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TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

AM for Defense & Gov't.: Additive Manufacturing and Integration of Electronics for Military Systems

BLUF

- Additive manufacturing technologies bring the promise of enhanced performance with the flexibility of historical additive processes like casting and welding
- In order to print parts, 3-D model data and machine manufacturing instructions are required (CAD + CAM)
- Pedigree of part is conditional upon certified materials, models and manufacturing data; Producibility, Quality, Reliability, Maintainability paramount for acceptance and utilization for DoD applications.
- An RDECOM Community of Practice, working with OGAs, industry and academia, has been established to perform the following inherently governmental functions:
  - Focus on Army-centric materials (warheads, ammunition, payloads, aviation)
  - Digital issues (software interface, 3D model storage, etc.)
  - Design for AM to reduce natural frequency vibration, lightweight designs, etc.

Army
S&T Performing Organizations

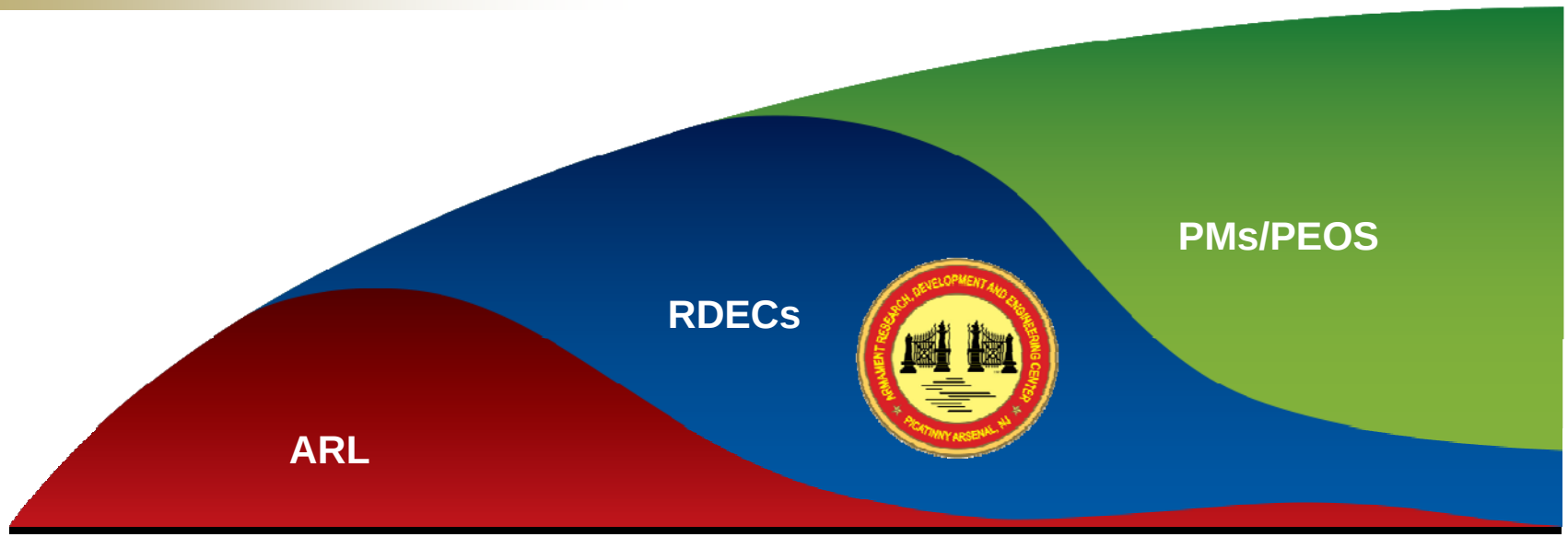
Personnel	Medical	Infrastructure/ Environmental	Materiel	Strategic Missile Defense	Test & Evaluation
G-1 HQDA, G-1 Personnel	MEDCOM Army Medical Command	USACE Army Corps of Engineers	AMC Army Materiel Command	SMDC Army Space & Missile Defense Command	ATEC Army Test & Evaluation Command
1.6%*	9.9%*	14.3%*	71.9%*	2.3%*	

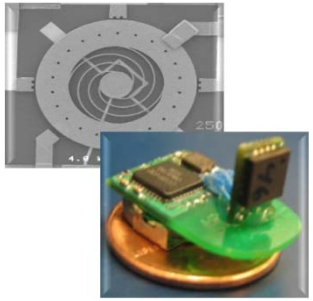
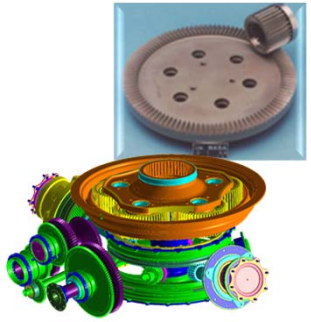
* Percent of S&T core program executed

