U.S. ARMY RDECOM
TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

U.S. ARMY ARMAMENT RESEARCH, DEVELOPMENT, & ENGINEERING CENTER (ARDEC)

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

ARDEC Science & Technology Overview
(Presentation for NEMC INAUGURAL MEETING)

Bottom Line Up Front

The US Army RDECOM-ARDEC is interested in partnering with academic institutions to develop advanced technologies that will facilitate the modernization of the National Technology and Industrial Base for Defense Energetics.

ARDEC's Mission


RESEARCH


DEVELOPMENT


PRODUCTION


FIELD SUPPORT


DEMILITARIZATION

Advanced Weapons:

Line of sight/beyond line of sight fire; non line of sight fire; scalable effects; non-lethal; directed energy; autonomous weapons

Ammunition:

Small, medium, large caliber; propellants; explosives; pyrotechnics; warheads; insensitive munitions; logistics; packaging; fuzes; environmental technologies and explosive ordnance disposal

Fire Control:

Battlefield digitization; embedded system software; aero ballistics and telemetry

ARDEC provides the technology for over 90% of the Army's lethality and a significant amount of support for other services' lethality

DoD Energetics at a Glance

Idea/Concept → S&T → SDD → Production → Sustainment & Logistics → Demil & Environment

Products

- Explosives
- Propellants
- Pyrotechnics
- Warheads

Mission Functions and Scope

Monitor advanced Technology Developments within the world

Coordinate and facilitate the linkage between technology providers to people who understand military systems

Demonstrate and transition those solutions to the field and to the industrial base

Technology Focus

Past	Present	Future
Greater Performance Power and Energy	Greater insensitivity with equal or better performance Environmentally Safe Materials Availability	Greater Efficiency, flexible/ agile processes, more leverage of commercial capability

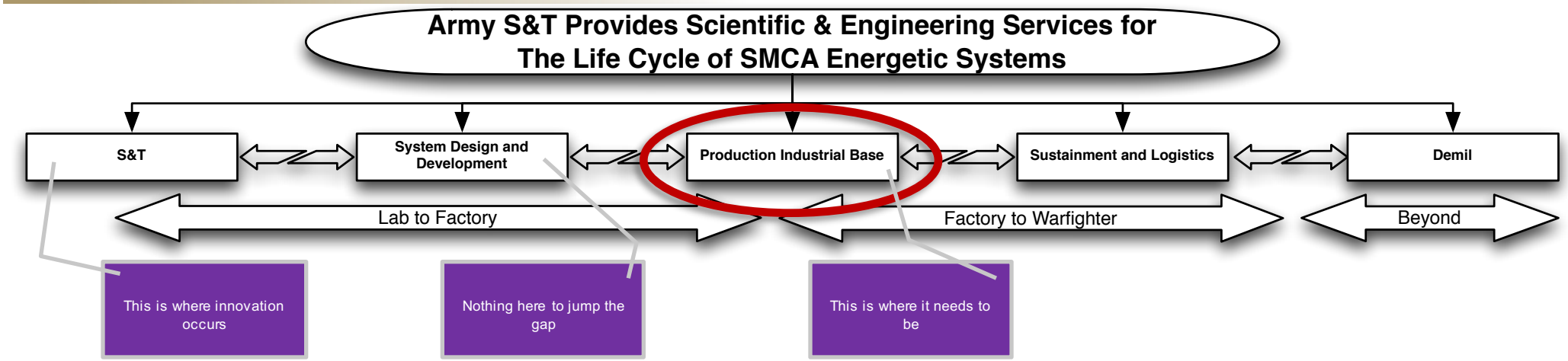
Issues/Concerns

Difficult to articulate the warfighter needs to requirements for energetics

DoD's Energetics industrial base is geared to legacy materials and tremendous capacity.

The DoD maintains and develops Energetics & Warheads as a critical competency executing S&T Programs. These skills are then used to solve problems throughout the product life cycle.

