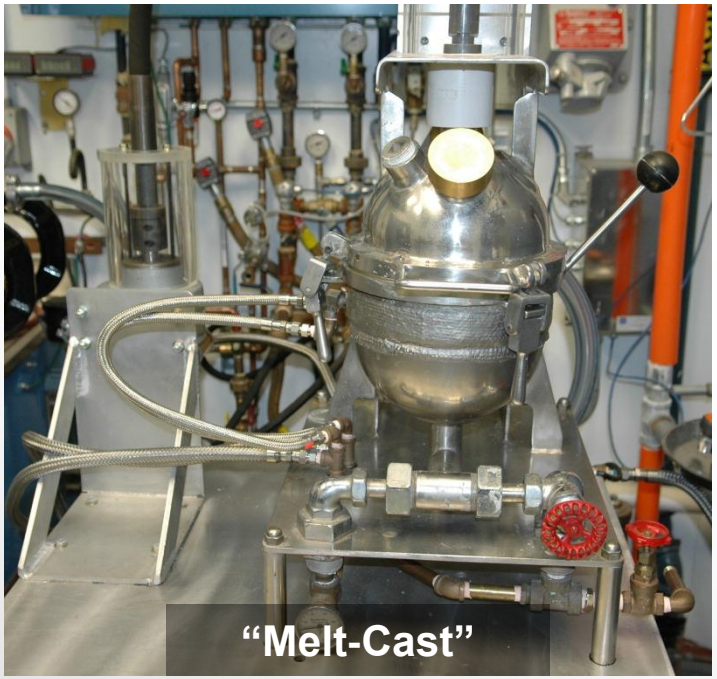
Energetic Materials Additive Manufacturing

Overview

- Background
- Goals
- General Approach & Anticipated Phases
- Summary

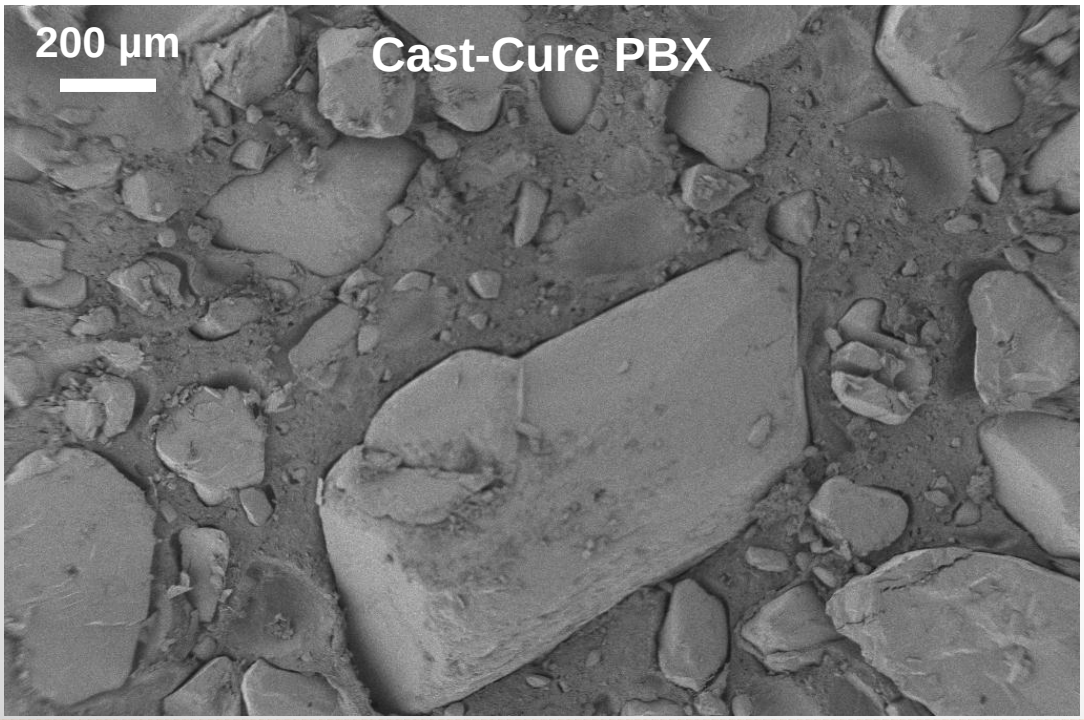
Manufacturing Today

- **Typical Explosive Formulation:**
  - **80-98% Solids: TNT, RDX, CL-20, Al, etc.**
  - **1-20% Polymeric and/or wax binders**
- **Classical Production Methods:**