RDECOM
Research, Development & Engineering Command

- **ARL** — Army Research Laboratory
- **AMRDEC** — Aviation & Missile Research, Development & Engineering Command
- **ARDEC** — Armaments Research, Development & Engineering Command
- **CERDEC** — Communications-Electronics Research, Development & Engineering Command
- **ECBC** — Edgewood Chemical Biological Center
- **NSRDEC** — Natick Soldier Research, Development & Engineering Command
- **TARDEC** — Tank-Automotive Research, Development & Engineering Command

S&T in RDECOM



Discovery	Innovation	Advanced Development	Engineering & Production	Support to Warfighter
 Translational Neuroscience	MEMS TBI Sensor 	 MRAP Armor	Face-Gear Technology for Block III Apache 	 XM25 Counter Defilade Target Engagement System

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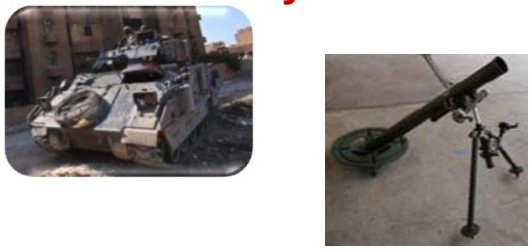
Opportunity Space

There are opportunities for AM & PE to impact all Army systems

UAVs, UGVs

Logistics

Vehicles & Sub-Systems

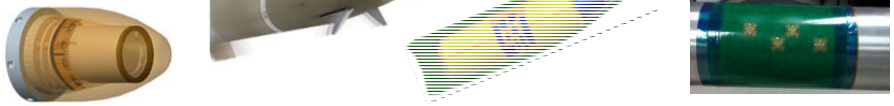


Individual Soldier Protection

Missiles/Munitions: Warheads, Fuzes

Communications Command & Controls

Weapons Components



TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

Armament Research, Development and Engineering Center

Research

Development

Production

Field Support

Demilitarization

Vision:

Innovative Armaments Solutions for Today and Tomorrow

Mission:

To develop and maintain a customer focused, world-class workforce that will execute, manage and continuously improve integrated life cycle engineering processes required for the research, development, production, field support and demilitarization of munitions, weapons, fire control and associated items.

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 Provides Significant Support to other Services' Lethality

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

Mission

VISION

To advance and utilize printed electronics and additive manufacturing technologies to provide our War Fighter with state of the art armament solutions.

MISSION

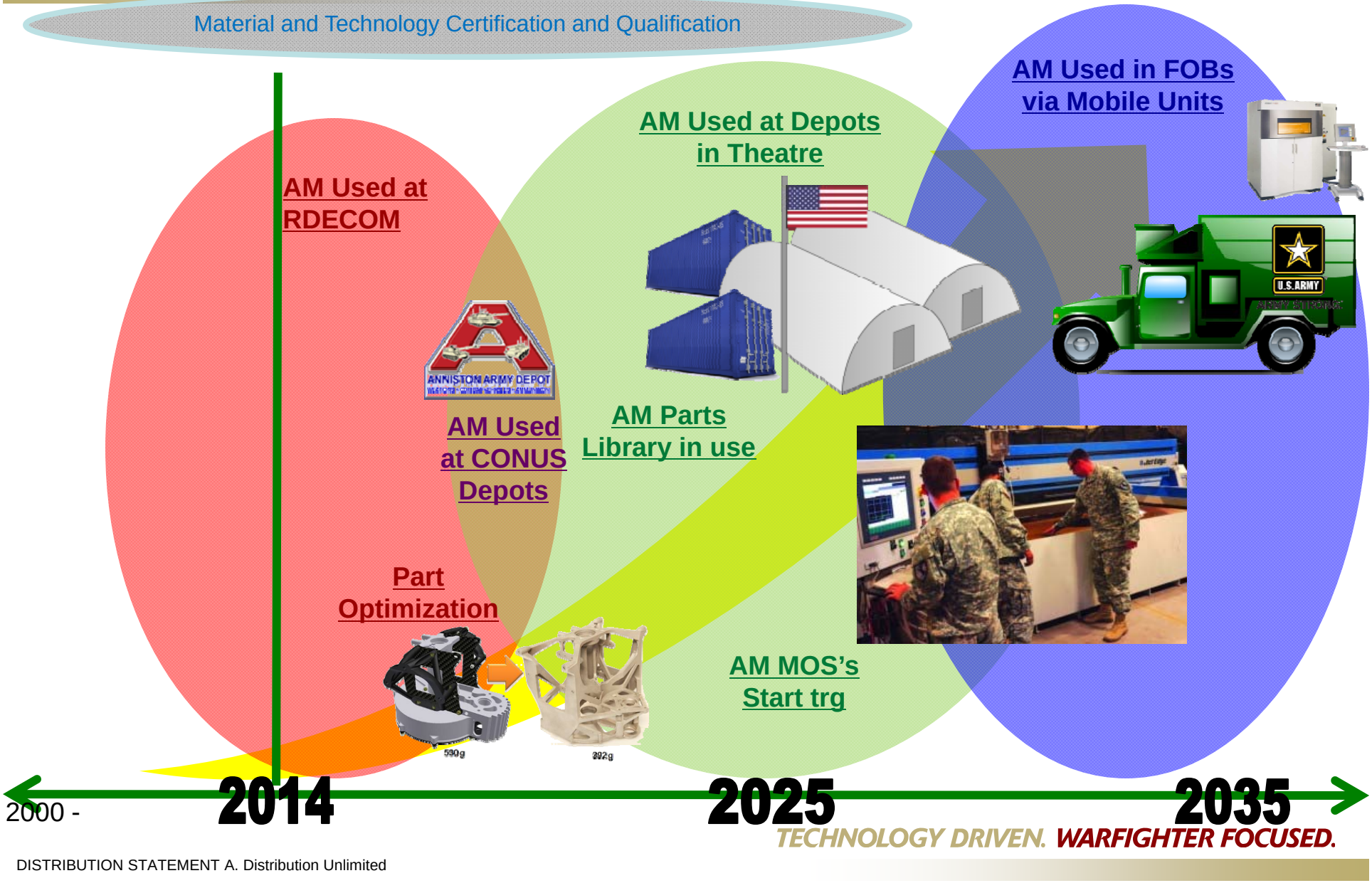
Develop and integrate state-of-the-art materials printing technologies to enhance capabilities for current and future munitions & weapon systems. Build expertise and knowledge base for the design, fabrication, testing, & integration of Printed Technologies for Armaments and Munitions to increase force effectiveness and reduce operations and support costs.

