loading and acceleration interact
  - For a given formulation, there is an optimal acceleration for the most consistent and homogeneous mixing

Temperature Control

Heating or Cooling

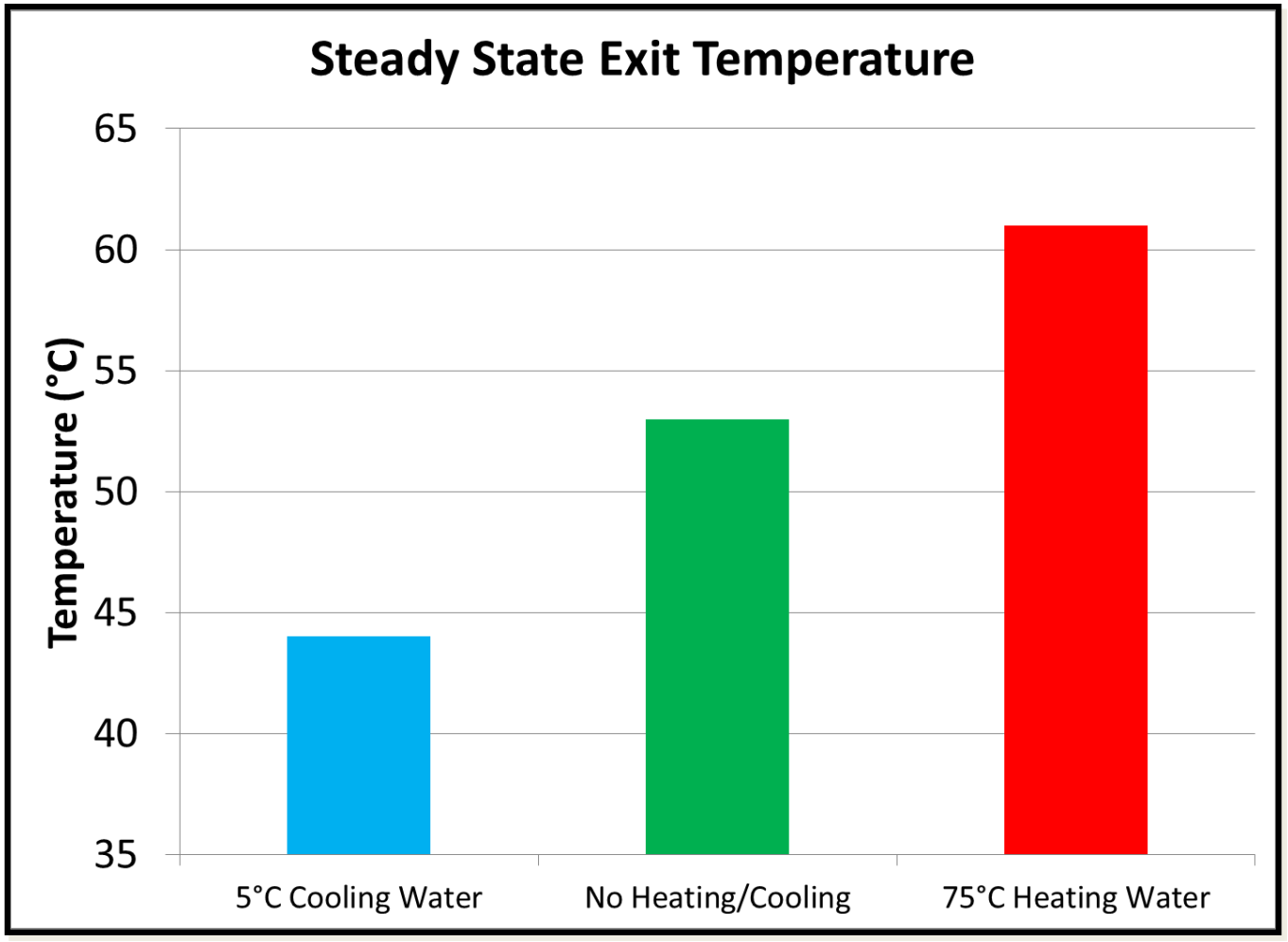
- Embedded heat transfer channels within CAM modules