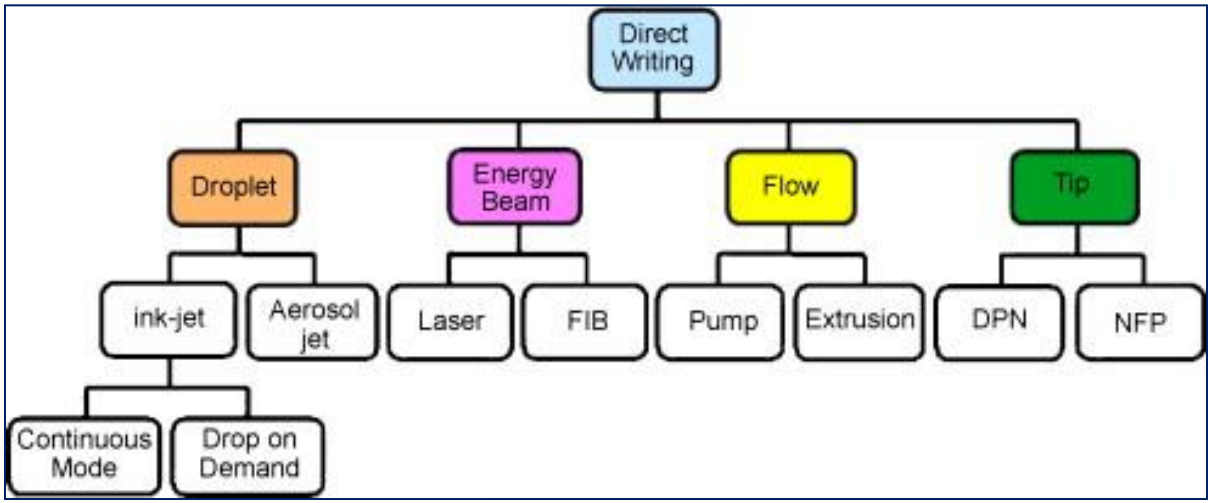


Current Issues

- Shrinking industrial base
- Batch variation
- Random, inhomogeneous products
- ***Limited design options***
- Reaching ***limit of gains*** from bulk ingredients



A Material Revolution



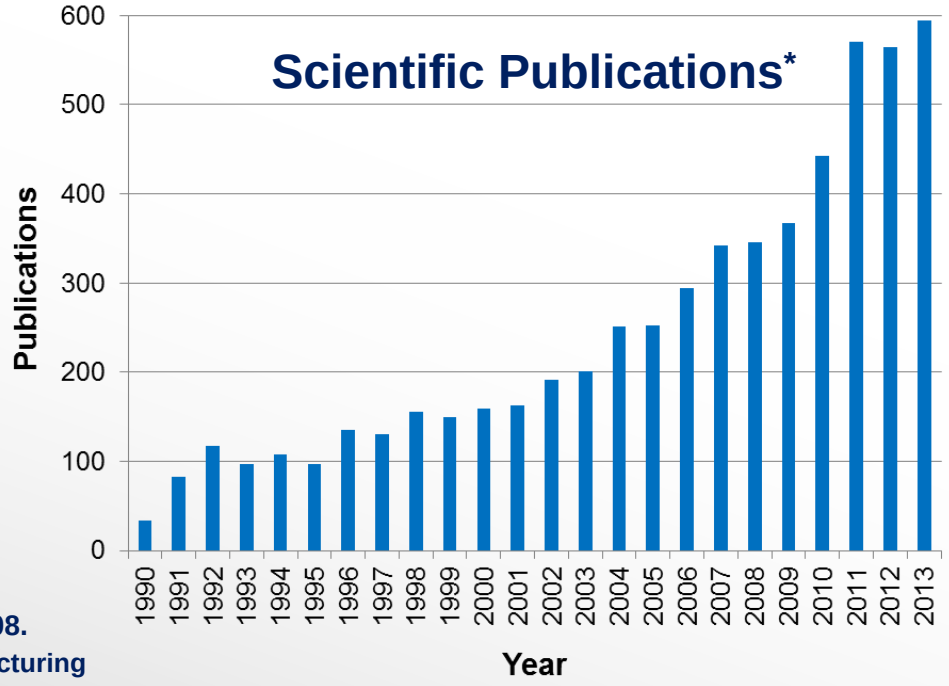


Figure: K.K.B. Hon, et al. *CIRP Annals - Manufacturing Technology* 2008.