Military Considerations

- DOD heavily investigating the utilization of Printed Electronics in weapon systems.
- Transportation, storage, and operational environments must be considered.
- DOD represents unique environment for printed electronics utilization.
  - High G loads
  - Extreme Temperature and Humidity ranges
  - High shock and vibration loads
  - Extended Periods of dormancy (+20 Years)
- Limited data for failure mechanisms, failure rates, reliability, survivability.
- Need for high reliability devices in DOD applications.

AM In the Field Road Map (Notional)

Material and Technology Certification and Qualification



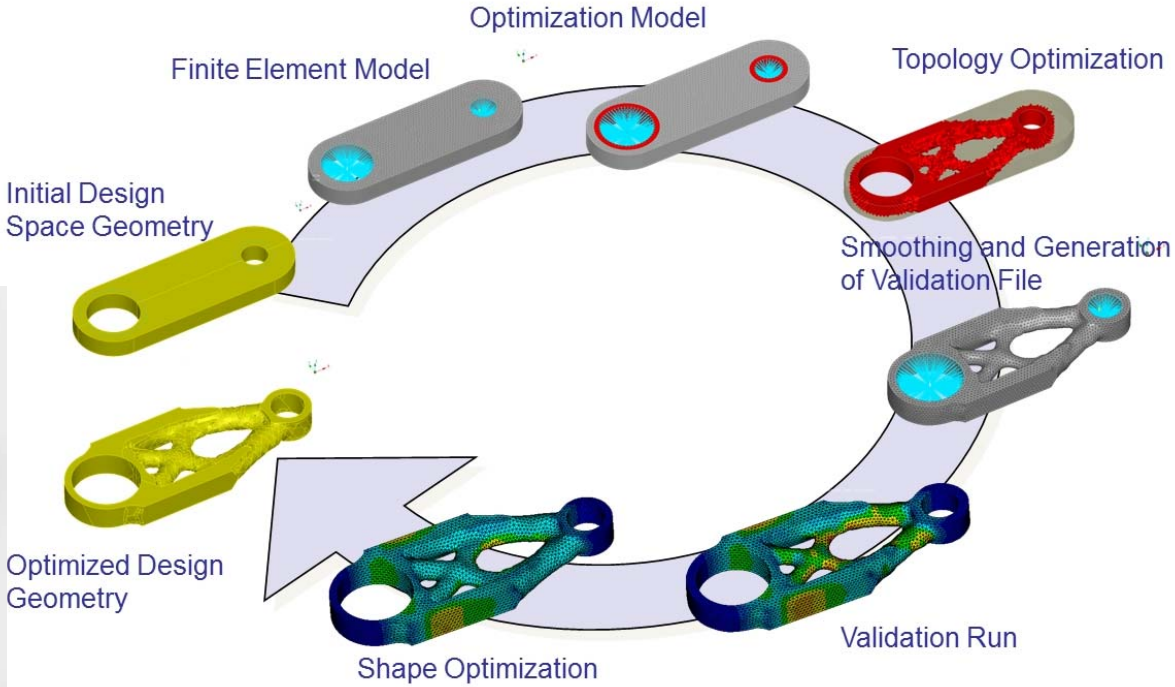
TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

