U.S. Army RDECOM Additive Manufacturing Plans & Activities

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US Army RDECOM-ARDEC
Agenda

• Army-Unique Challenges
• AM Opportunity Space
• AM Acquisition Challenges & Logistics Challenges
• AM Activities Across the Army Materiel Command (AMC)
  • TRADOC/CASCOM/G-4 (Logistics)
  • RDECOM
  • Depots
• AMC-RDECOM Community of Practice (CoP)
  • Army-centric Materials
    • Steel 4340
    • Novel Polymer Composites
  • Design for Additive Manufacturing
  • 3D Model Based Enterprise
Additive manufacturing technologies bring the promise of enhanced performance and reduced logistics burden

However, there are also important considerations and limitations:

Each part is unique, therefore certification/qualification of the material and process are paramount
- There are very limited published standards and much of the work is still in progress
- There are a limited number of machines, additive processes and materials available from the equipment manufacturers
- Material performance is not “as advertised” on the equipment mfr. Data sheets and not fully characterized for all use cases
- No full materiel releases – no systems in the field using additive parts
- The few cases where additive has been used to produce a part are on an exception basis: SOCOM, REF for spares, repairs and/or tooling

In order to fully realize the benefits of Additive Mfg, the community has recognized that there are specific roles the Army must play to mature this technology
• Wide breadth of equipment, platforms and payloads (186K items in inventory)

• Many depots and arsenals have traditional manufacturing capabilities.

• Few “high value” items compared to AF and Navy

• Disconnects between R&D, depots and program managers (different Chains of Command)

In order to fully realize the benefits of Additive Mfg, the Army community needs to decide to work together…this decision cannot be done from the “top down”.
There are opportunities for AM to impact all Army systems

UAVs, UGVs
Control Surfaces, Engines

Vehicle Subsystems:
Drive Train, Suspension, Engine

Individual Soldier Protection

Missiles/Munitions:
Warheads, Fuzes

What are most common AM needs for the Army in materials, processes?
• Both communities can garner the benefits of AM, but often have conflicting needs.

<table>
<thead>
<tr>
<th>Acquisition Domain</th>
<th>Logistics Domain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost is often a driver</td>
<td>Time is often a driver</td>
</tr>
<tr>
<td>All parts must meet inspection and acceptance criteria</td>
<td>Not all parts are “critical”</td>
</tr>
<tr>
<td>Manufacturing processes must be reproducible</td>
<td>“Onesies” and “twosies” are OK</td>
</tr>
</tbody>
</table>

• Regardless, both require the use of 3D, digital data to store drawings and mfg data, which is still not considered “official data” by Army.

Develop business case for AM in part alternative scenarios at Point of Use and within the supply chain
AM Activities Across the Army*

• **TRADOC/CASCOM**: Developing policy and requirements to reduce logistical burden through point of use manufacturing
  – Evaluating the Business Case for using AM at Point-of-Use
  – Working with Rapid Equipping Force on requirements for in-theatre manufacturing
  – Focus on parts that don’t have extensive qualification requirements

• **RDECOM**: Develop, mature and transition AM materials, technologies and processes to support qualified processes for end-item user requirements
  – DoD and Industry recognized subject matter experts in metal and polymeric AM processes
  – Army Research Laboratory (ARL) focus’ on research related to enhancing machine performance, material development, direct-write electronics and hybridization of processes
  – Research, Development & Engineering Centers (RDECs) focus on applications in prototyping, discrete part manufacturing, low-cost tooling, repair of metallic components and rapid fielding
  – Initiated an AM Community of Practice to leverage knowledge, materials and machines
  – With America Makes, kicking off an Army AM Strategic Road Mapping Exercise with all Army partners (summer 2015)

• **Army Depots and Arsenals**
  – Mostly metal-based technologies with some polymeric technologies
  – Depots: Some examples of using AM for repair; require validated material, process and engineering data before implementing AM-based repair processes on Army systems
• **The challenge of material and process certification demands collaboration**
  - Robust data is required from multiple machines – *enterprise approach for Knowledge Management is needed*
  - Sharing of data
  - Domain expertise in products maximize the potential for variety of applications for a given material (ground to aviation)

• **AM machines are costly and complex**
  - Need to maximize best practices
  - No one site can own all capability