Issues in the Life Cycle

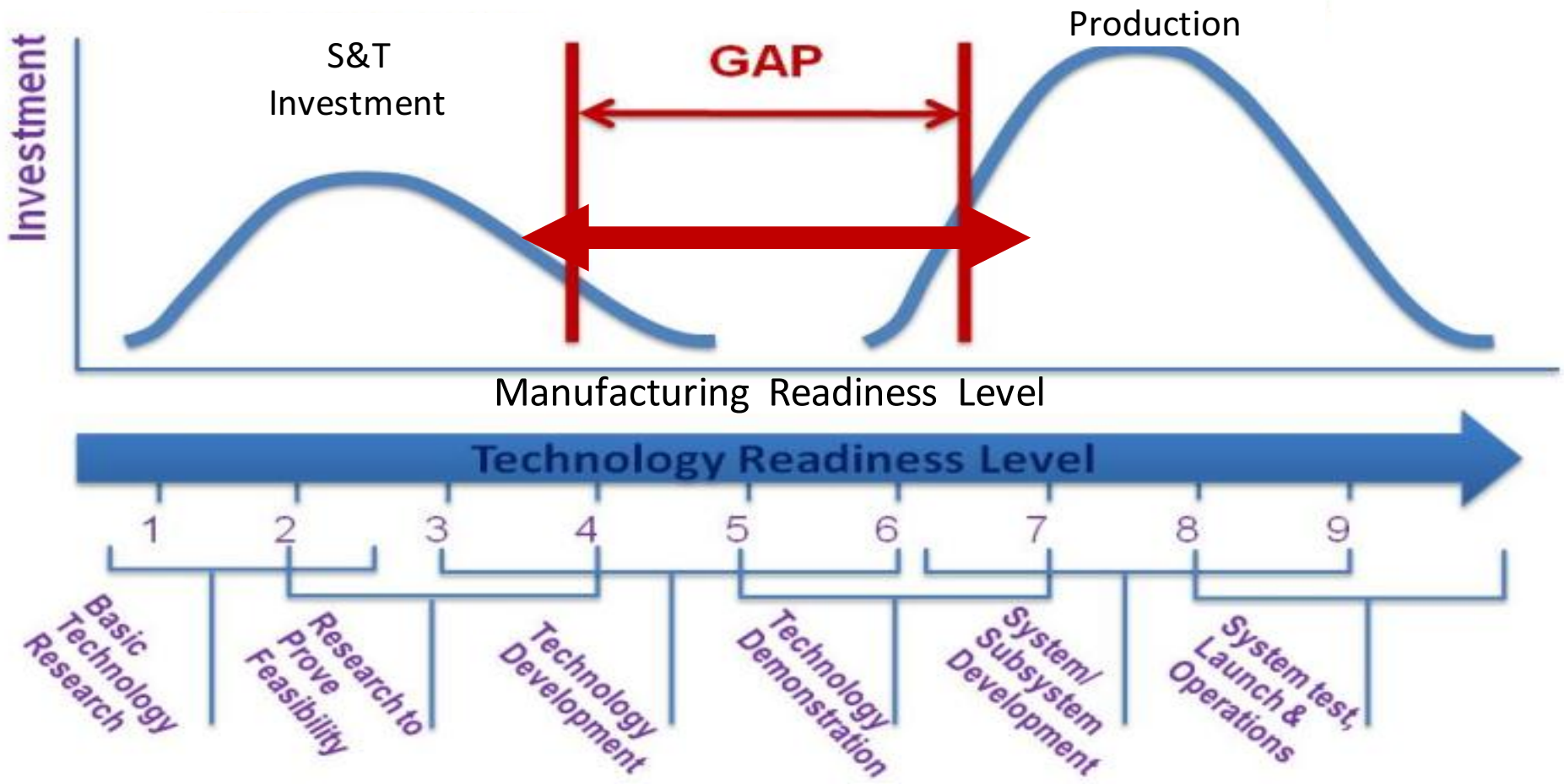


There is no existing Industrial Base capability to produce Next Generation Energetic Materials currently in Development

- **Life cycle phases are not connected** under a "Life Cycle Strategy"
  - Different elements of the Life Cycle are managed by different organizations
- Current **industrial base infrastructure designed for legacy items/materials** and **not capable of** flexible or "high tech" production
- Current **S&T investments are insufficient** to fill technology gaps:
  - New environmental regulations, Sensitivity/Performance regulations
  - Technology development cycles are long
- Capacity and cost issues associated with the base form significant barriers to the transition of new energetics technologies to the field

