

# ADDITIVE MANUFACTURING APPLICATIONS



Energetic Materials & Products, Inc (EMPI)

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John Granier

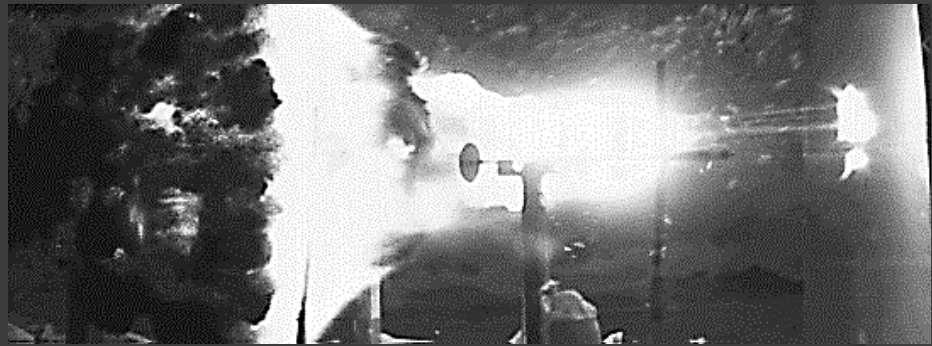
[John.granier@empi-inc.com](mailto:John.granier@empi-inc.com) 512.380.1945

TTU Energetic Materials Conference

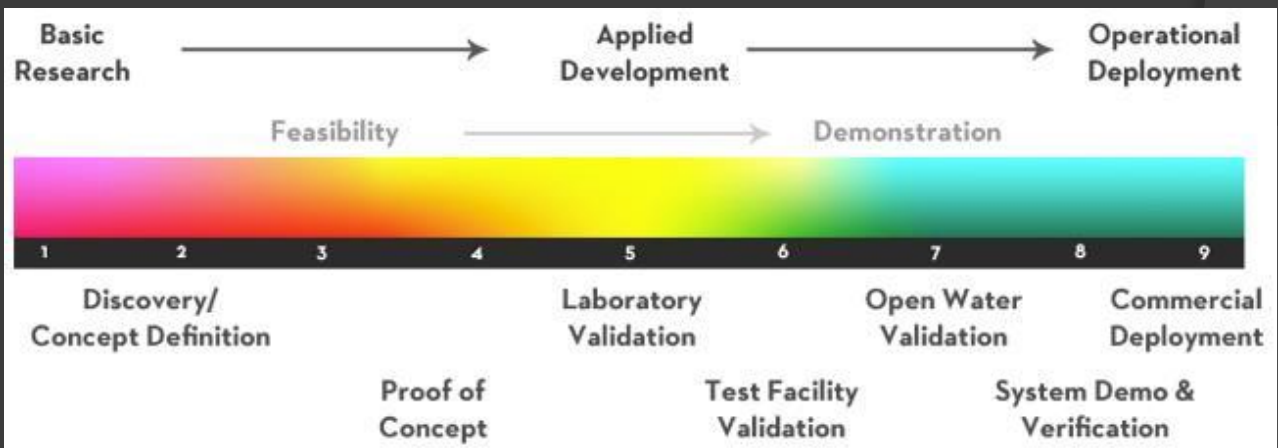


# Who We Are?

- **Technology Development**
  - Team of engineers and technicians specializing in explosives, pyrotechnics, and ballistics



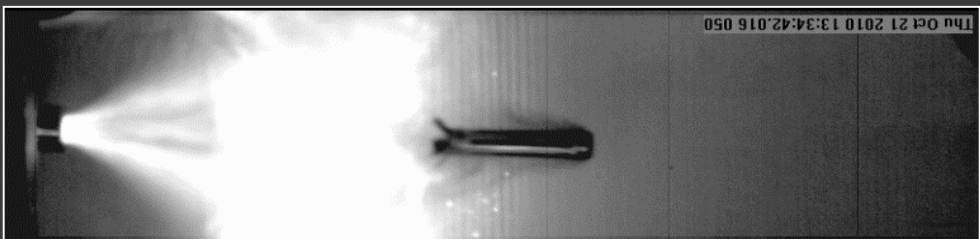
- **Product Development**
  - Energetic products
  - Strong **Mechanical Design | Prototype testing | Integration**
  - Specializing in **TRL 3-6**