• **Army-centric materials need to be addressed**
  Materials of Interest:  
  - Steel 4340 (ARDEC PhD candidate is developing AM build parameters for this steel)
  - Steel 52100 (ARDEC M&S Division has submitted a TEX3 proposal to study this bearing steel)
  - Tungsten - warheads
  - Tantalum - warheads
  - Copper - warheads
  - Titanium (to build upon prior Army efforts in lightweighting)
  - Aluminum - lightweighting
  - Ceramics - warheads, flexible electronics, capacitors

• **Product data challenge requires enterprise sharing of design and manufacturing data**
### RDECOM AM Capabilities

<table>
<thead>
<tr>
<th>RDECOM AM Capabilities</th>
<th>TARDEC</th>
<th>ARDEC</th>
<th>Army Research Lab</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Ground and Support Systems Technology Prototyping &amp; Integration</strong></td>
<td><strong>Aviation and Missile Technology Prototyping &amp; Integration</strong></td>
<td><strong>Armaments Technology Prototyping &amp; Integration</strong></td>
<td><strong>Processes</strong></td>
</tr>
<tr>
<td><strong>Processes</strong></td>
<td>• Direct Metal Deposition</td>
<td>• Polymer Extrusion, Vat Polymerization, Powder Bed Polymer, LENS, DMLS</td>
<td></td>
</tr>
<tr>
<td><strong>Total # of machines</strong></td>
<td>• Fused Deposition Modeling</td>
<td>16 machines in total</td>
<td></td>
</tr>
<tr>
<td><strong>Materials</strong></td>
<td>• Selectively depositing liquid binding material</td>
<td><strong>Materials</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Applications</strong></td>
<td>• 4 machines in total</td>
<td>• Epoxy, ABS, PLA, Wax, 17-4 SS, 300 Maraging Steel, Nylon, Alumide</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Fe, Co, Ni, Ti, and Cermets</td>
<td><strong>Applications</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Coating / part repair, 3D printing, &amp; Multi-material joining</td>
<td>• Casting molds, Prototypes</td>
<td></td>
</tr>
<tr>
<td><strong>AMRDEC</strong></td>
<td><strong>ARDEC</strong></td>
<td><strong>Army Research Lab</strong></td>
<td><strong>Processes</strong></td>
</tr>
<tr>
<td><strong>Aviation and Missile Technology Prototyping &amp; Integration</strong></td>
<td><strong>Armaments Technology Prototyping &amp; Integration</strong></td>
<td><strong>Processes</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Processes</strong></td>
<td>• Polymer Extrusion, Vat Polymerization, Powder Bed Polymer, LENS, DMLS</td>
<td>• Polymer extrusion</td>
<td></td>
</tr>
<tr>
<td><strong>Total # of machines</strong></td>
<td>16 machines in total</td>
<td>• Vat Polymerization</td>
<td></td>
</tr>
<tr>
<td><strong>Materials</strong></td>
<td><strong>Materials</strong></td>
<td>• Powder Bed Metal</td>
<td></td>
</tr>
<tr>
<td><strong>Applications</strong></td>
<td>• Epoxy, ABS, PLA, Wax, 17-4 SS, 300 Maraging Steel, Nylon, Alumide</td>
<td>• Inkjet</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Casting molds, Prototypes</td>
<td>• Aerosol Jet</td>
<td></td>
</tr>
<tr>
<td><strong>ARMDEC</strong></td>
<td><strong>CERDEC</strong></td>
<td><strong>ECBC</strong></td>
<td><strong>Processes</strong></td>
</tr>
<tr>
<td><strong>Armaments Technology Prototyping &amp; Integration</strong></td>
<td><strong>C4ISR Technology Prototyping &amp; Integration</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Processes</strong></td>
<td>• Polymer jet printing</td>
<td>• Polymer extrusion</td>
<td></td>
</tr>
<tr>
<td><strong>Total # of machines</strong></td>
<td>1 machine</td>
<td>• Vat Polymerization</td>
<td></td>
</tr>
<tr>
<td><strong>Materials</strong></td>
<td><strong>Materials</strong></td>
<td>• Powder Bed Polymer and Metal</td>
<td></td>
</tr>
<tr>
<td><strong>Applications</strong></td>
<td>• photopolymer</td>
<td>• Polymer Jetting</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Engineering development prototyping</td>
<td>• Binder Jetting</td>
<td></td>
</tr>
<tr>
<td><strong>ARMDEC</strong></td>
<td><strong>CERDEC</strong></td>
<td><strong>ECBC</strong></td>
<td><strong>Materials</strong></td>
</tr>
<tr>
<td><strong>Processes</strong></td>
<td><strong>Processes</strong></td>
<td>• Polymers, Metals, Ceramics &amp; materials for printed electronics</td>
<td></td>
</tr>
<tr>
<td><strong>Total # of machines</strong></td>
<td>• Polymer Jetting</td>
<td>• 6.1-6.2 materials and tech development</td>
<td></td>
</tr>
<tr>
<td><strong>Materials</strong></td>
<td><strong>Materials</strong></td>
<td><strong>Applications</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Applications</strong></td>
<td>• Powder Bed Metal</td>
<td>• 13 machines in total</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Epoxy, ABS, PLA, Wax, 17-4 SS, 300 Maraging Steel, Nylon, Alumide</td>
<td><strong>Applications</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Casting molds, Prototypes</td>
<td>• ABS, ULTEM*, PC, PPSF (polyphenylsulfone), Nylon 11, Nylon 12, Steels, Cobalt Chrome, plus more.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Prototypes, unique fixtures, end-use items, Tooling and tooling inserts</td>
<td><strong>Materials</strong></td>
<td></td>
</tr>
</tbody>
</table>