Unique Capabilities via AM

- Traditional Part Duplicator

AND

- Part Optimization
  - Lighter with same or better strength



Integrated Printed Electronics for Munitions Capabilities

- **Ink Jet**
  - Dimatix, Epson, PixDro
- **Aerosol Jet**
  - Optomec
- **Micropen / Direct Write / DipPen**
  - Sonoplot, EFD, M3P, NanoInk, Controlled Syringe
- **MicroPump**
  - nScrypt
- **Screening & Stenciling**
- **Etching & Routing**
- **Transfer & Plating**
- **Multi-tool SuperScrypt**
- **Multi-Axis Module Manufacturing Platform (M3P)**
- **Numerous 3D Capabilities**

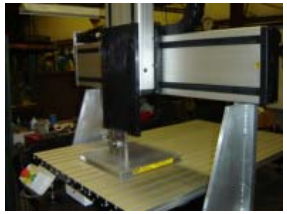


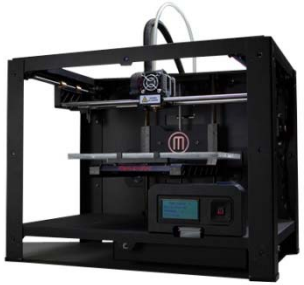




ARDEC 3D Printing Capabilities

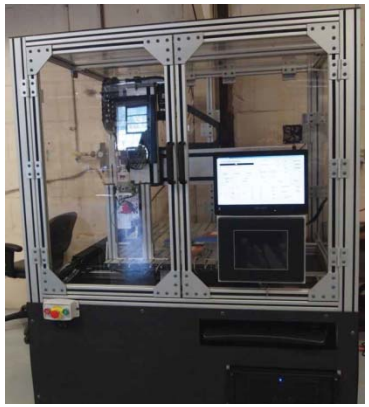
- **Material Printers / 3D Printers**
  - **Plastics (PLA, ABS, other)**
  - **Inks**
  - **Powder-Binder**
  - **FDM**
  - **LOM (Laminates)**
  - **Direct Laser Sintering (Metals & Plastics)**
  - **Several Custom & Multi-material systems**



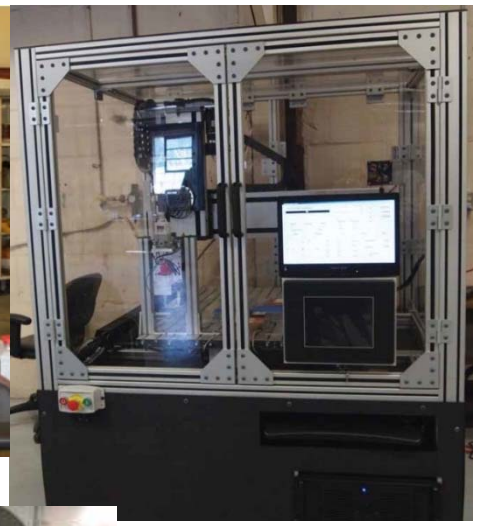


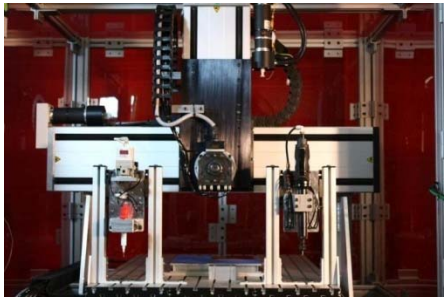
- **3D Scanners**
  - **Photo, Digital, Laser, etc.**

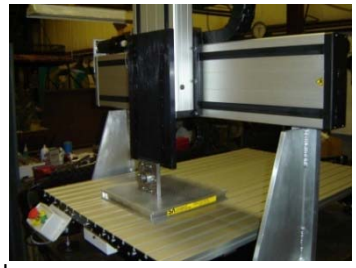
- **3D CAD / Modeling**
  - **NetFab**
  - **MasterCam**
  - **Pro-E**
  - **Maya**
  - **Solid Works**
  - **Sketch-Up**
  - **Adobe Design Suite**
  - **3D Studio Max**
  - **Z-Edit**
  - **Others**



Multi-Axis Multifunctional Manufacturing Platform M^3P







ABS extruder tool module

Camera/inspection tool module

Syringe deposition tool module

Spray/encapsulant tool module

4-point robe/inspection tool module

Router tool module

The M^3Platform is a part of the concepts being developed at ARDEC looking at new and innovative production methods to better meet future Army needs. By combining multiple manufacturing techniques with direct write and additive manufacturing capabilities, ARDEC's goal is to have flexible and low cost capabilities for prototyping and production. Just-in-Time Manufacturing and Fab-in-the-Field concepts are being explored.