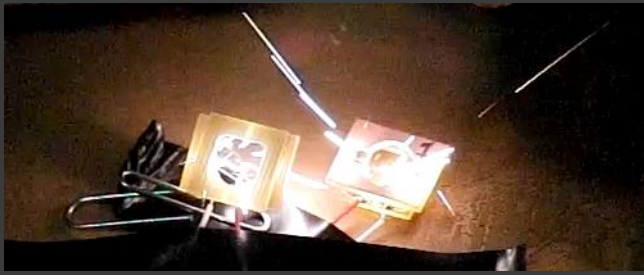


# Technology Fields

➤ Ballistics



➤ Pyrotechnics



➤ Explosives



➤ Military | Commercial | Industrial



# AM Enabled Innovation

- AM = Additive Manufacturing
- Demonstrated Case Studies
  1. Tooling and Fixtures
  2. Test Items
  3. Products
- Pushing what's possible
  - A. High density metals
  - B. Ceramics
  - C. Energetic Materials



# 1. Tooling & Fixtures

- Molding
  - Quick geometries
- Vacuum Forming
  - Printed porous positive to draw heated plastic film tighter during cooling





# 1. Tooling & Fixtures

## FAE Program

Hydrocode Modeling & Simulation based on ideal symmetry spherical geometry

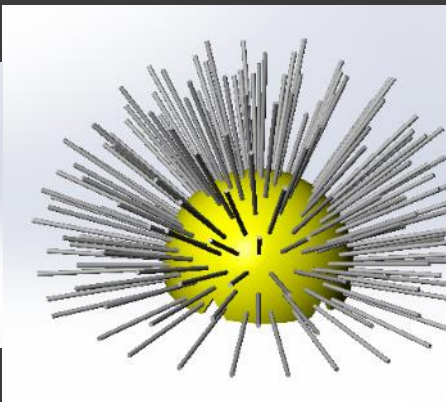
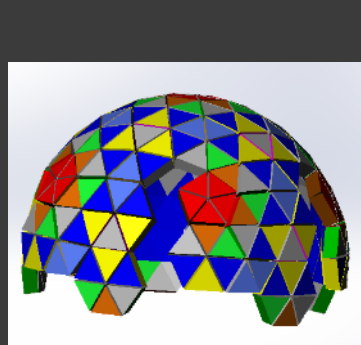
Jetting at geodesic dome nodes

**!! Spheres are hard to machine**

Hemisphere steel shell

Hand-drilled using SLS GFR Nylon

Gunger Engineering



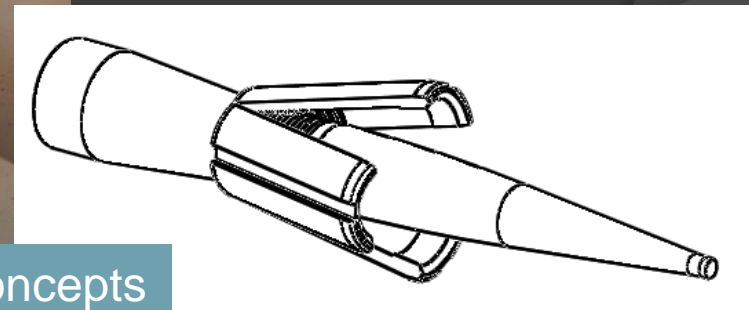
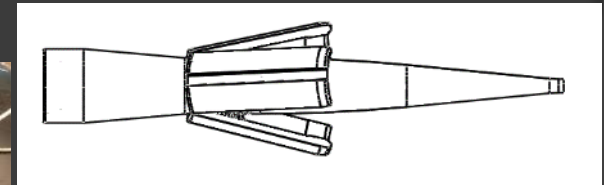
# FAE TA Jet Expansion HSV