Through Plate Channels

Temperature Control Manifolds

Thermowells

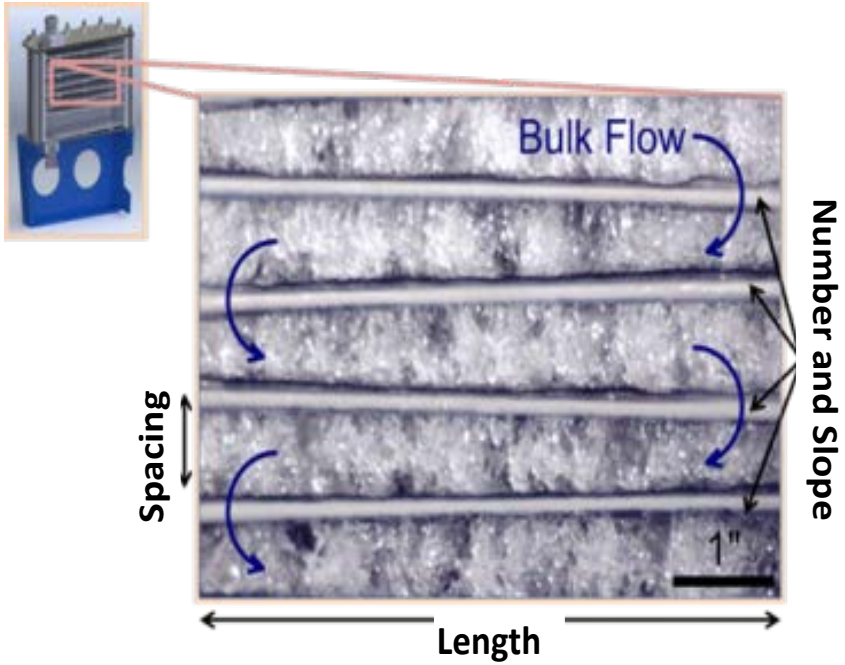
CAM-CIP Temperature Control



Clean-in-Place (CIP)

- Current typical batch cleaning
  - Uses solvents
    - Hazardous Air Pollutants (HAP)
    - Exposure source for workers
  - Creates waste
    - Residual material ≈ 5% by mass
    - Cleaning supplies and PPE ≈ 10% by mass

Clean-in-Place (CIP)



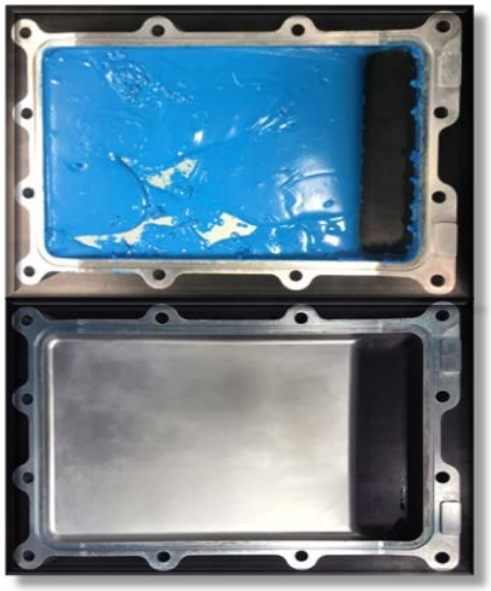
Prototype CAM Processing Water and Air

CAM Clean-in-Place (CIP)

- Cleaning inert PBX surrogate from CAM using CIP
- 5 kg of material wasted
- Less than 9 L of aqueous waste
- 100% removal efficiency achieved