Unique AM Technology

SuperScrypt

Dubbed the SuperScrypt, this multi-technology printing system is the only one of its kind. The system is based on nScrypt processing controls and software, which are fully open for manipulation (variation of processing parameters). This system includes:

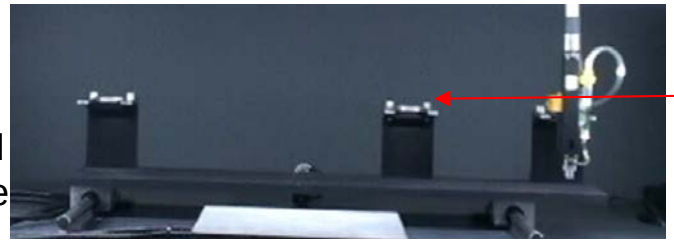
- Line Scanning
- Thermoplastic Extrusion (up to 400°)
- Thermoset Deposition
- Ink Deposition
- 6-Axis Motion Control

(0 to 2,000,000cP, with pico-liter control)

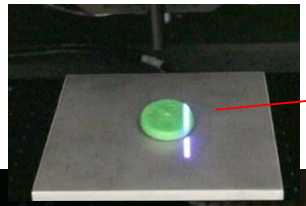
- Tool Switching
- Pick-n-Place

To be added in FY15:

- Micro-milling
- Laser Sintering
- Aerosol Jet Deposition
- Drop-on-Demand
- Micro Cold Spray Deposition