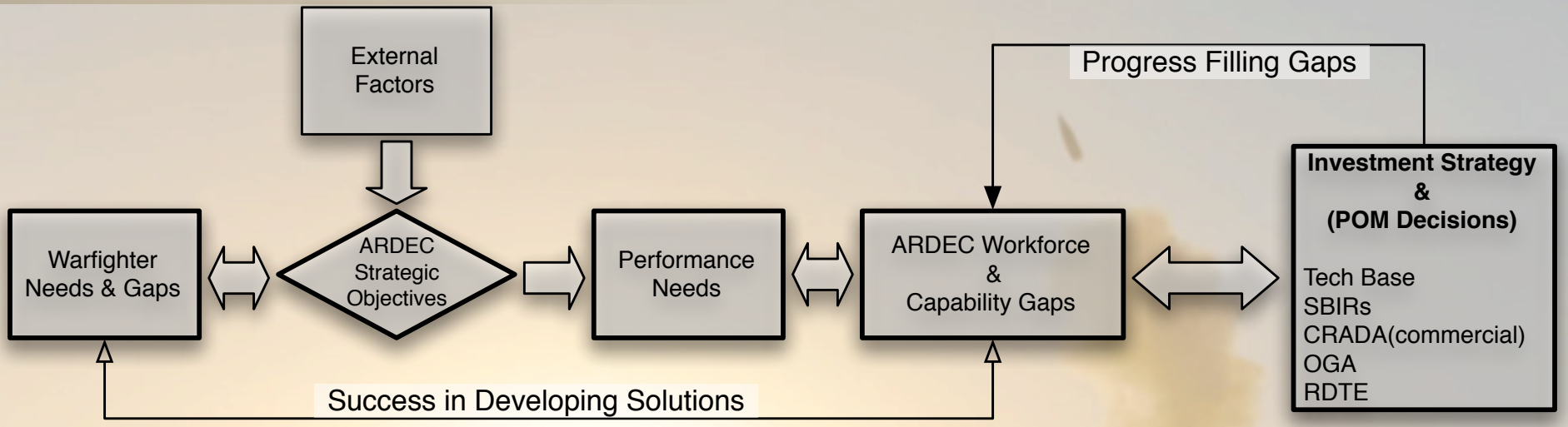
TRL-MRL Challenge

Gap in Manufacturing Innovation



Most innovative projects end at TRL 6 and MRL 3

Science &Technology Planning



Performance Needs

- Performance needs center around:
  - Improved or enhanced functionality of an existing system
  - Improvements in product or service quality
  - Reductions in cycle times for processes
  - Reductions in costs
  - New products and services

Workforce &Capability Gaps

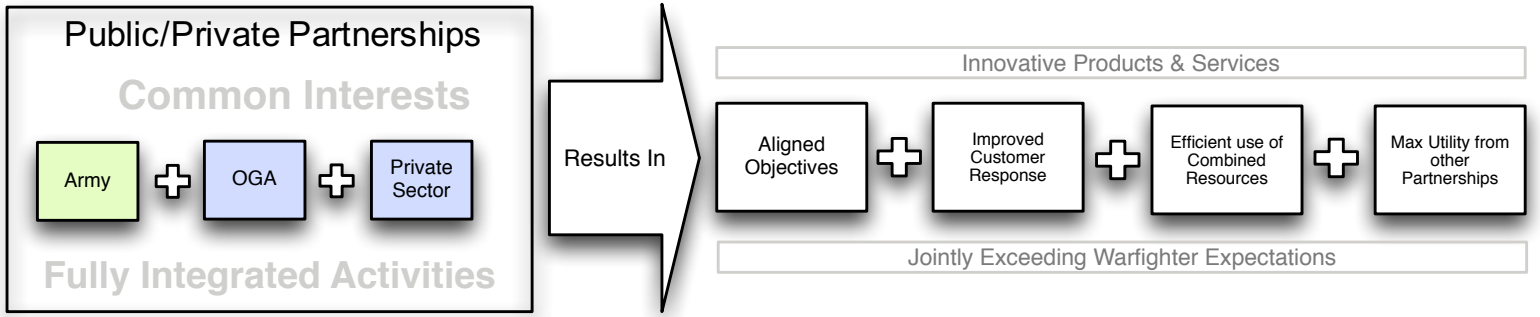
- Required level of human resources and skill sets
- Required equipment and infrastructure
- Required training