After runout
Before cleaning

After Clean-in-Place



CAM-CIP Project Results to Date

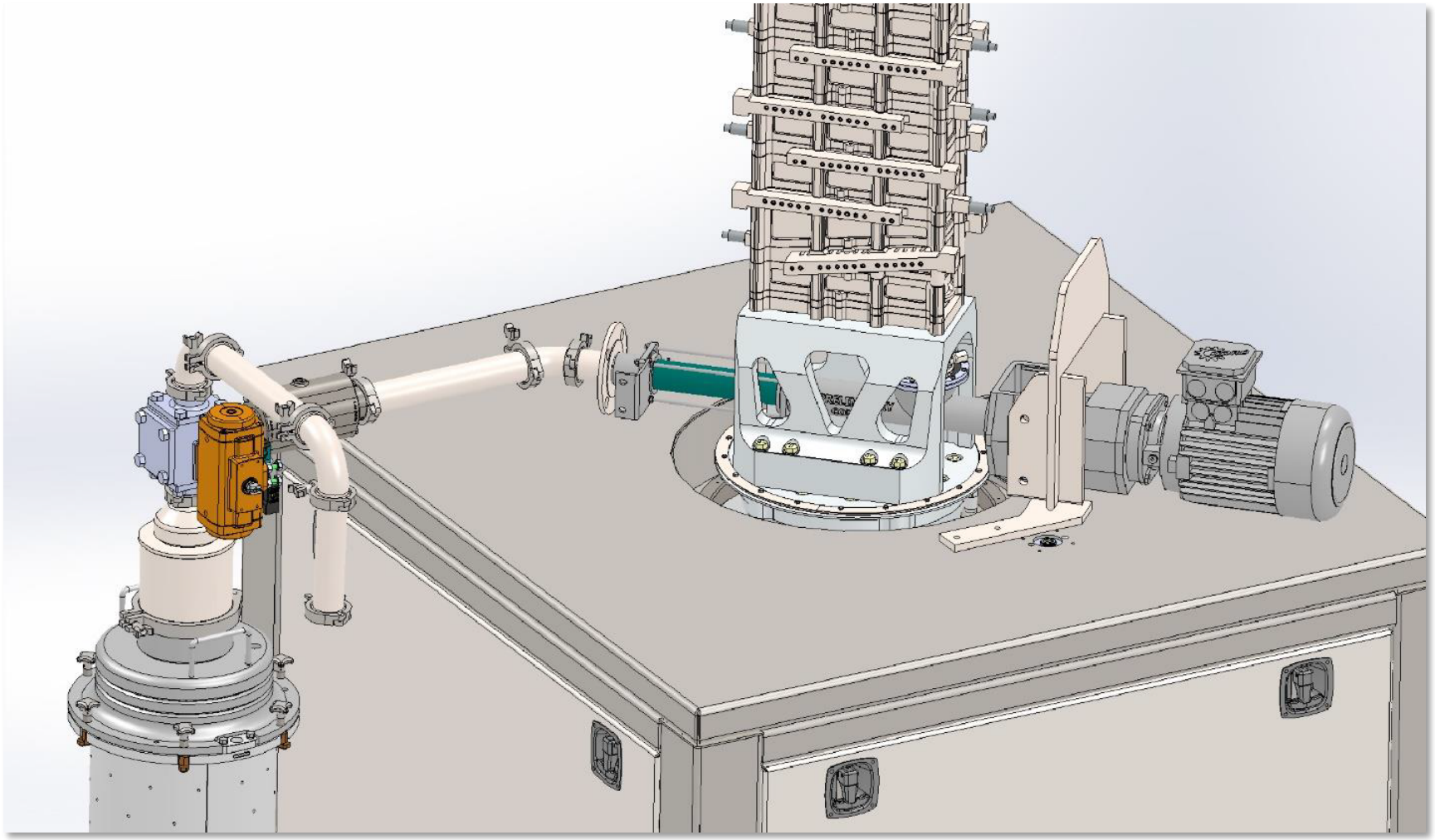
- Organic solvents eliminated
- Operator exposure to hazardous solutions and explosives virtually eliminated
- The amount of waste generated decoupled from the amount of material produced