***Thomson Reuters search of nanoenergetics, direct write, additive manufacturing**

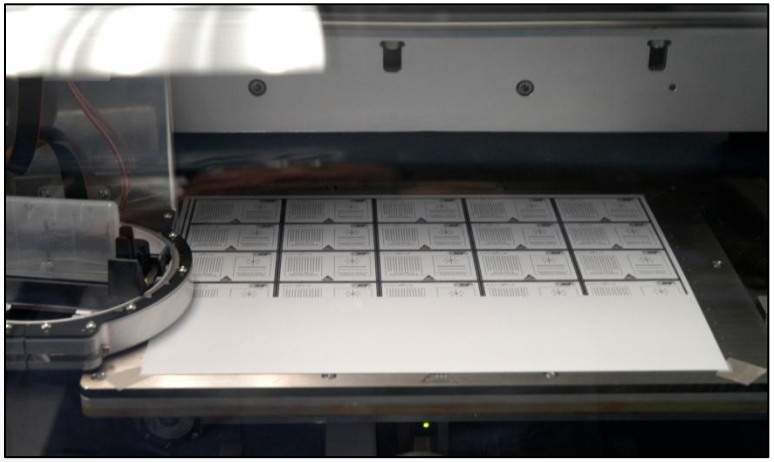
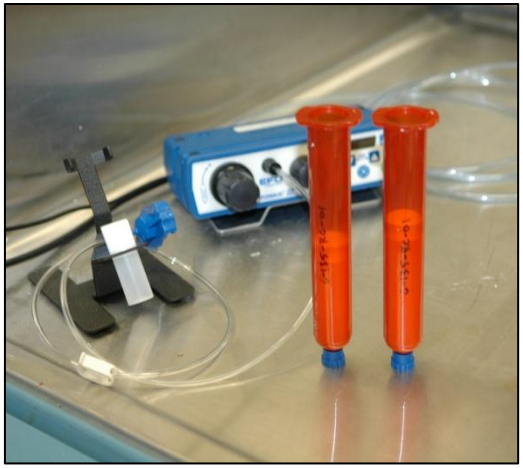
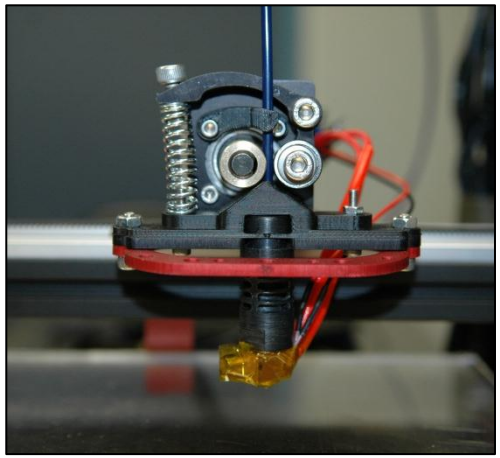
EMAM Goals

Integrated Warhead & Rocket Motor Manufacturing

- ***Performance*** - integrated warhead manufacturing *enables chemical and physical output phenomena* not feasible with traditional propellant/explosives processing
- ***Improve IM response*** via non-conventional multi-point technologies with high simultaneity
- ***Speed to fleet*** – idea to design to print to test to fleet
- ***Reduced cost*** – storage and transportation; no production line retooling; ideal for limited production runs
- ***Production stability*** – government owned designs and ability to do production at multiple manufacturing sites including DoD facilities

Current and Future Capabilities

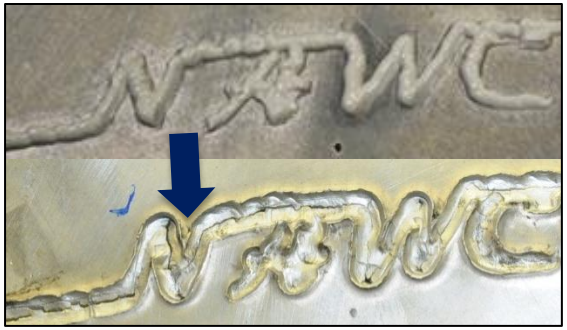
- **Current capabilities:**

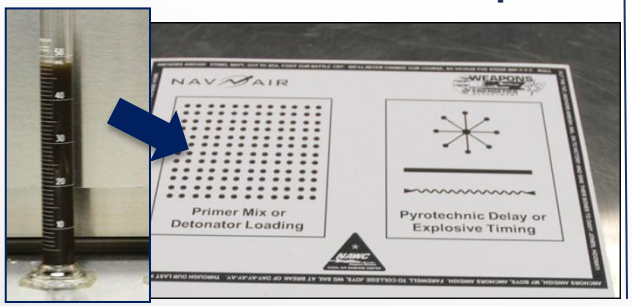
- **Current efforts lay foundation for Nanoenergetics & Additive Energetics Manufacturing CIP:**
  - Effort executed in FY16 and FY17
  - Establish a full suite of formulation, characterization and printing capabilities
  - Expand upon current nanoenergetic production capabilities
  - Investigate all “3D” technologies