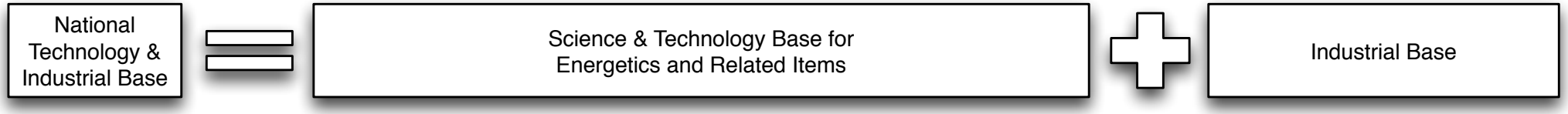
Project Selection & Execution Strategy

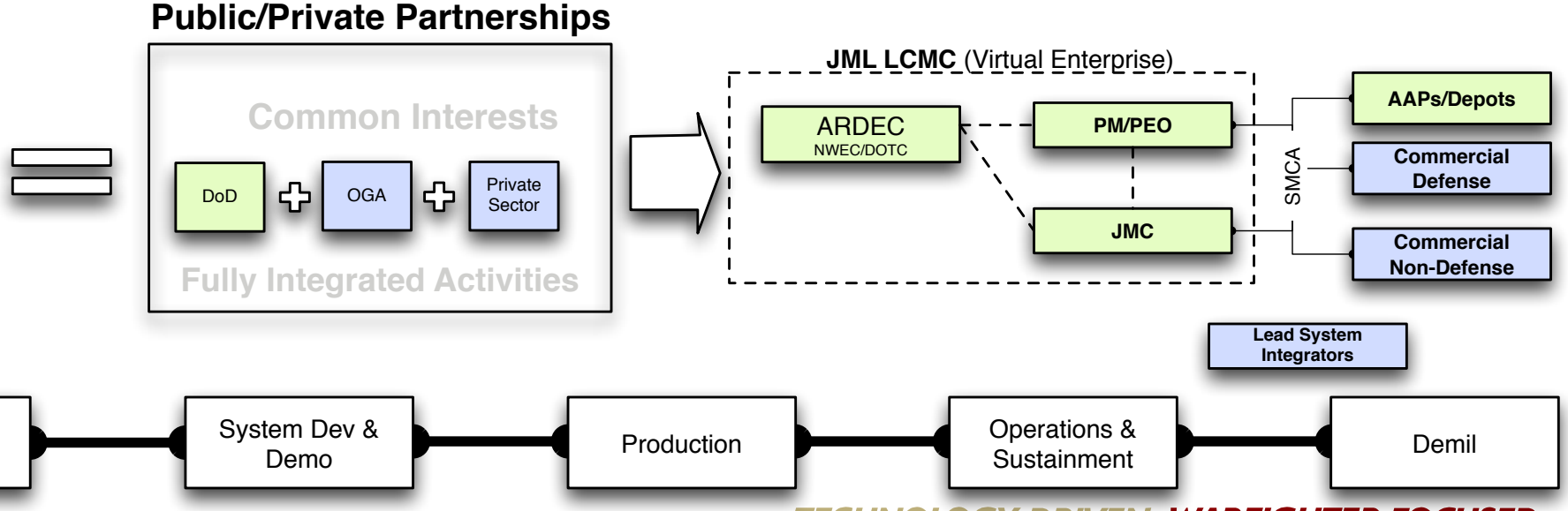
- Make In-House
- Acquire Through Contract
- Acquire Through Partnerships

ARDEC seeks Partnerships in areas that would be of mutual interest and collaborates through data exchange and/or cooperative programs