RAM 5 Maximum CAM

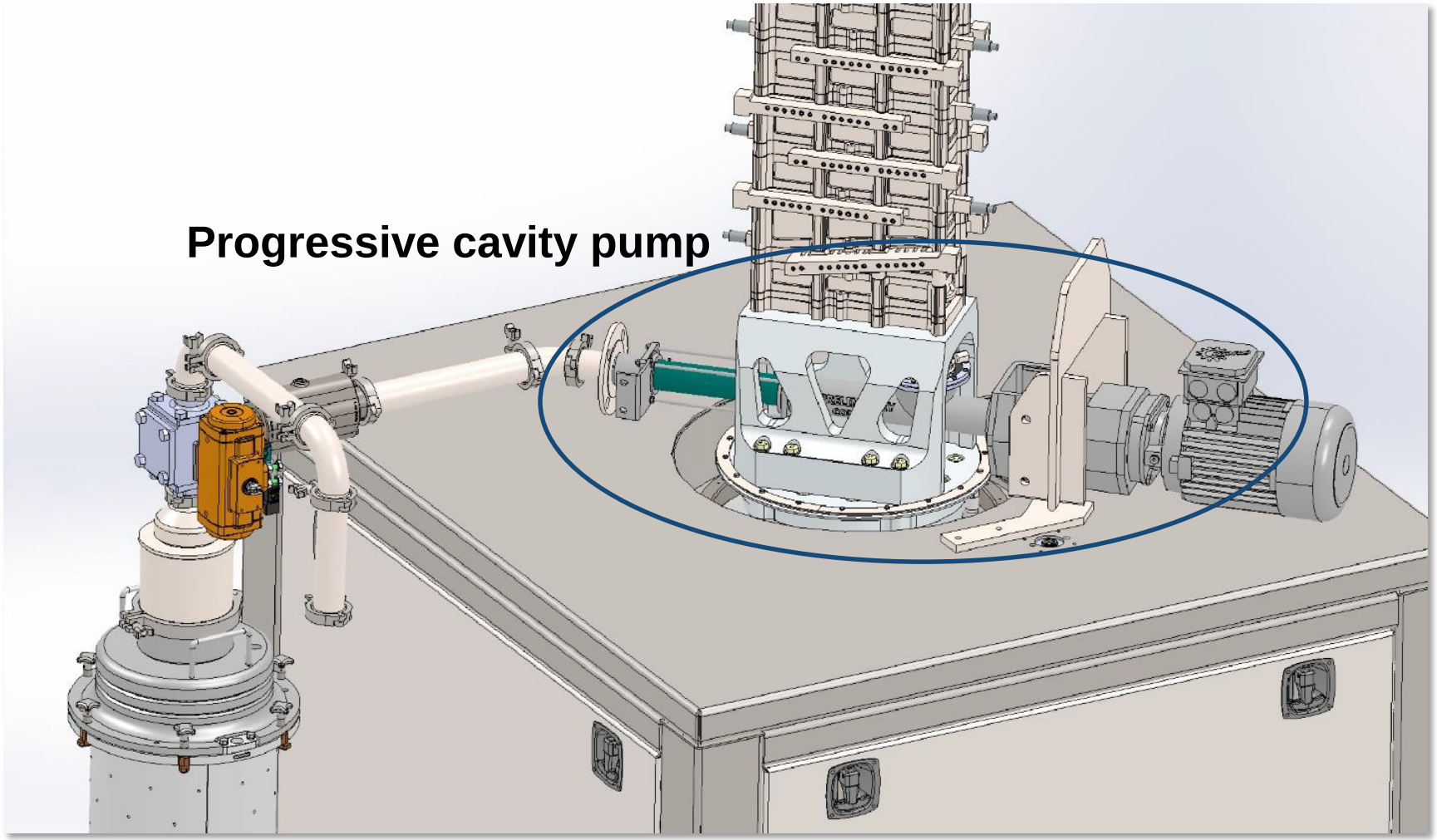
Processing Capacity

- RAM 5 processing rate is limited to a total weight of 36 kg of material at any one time
- Flow rate in the CAM is dependent on the residence time required for mixing
- Example
  - If residence time is 4 minutes
  - Then, 36 kg / 4 min is
    - 9 kg/min
      or
    - 540 kg/hr