# 2. Test Items

- How can AM apply to advanced projectiles?
- Cheaper/Fast Manuf. **Sabots**
  - SLS Nylon GF oversized
  - OD post-machined to high dim. tolerance



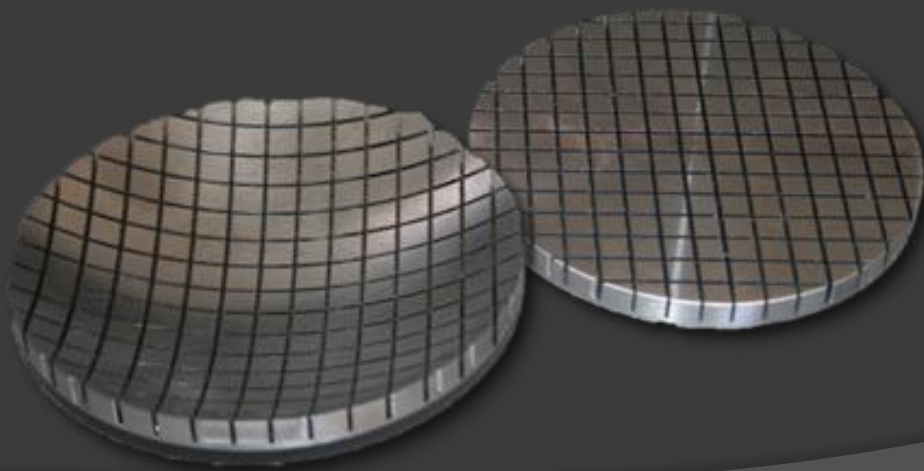
Advanced Acoustic Concepts





## 2. Test Items

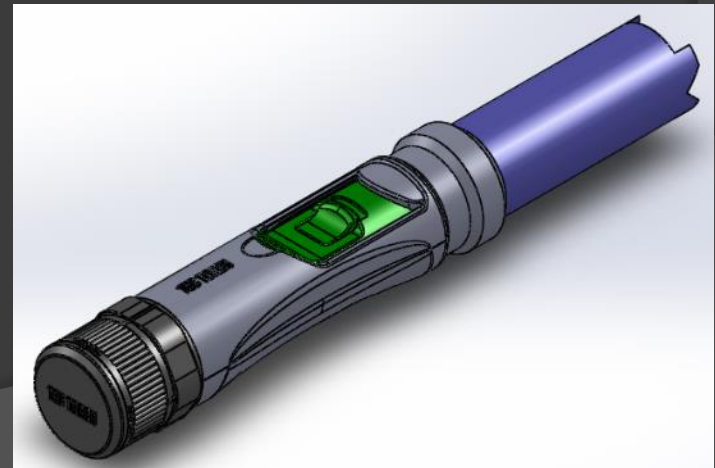
- Munition Frags / Preformed Frags
- Current: Machined or cast notches or Potted array of individual parts (cube/hex)
- AM: Printed munitions case
  - DMLS: Stainless PH17-4





# 3. Products

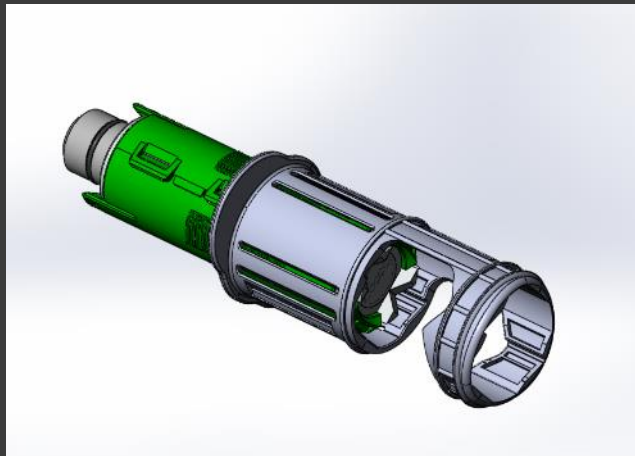
- TEC Torch® handles started as AM prototypes
- Relatively small tac-ops market ~1000 units/yr
  - Zero capital investment
  - Constant design improvement
  - Allows multiple models for user requirements (4)
  - Cheapest assembly labor & tooling for niche tactical market
  - Robust