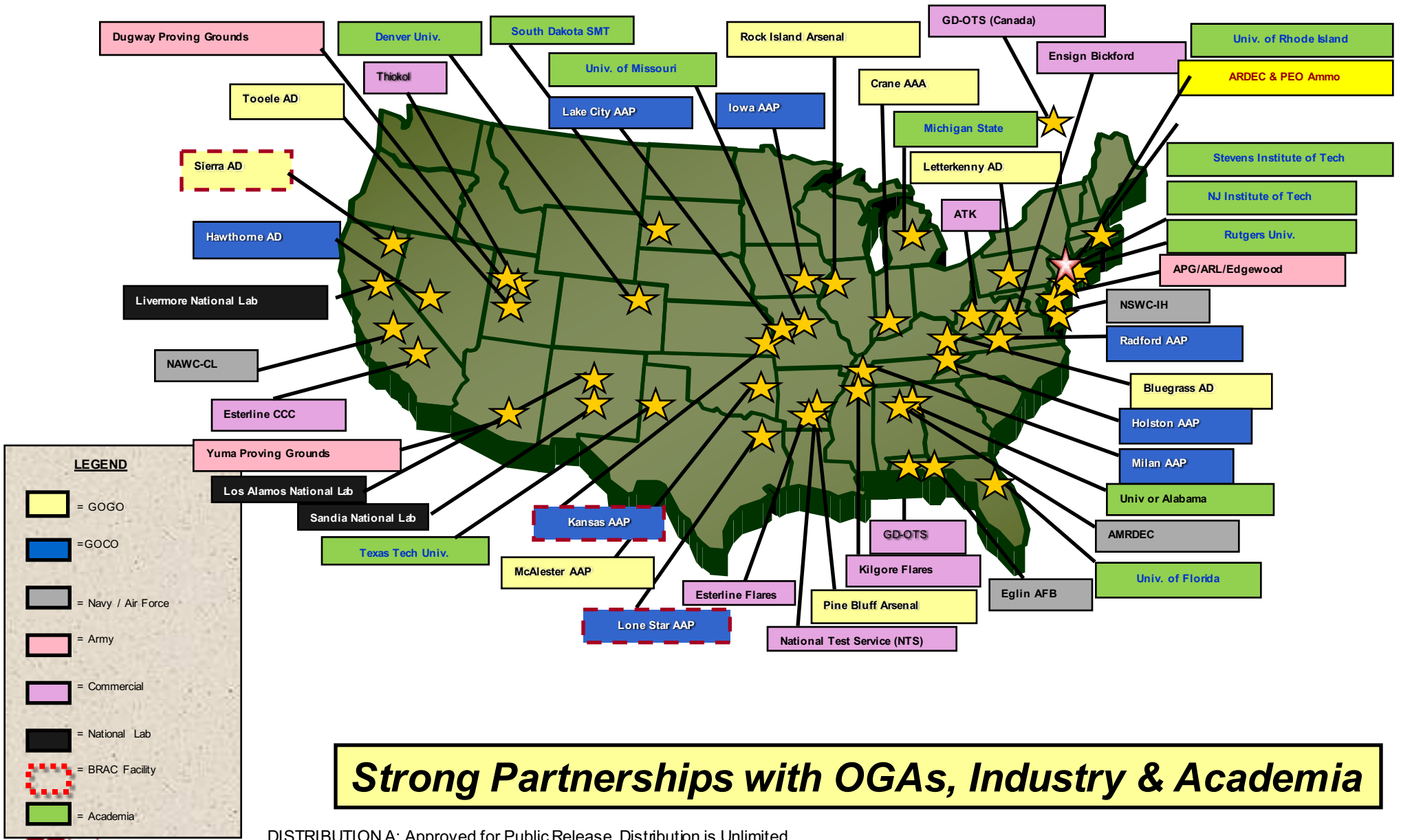
Partnership Approach







ARDEC Partners in the Energetics Area



Strong Partnerships with OGAs, Industry & Academia

DISTRIBUTION A: Approved for Public Release, Distribution is Unlimited

Energetic Material Development Goals & Objectives

Time Frame	Materials	Processes
Near Term	Traditional CHNO synthesis Co-Crystals Explosives integration to MEMs Green Primers	Flexible Agile Continuous
Mid Term	Explosive inks High efficiency Tailored Energy Release Nano-organics	2D/3D Printing Spray Drying and Coating Resonance Mixing Continuous Synthesis
Far Term	Disruptive Energetics Energetic Glasses	TBD

Energetics Competency Areas Across the Life-Cycle

Modeling and simulation

- Predictive molecular properties
- Formulation property
- Chemical process
- Energetic performance

Material Dev.