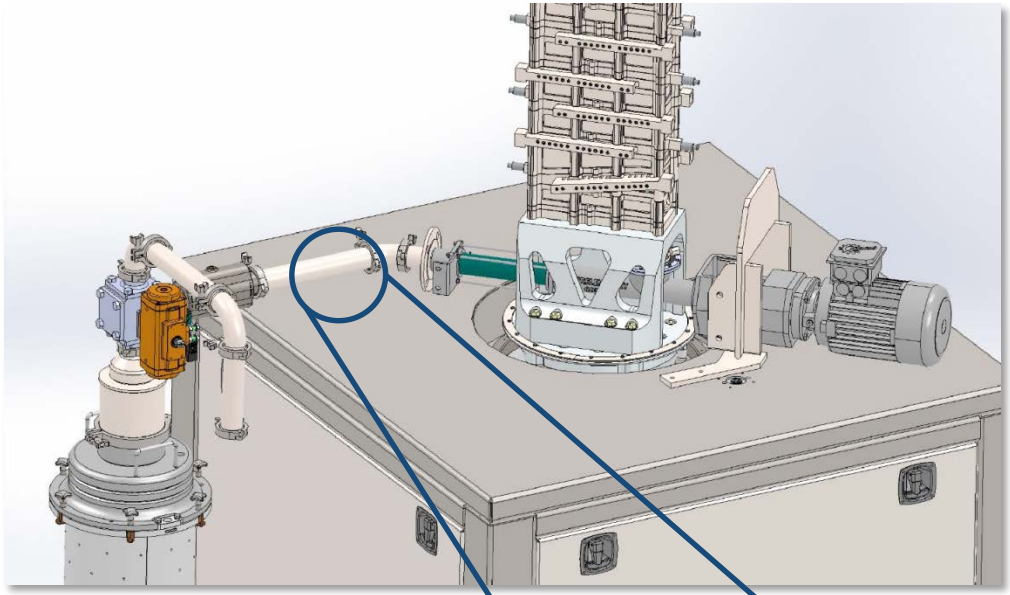
Commercializing the Process



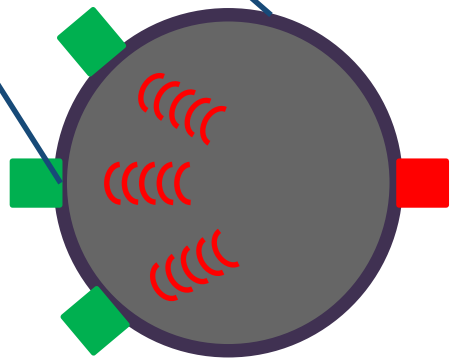
Material Transport



Mixedness Sensor