EMAM Approach

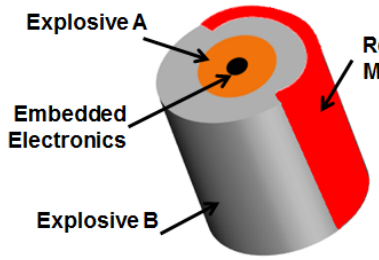
Near Term

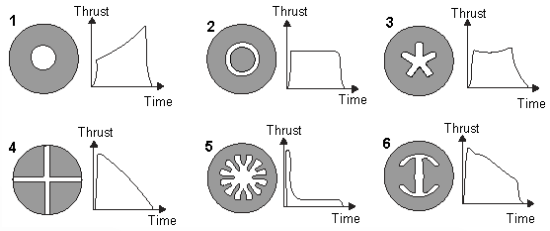


New Material Development



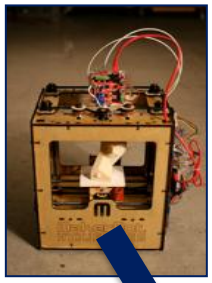
Mid Term

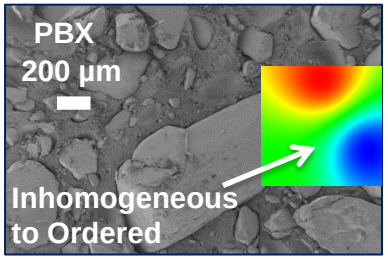




Integrated Printing Process and Device Development

Long Term





Designer Energetics

Task	FY-15				FY-16				FY-17				FY-18			
	1ST QTR	2ND QTR	3RD QTR	4TH QTR	1ST QTR	2ND QTR	3RD QTR	4TH QTR	1ST QTR	2ND QTR	3RD QTR	4TH QTR	1ST QTR	2ND QTR	3RD QTR	4TH QTR
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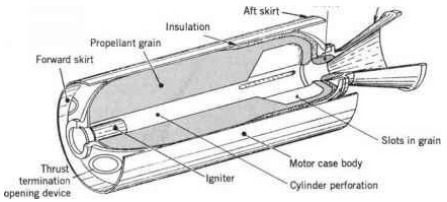
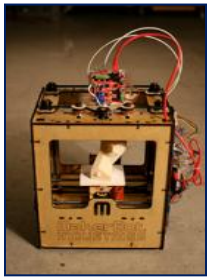
AM Explosive Proof-of-Concept																
Prototype Energetic Filaments																
Explosive Train																
Propellant Grain																
Warhead																
Rocket Motor																
All-up Round																
Designer Energetics																
Capabilities, Workforce, Protocol																
Characterization, Test and Evaluation																

Advancing Ordnance Manufacturing

- Deliverables:
  - Printed Warhead
  - Printed Rocket Motor
- Impact:
  - *Speed to fleet* - idea to print to test to fleet
  - *Performance* - enables warhead output phenomena and solid propellant grain design not feasible with current production methods; improve IM response; directed energy
  - *Production stability at reduced cost* – government owned/licensed designs, multiple manufacturing production sites including DoD facilities; no production line retooling; ideal for limited production runs





- Technology Challenges:
  - Paradigm change in energetics processing
  - Integrating explosives, propellants and pyrotechnics with AM environment
  - Development of novel energetic formulations
- Approach:
  - Potential Research Partners
    - NAVAIR AM IPT, DARPA, ONR
    - Universities
    - Commercial Sector
  - Anticipated Resources Leveraged
    - JANNAF community
    - SNL, ARDEC, AFRL-Eglin
- Dependencies:
  - OEM for custom printers

- Current Status:
  - Initial R&D on energetic materials and additive manufacturing techniques
  - Developing SOPs
  - Leveraging capabilities and prior research in both manufacturing and energetics
  - Selecting and developing materials for use in AM environment and process mechanisms
  - Working with equipment experts to develop requirements for energetics printers
  - Installing/developing energetic AM capabilities
  - Interfacing with characterization groups on NDE concerns