- Chemical Synthesis
- Nitration/Crystallization
- Compound Mixing
- Energetics Casting, Pressing, Injecting, Extruding, Spraying & Printing
- Coating, curing, & Drying
- Machining and forming

Testing & Characterization

- Material Physical Properties
- Process Rheology
- Energetic & Reactive properties
- Terminal effects
- Safety

Production Support

- Pilot Load Assemble & Packout
- In-process quality monitoring
- Munitions Systems Integration
- Lot acceptance and product quality characterization
- Surveillance

Advanced Processing for Next Generation Energetics

Advanced Energetics Processing and Prototyping Pilot Facility Thrust Areas

1. Next Gen LAP Technology
2. Flexible/Agile Chemical and Formulation Production Processes
3. Industrialization of Small Particle & Disruptive Energetics
4. Pyrotechnics and Reactive Materials

Next Gen LAP

Utilization of Auto loader for mass production of small items and 2D/3D printing technology to fabricate highly specialized energetic components for munitions, and special devices.

(Flexible/Agile) Chemical and Formulation Production Processing

Development of alternative chemical synthesis and mixing processes to maximize production flexibility/agility based on acoustic resonance mix technologies and continuous flow reactors

Industrialization of Small Particle & Disruptive Energetics

Development of coating and drying methods for organic nano particle energetics utilizing industrial spray coating equipment.

Pyrotechnic and Reactive Materials

Development safer and advanced processing and assembly technologies associated with pyrotechnic formulations, sub assemblies and end items with a focus on Nano and reactive materials

In Summary…

- ARDEC
  - Has energetic efforts are focused on meeting a wide range of Warfighter needs.
  - With it's partners, utilizing a System Engineering Approach, will generate a plan with goals to modernize aspects of the NTIB for Ammunition.
  - Utilizing all available national assets for energetics technology development is integral to the U.S. National Technology & Industrial Base (NTIB) for Conventional Ammunition.
  - ARDEC's extensive energetic prototyping and analytical facilities support transition of process technologies to ammunition producers.
  - Is effectively leveraging academic and commercial capabilities and we could do more.

ARDEC would like to work in Partnership with Academic Institutions interested in Energetics