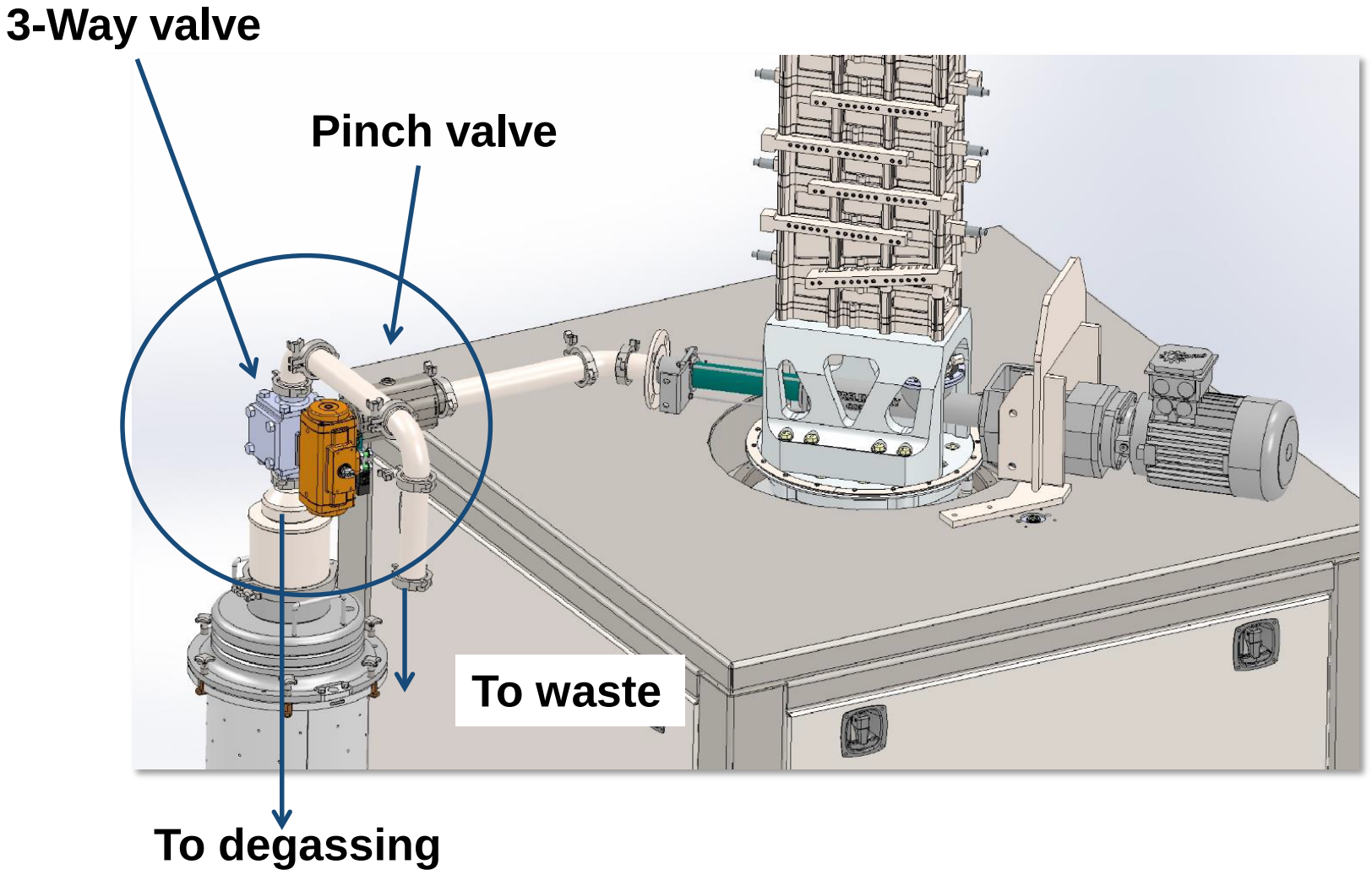
- One transmitter and multiple receivers can measure composition and mixedness by analyzing the time of flights against a standard and to each other