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Three 5-year progressive stages of adoption with four distinct pillars of investment:

- **FY14–19**
  - Part Alternative
    - Tooling and Repair
    - Part Substitution

- **FY20–24**
  - Process Alternative
    - Process Substitution
    - Primary manufacturing
    - Point of Use manufacturing

- **FY25–29+**
  - Product Alternative
    - Novel Designs
    - Novel Materials

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**Pillar 1:** Material and process certification and qualification

**Pillar 2:** Army Additive Manufacturing Knowledge-base

**Pillar 3:** Machine Technology and Material Improvements

**Pillar 4:** Transfer technology to the industrial base and field

*Level of complexity from low to high, evolving from part to system, and from early adopters to traditional acquisition*
Army-Centric Materials (ARDEC, ARL)

<table>
<thead>
<tr>
<th>Material Condition</th>
<th>Modulus</th>
<th>Yield Strength</th>
<th>Tensile</th>
<th>Elongation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Typical wrought 4340 properties</td>
<td>29,000 ksi</td>
<td>183 ksi</td>
<td>199 ksi</td>
<td>15%</td>
</tr>
<tr>
<td>from ASM International</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Run A: DMLS of Virgin Powder</td>
<td>31,000 ksi</td>
<td>189 ksi</td>
<td>198 ksi</td>
<td>16-17%</td>
</tr>
<tr>
<td>Run B: DMLS after once recycled powder.</td>
<td>31,000 ksi</td>
<td>187 ksi</td>
<td>198 ksi</td>
<td>16-17%</td>
</tr>
</tbody>
</table>
Design for Additive Manufacturing (AMRDEC)
Direct metal Deposition – Abrams Suspension Arm

Technology available at TARDEC, Benet Labs (ARDEC), & Anniston Army Depot

Reduced down time and costs. Must work with OEM.
Model Based Definition (MBD)

- Fully annotated 3D models
  - that include all information typically found on a 2D drawing
  - Follow MIL-STD-31000A
  - Reusable by activities throughout the product lifecycle
  - The basis for Digital Work Instructions and Interactive Electronic Technical Manuals

Model Based Enterprise (MBE)

- An integrated and collaborative digital environment that deploys MBD
- Connects and automates the system engineering process around the product technical data
- Enables reuse of 3D tech data at all points on the lifecycle
An Army AM CoP Can Contribute

- **Government-driven efforts can help create “predictive models” by creating Knowledge Management systems**
  - Community/shared data will accelerate standards development
  - Expand the scope of materials beyond the interest of risk of industry

- **Lead enterprise efforts in creating Parts Libraries**
  - PLM/ePDM efforts are ready to store both geometry and process information in enterprise product data systems
  - RDECOM enterprise approach in product data will make AM available to the industrial base

- **Provide qualified processes to depots/ arsenals to help them use AM and become more competitive**
  - Work with depots to scale their capability to use AM where business case warrants
  - Help depots be ready for future products that use AM processes (particularly unique materials like ammo/energetics)
Summary

- Additive Manufacturing is an enabling technology that has the potential to provide rapid, agile, efficient and complex production solutions with improved cost, schedule and performance

- The U.S. Army RDECOM focus is on
  - AM material and process certification/qualification
  - Establishing a robust knowledge base for AM processes and parts
  - Improving AM materials and machine technologies
  - Transferring AM technology to the industrial base

- Partnerships will be the key to success