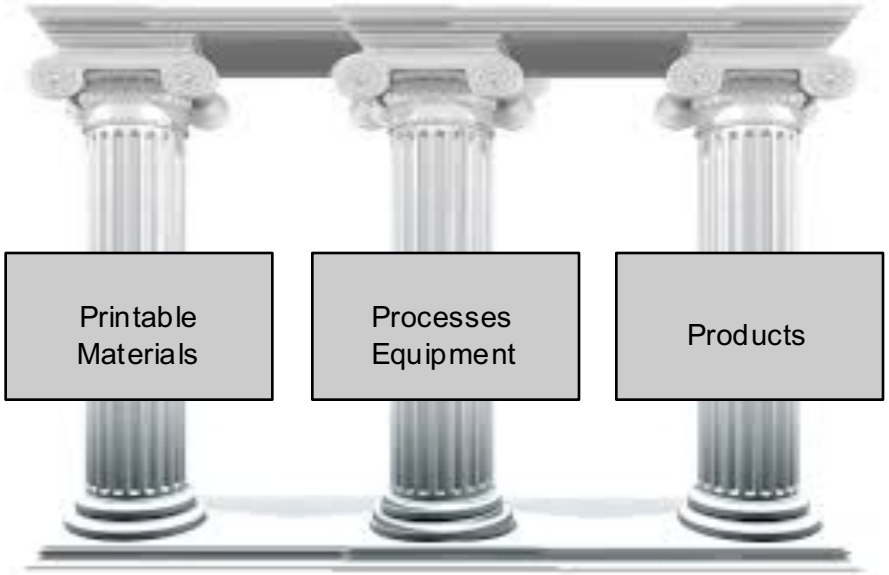
- Backup Charts

Initial Proposed Projects

Thrust Area	Proposed Project
Next Gen LAP Utilization of Auto loader for mass production of small items and 2D/3D printing technology to fabricate highly specialized energetic components for munitions, and special devices.	2D/3D Explosives printing technology
	Industrialization of Automated Robotic Loading of Primaries and Detonators
(Flexible/Agile) Chemical and Formulation Production Processing Development of alternative chemical synthesis and mixing processes to maximize production flexibility/agility based on acoustic resonance mix technologies and continuous flow reactors	Resonance Acoustic Mixing/Processing
	Continuous Synthesis Reactor
Industrialization of Small Particle & Disruptive Energetics Development of coating and drying methods for organic nano particle energetics utilizing industrial spray coating equipment.	Nano Phase Spray Coater/Dryer
Pyrotechnic and Reactive Materials Development safer and advanced processing and assembly technologies associated with pyrotechnic formulations, sub assemblies and end items with a focus on Nano and reactive materials	Industrialization of Automated Robotic Loading of Primers

3D Printing / Additive Manufacturing

- **Additive manufacturing or 3D printing** - is a process of making a three-dimensional solid object of virtually any shape from a digital model. 3D printing is achieved using an additive process, where successive layers of material are laid down in different shapes. 3D printing is also considered distinct from traditional machining techniques, which mostly rely on the removal of material by methods such as cutting or drilling (subtractive processes)
- National Initiative with 3 Pillars for development



Hybrid Approach:
Print what makes sense

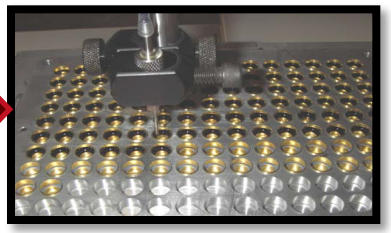
Technical Challenges

- (U) Energetics and Processing for Legacy Items, Enabling Emerging Technology Integration into Munitions Designs
  - (U) Viscosity
  - (U) Final density
  - (U) Mechanical properties
  - (U) Materials/equipment dependencies
  - (U) Integrating electronics and explosives
  - (U) Materials compatibilities
  - (U) Energetics processing equipment
  - (U) Quality
  - (U) Environmental (humidity, temp.)
  - (U) Gun launch survivability
- (U) Line layout, pilot installation, industrial processing equipment, installation of infrastructure, and prove out (ESIP Modernization)
- (U) Product implementation, qualification, and training

Automated Robotic Loading of Primaries

- Establish Pilot Processing Line With Multiple Capabilities via State-of-the-Art Robotic Printing/Dispensing platform to
  - Replace conventional loading of primers/detonators, etc
  - Reduce/eliminate touch labor and process waste of energetic materials
  - Eliminate breathing of solvents vapor
  - Enable high throughput continuous loading process for millions of primers ,detonators.
  - Enable high throughput of success by increasing control standards and product consistency