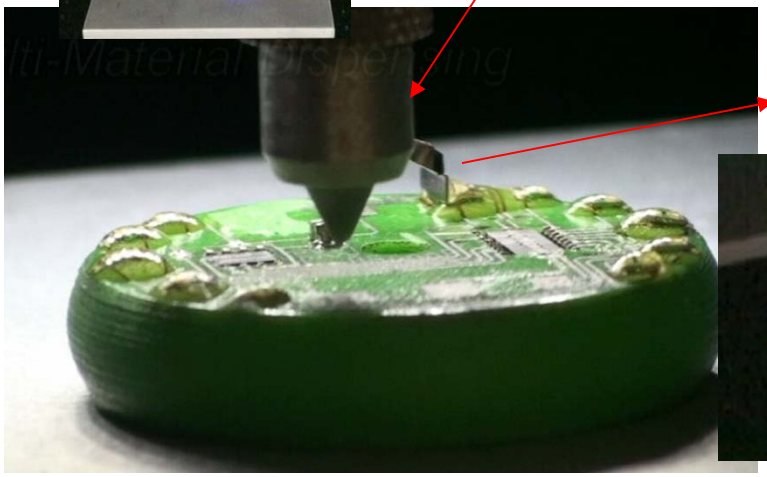


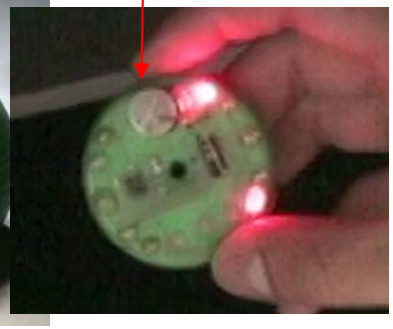
Tools can be added as needed



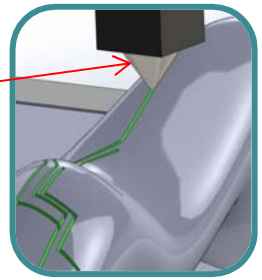
Scan-to-Print

Fabricate a functioning device



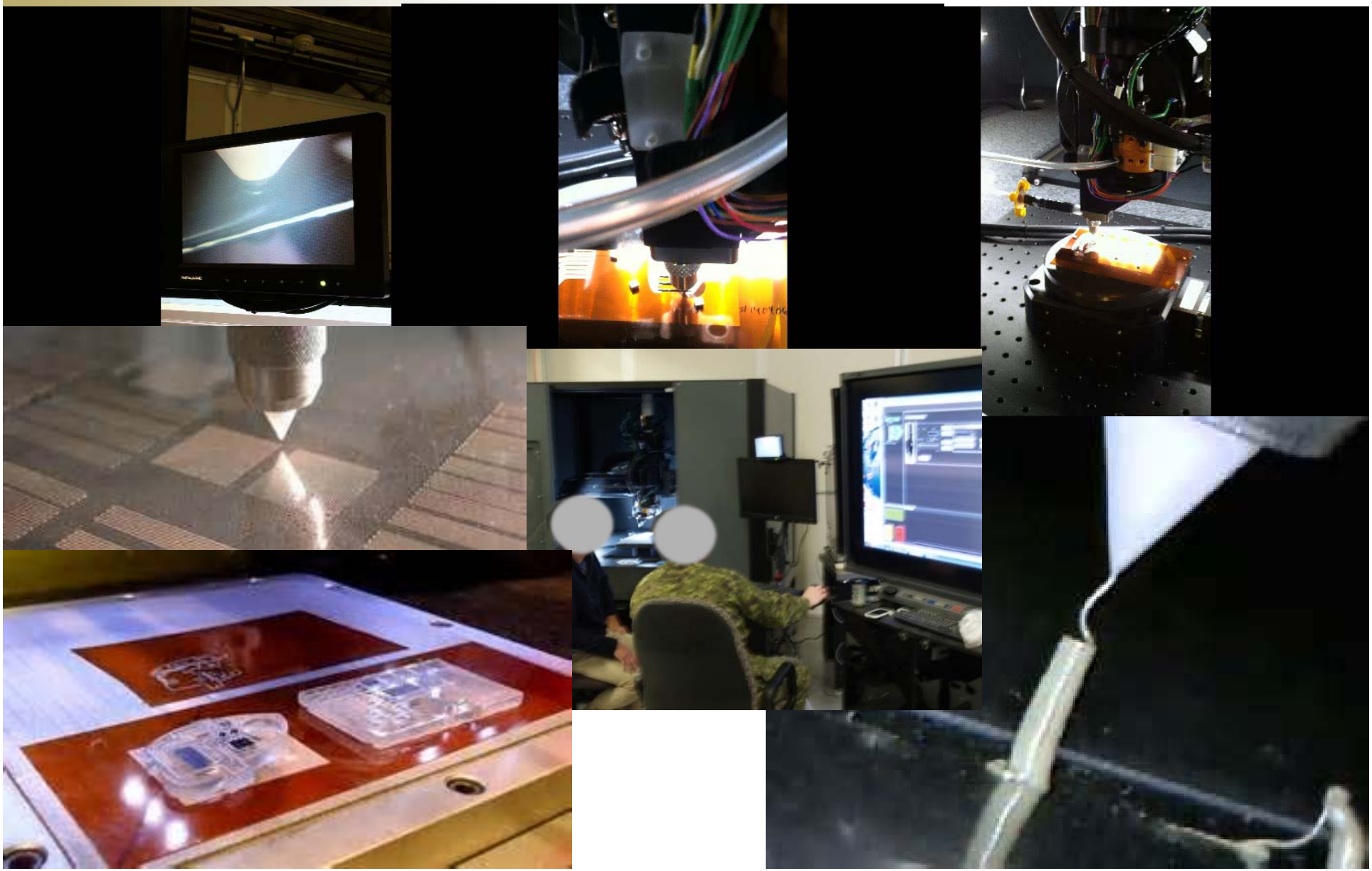


Conformal Printing



With Scan-to-print capability, the SuperScrypt can deposit on complex curves, or build 3D shapes from scan data.
Inverse kinematics enabled 6-axis motion control allows for true 3D printing instead of stacking 2D layers. Robust hardware allows for +/- 200nm precision.

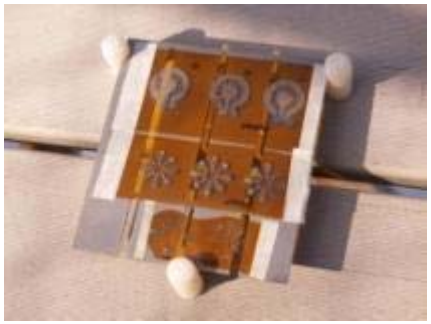
SuperScrypt System



Key Areas of R&D

- Nanomaterials Development
- Manufacturing Techniques
- Ink Development
- Materials Printing Techniques
- Testing and Evaluation
  - Qualification
  - Reliability
  - Long-term Survivability
- Flexible Electronics
- Power Generation/Energy Harvesting
- Thin Film Batteries
- Active Sensor Systems
- Device Miniaturization
- Homeland Defense / Homeland Security
- Fuzing
- Sensor Integration
- Antenna
- Remote Weapon Systems

Detonation Sensor



Process Development Efforts

- Materials Development (Inks, Powders, Binders, etc.)
- Ink Formulations
- Recycling / material Re-use
- Additive Manufacturing Techniques
- Integration of 2D & 3D Printing
- Integration into Muntions
- Equipment modification / Development (i.e. multi-head /material capabilities)
- Deposition Techniques
- Testing and Evaluation
  - Qualification
  - High –G survivability
  - Reliability
  - Long-term Survivability
- Interconnects / Solderability

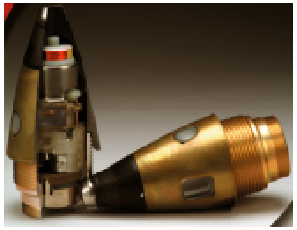
Current Efforts & Opportunities Munition Systems

PROBLEM:

- Army is not realizing benefits of material printing & printed electronics as new enabling technologies to reduce size, weight, and cost for munitions
- Desire to add more capabilities into existing Fuze systems
- Need for more antennas and electronics into already “full” Fuze bodies.