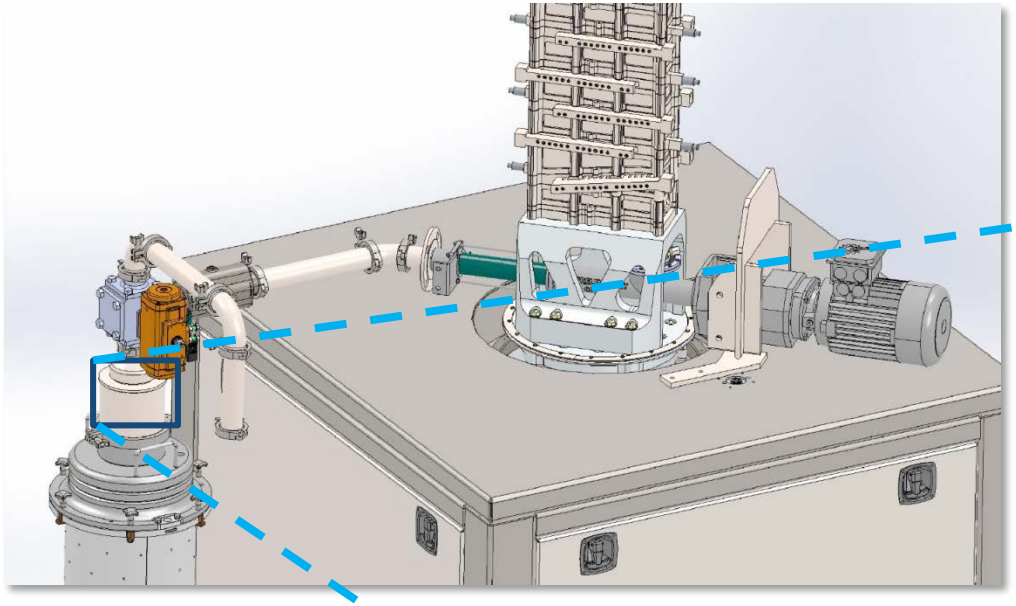
Ultrasonic Receivers

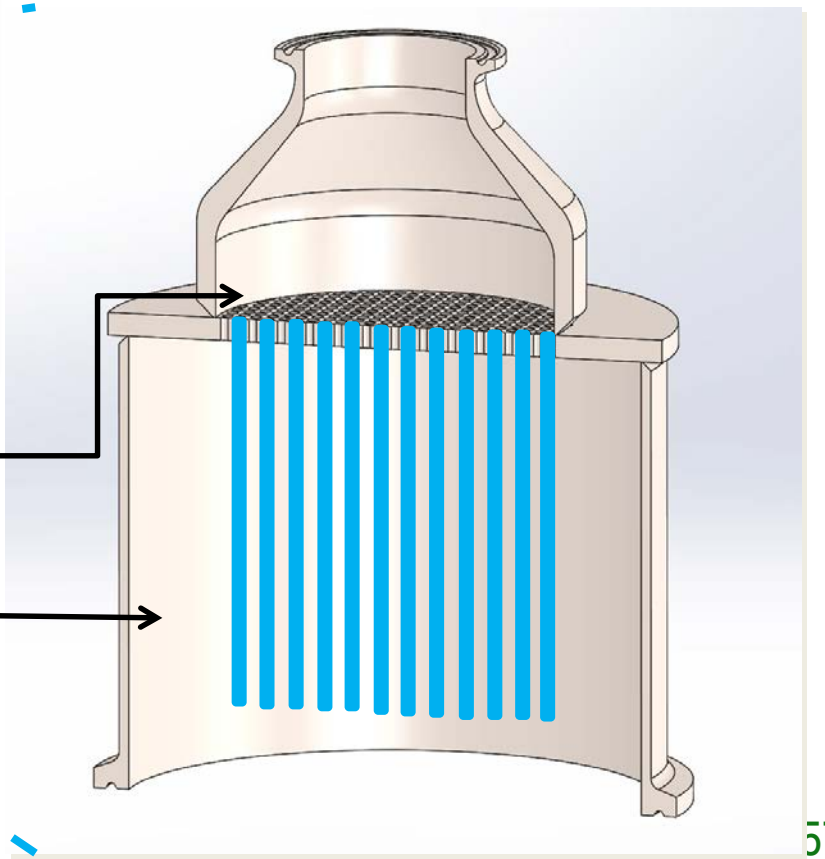
Ultrasonic Transmitter

Automatic Diversion System



Continuous Degassing System





- Adequate surface area for production rate
- Spacing to allow strand expansion

Summary

- Energetics rated CAM-CIP ready for energetics testing
- CAM-CIP has been demonstrated with 100% efficiency
- Energetics rated CAM system under development
- Production of energetic material this year at NAWCWD China Lake

Acknowledgments

- Mr. Zachery Martineaux
  - Senior Mechanical Engineer, Resodyn Corporation
  - Expert in mechanical RAM design
- Dr. Andrew Nelson
  - Research Scientist, NAWCWD
  - Subject matter expert in energetics and chemistry
- Mr. Mike Siirila
  - Lead Engineer, NAWCWD
  - Expert in energetics processing

For additional information, please visit

www.serdp-estcp.org/Program-Areas/Weapons-Systems-and-Platforms/Energetic-Materials-and-Munitions/Explosives/WP-2605

Speaker Contact Information

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SERDP DOD • EPA • DOE | ESTCP

Q&A Session 2

The next webinar is on March 12, 2020

Applying Compound-Specific Isotope Analysis to Document Contaminant Degradation and Distinguish Sources

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Survey Reminder

Please take a moment to complete the survey that will pop up on your screen when the webinar ends