Current Manual Process



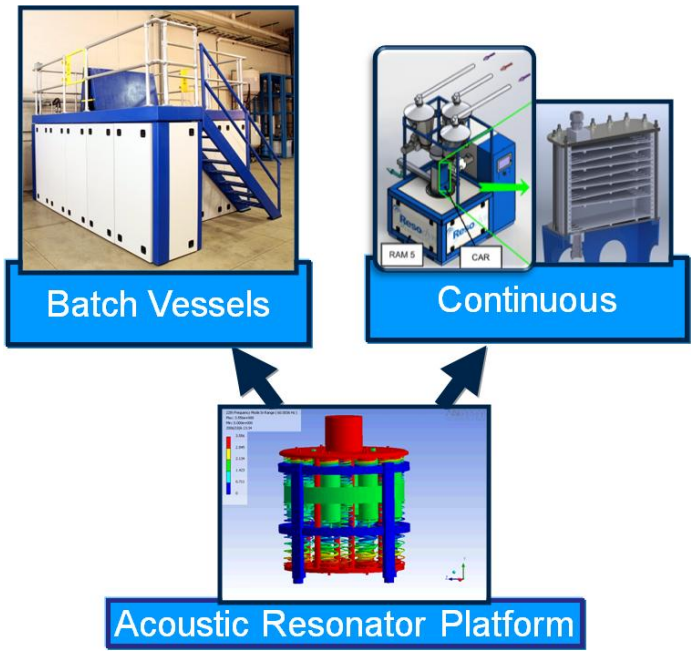
Future Automated Dispensing Process

Technology Gaps to Implementation

- **Rheological Modeling**
  - **Viscosity/Flow parameters**
  - **Thermodynamics**
  - **Solubility**
  - **Crystallization**
  - **Mixing**
- **Equipment validation/Producibility - Can we produce at better rate and have homogeneity to produce in millions (Quality Control)**
- **Characterization/Performance – characterize solvents and formulations; performance tests**
- **Other items: Can we use this for other items that can reduce/eliminate operator's hands-on work with primary explosives?**

Resonance Acoustic Mixing

- Establish Pilot Processing Line With Multiple Capabilities via Single State-of-the-Art Resonant Acoustic Platform
  - Replace conventional batch processing equipment (incorporation kettle, high shear mixer, slurry coater, etc.) for batch formulations
  - Enable high throughput continuous mixing of low to medium viscosity gels and pastes for rapid material processing
  - Enable high throughput continuous chemical reaction for synthetic applications

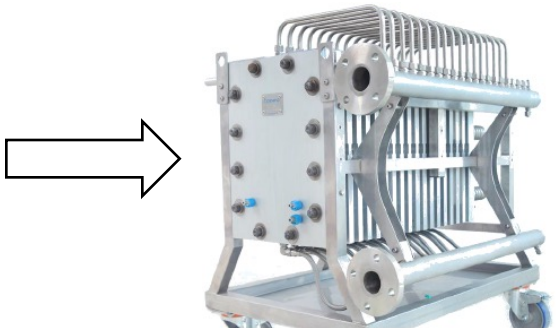


Advantages

- Develop Process Parameters and Techniques for Each Capability to Illustrate Cost and Time Savings Via Resonant Acoustic Processing
  - Scale-up is a flat profile
    - Parameters developed in laboratory scale apparatus can be directly applied to pilot plant and production scale equipment
  - Capability to mix in-item
    - Reduction in number of processing steps and waste generation
      - Eliminate process steps of mixing in separate container and transfer of material to end item
      - Eliminate disposal of mixing container, excess formulation, cleaning materials and processing solvents
- Baseline Comparison of Pilot Plant Vs. Existing Procedures to be Performed

Continuous Flow Reactor

- Demonstrate the advantages of continuous flow reactions for energetic material synthesis.
  - Replace conventional batch processing equipment for batch chemical synthesis with Advanced Flow Reactors (AFR).
  - Adapt batch reactions to high throughput continuous processes for typical energetic material reactions:
    - Highly exothermic reactions
    - Gas producing reactions
    - Solubility limited reactions
  - Realize reduced costs, improved safety and environmental benefits of AFR reactions.



Advantages/Disadvantages

- Select a compound to synthesize, adapt the process to continuous flow and scale to pilot plant quantities.
  - Reduction in number of processing steps and waste generation
    - Batch – prepare reagents, charge, heat, cool, discharge, work-up, extract, crystallize, clean, start over.
    - Continuous – prepare reagents, start pumps, extract, crystallize, clean (when changing reactions).
  - Continuous flow offers superior mixing, heat and mass transfer.
    - Improves safety (low reaction volume, no unstable intermediate accumulation, better heat dissipation), improves yields. Less solvent, waste, energy.
  - Scale-up is a flat profile
    - Kinetics, mass and heat transfer remain constant during transition from Low-Flow reactor to the G4 reactor.
- Baseline Comparison of continuous flow reactions Vs. batch reactions: waste, cost, yield, time.

Nano Energetic Spray Drying/Coating

- Industrialization of insensitive small particle energetic materials to meet IM requirements
  - Design & Implementation of “small particle production” at Pilot Scale level
  - Prove out process parameters
  - Develop Spec at Pilot scale
  - Transition technology to contractors for production

New Army Capability

- The ARMY will have the most cost effective and largest production method for producing small particle energetics
  - Implementation of proven technology from food and pharmaceutical industry
  - Currently all other competing technologies are more costly