SOLUTION/CONCEPT:

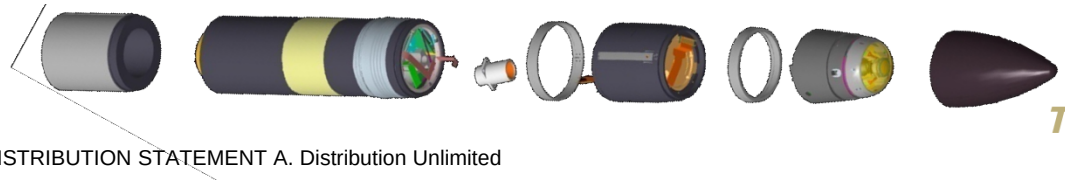
- Enabling PEEPS for Munitions
- Integrated flexible electronics with munition components
- Printed electronics with “novel” materials for High-G applications
- Printed components embedded into windscreens/radomes
- Conformal & direct write antennas & sensors onto curvilinear surfaces
- Printed Chaff



BENEFIT / SAVINGS

- Increased survivability and operations in denied environments
- Decreased size and weight,
- Lower power requirements
- Greater range and sensitivity

Windscreens



Current Efforts & Opportunities Interconnects & e-Textiles

PROBLEM:

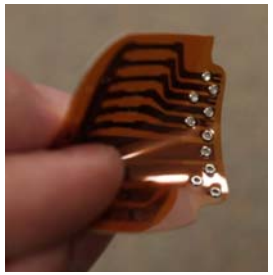
- Unreliable interconnects and bonding on flexible substrates and fabrics
- Robust solutions needed to connect COTS components and connectors
- Best-practices, fabrication methods and test procedures needed

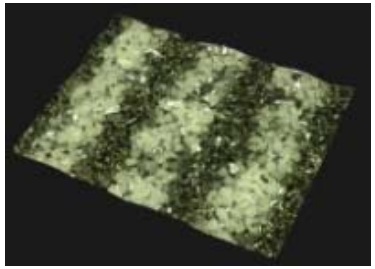
SOLUTION/CONCEPT:

- Partnering with OGAs and strategic partners
- Embroided wires, and novel interconnects
- Developing new interconnect systems for flex & fabrics
- Developing new materials with improved properties

BENEFIT / SAVINGS

- Game changing electronics integration
- Increased reliability & survivability of flexible electronics and smart textiles
- Increased producibility and manufacturing readiness

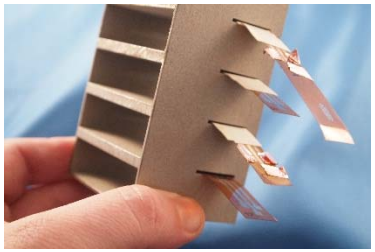


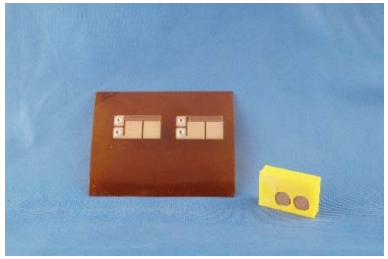


Current Efforts & Opportunities
Integrated Solutions

PROBLEM:

- Need for integrated systems and sub-systems
- Numerous materials and techniques in Additive Manufacturing that require systems to be integrated and embedded
- Materials & process mis-matching causes failures and inconsistencies
- New fabrication methodologies and procedures need to be developed





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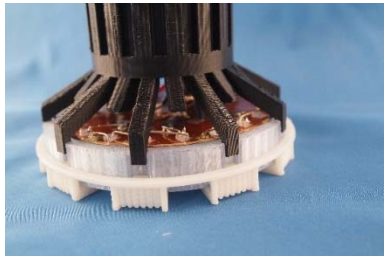


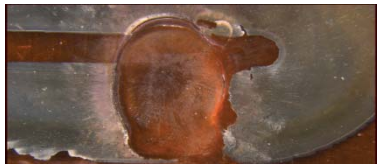
BENEFIT / SAVINGS

- Reduced size & weight
- Reliable integration of 2D & 3D Printing
- Embedded capabilities for enhancements to current & future weapon systems
- Increased reliability & survivability of electronics and sub-components
- More robust systems for High-G, extreme temperature, and multi-mode capabilities

Current Efforts & Opportunities
Integration of Electronics & Energetics

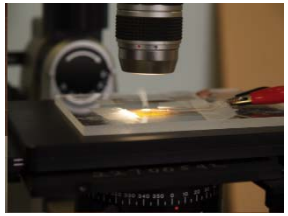
PROBLEM:

- Lack of low cost fabrication methods for advanced munitions concepts
- Geometric and functional challenges in current munition designs and fabrication
- electronic initiation system for grenades & other munitions
- Desire to add more capabilities into systems
- Need for more antennas and electronics into already “full” Fuze bodies.



SOLUTION/CONCEPT:

- Develop new writeable explosives and technologies
- Advance the state-of-the-art in Energetics processing
- Novel detonation physics concepts
- Move towards fully printed munitions and weapon systems



BENEFIT / SAVINGS

- Multiple Warhead responses
- Mission tailorable systems
- Significantly reduces distribution & logistics
- Rapid development and prototyping of solutions for current and emerging threats

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Current Efforts & Opportunities Training Systems

PROBLEM:

- Existing Multiple Integrated Laser Engagement System (MILES) training system is heavy and cumbersome 6-8 Lbs.
- No integration of soldier system(s) to weapon systems.
- Large heavy battery packs
- Soldiers often “hide” or “block” sensors during training

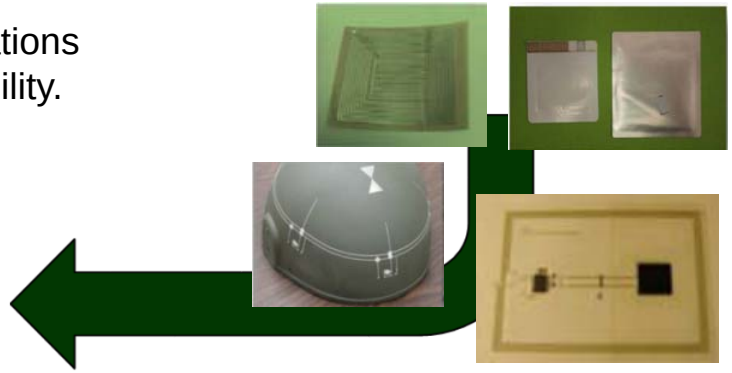
Current MILES system does NOT allow Warfighter to “Training Like You Fight”

SOLUTION/CONCEPT:

- “Patch” with integrated printed/flexible rechargeable power, detectors, sensors, antenna, etc.
- HERO Safe RF Tags for tracking and monitoring
- Soldier worn and vehicle/weapon system compatible patch/tags for integrated training and simulation capabilities.

BENEFIT / SAVINGS

- Optimized Training & Simulation with weight for Warfighter
- Better Training capabilities
- Data collections and cross system integration / Net Centric Operations
- Universal “tags” with higher MRL for cost savings and interoperability.



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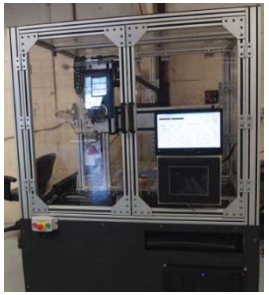
Other Areas of Development & Collaboration

UAVs
Sensors / Antennas / Power

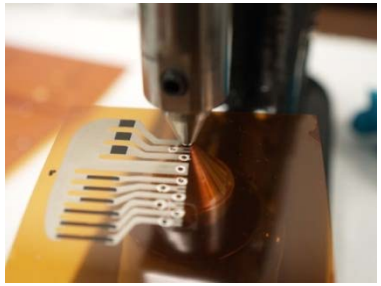
Uniform Integration
Sensors / Antennas / Power

Fuze Systems
Sensors / Antennas / Initiators / Power / C&C



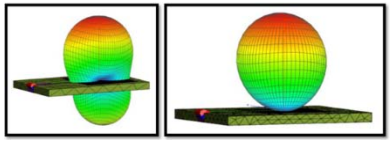
Multi-Tool Systems
Battlefield Manufacturing

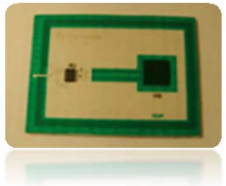
Munitions Monitoring
Prognostics / Diagnostics / Tracking / RFID /



Electronics for High-G

Sensor Development





Small Arms Electronics & Sensors

Warfighter Benefits

- Provide the Army with state-of-the-art technologies
- Weight / Volume savings
- Cost effective prototyping & fabrication techniques
- Increased force effectiveness and reduce operations, support, maintenance, and liability costs
- Transition from scheduled to condition based maintenance
- Increase Army readiness by reducing equipment downtime
- Increase safety by providing ammunition assurance
- Reduce reliance on proprietary systems
- Systems Resilient Engineering (IP Protection, Data Rights, Database Access)
- Cost effective prototyping & fabrication techniques
- Paradigm Shift in Energetics Development, Production & Testing
- Improved Testing Capabilities
- Improved Training & Planning Operations
- Optimized R&D / Systems Engineering

Summary

- Through the advancement of additive manufacturing, superior capabilities can be added to current and future military systems.
- US Army ARDEC has numerous Prototyping & Fabrication Techniques.
- Through its R&D efforts, ARDEC is helping to advance the capabilities of the Army by integrating state-of-the-art technology into and on military systems.
- These technologies will result in new and modernized weapons systems fielded globally that are capable of meeting current and potential challenges.
- Army transformation will result in new and modernized weapons systems fielded globally.
- Utilizing the manufacturing tools and philosophies of the electronics industry, long known for its innovative low cost and responsiveness manufacturing, to military systems, decreasing cost, improving reliability and shortening time form concept to fielding.

Questions?

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