# 3. Products

- Traditional Prototype Cycle using AM
- TEC Torch® Claw Clip
  - Ratcheting mechanical clamp
    - Sensitive dimensional tolerance; ~8 AM prototype cycles
    - Now injected molded parts



- AM geometry strength testing
- AM human interface testing





# Future Needs

- Reachable Goals
- Materials developers (You)
  - New materials
  - New procedures
- Technology developers (EMPI)
  - Concept
  - Feasibility testing
  - Programmatic evaluation
  - Product integration

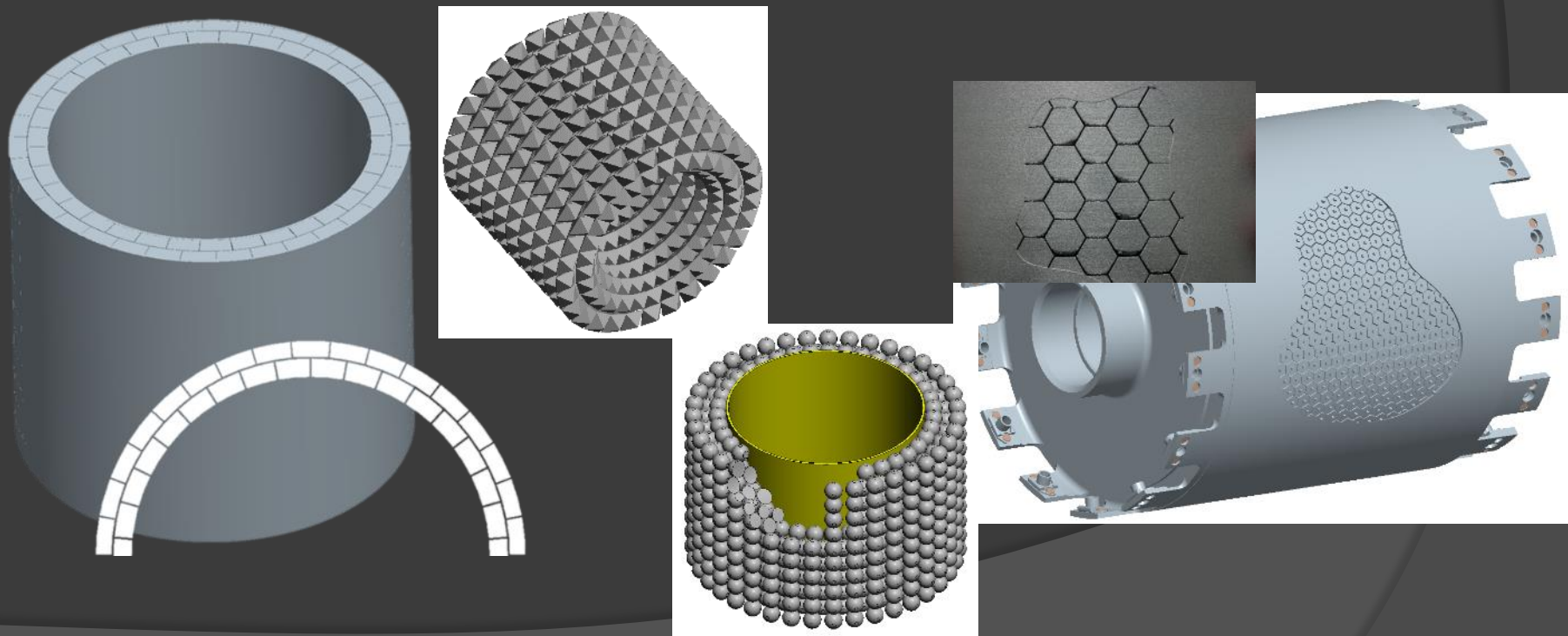




A. High density alloys  $>11\text{g/cc}$  or  $>16\text{g/cc}$

Not for all munitions

But for precision platforms, AM enables minor munitions alterations by modular design



# B. Ceramics / Refractory Materials

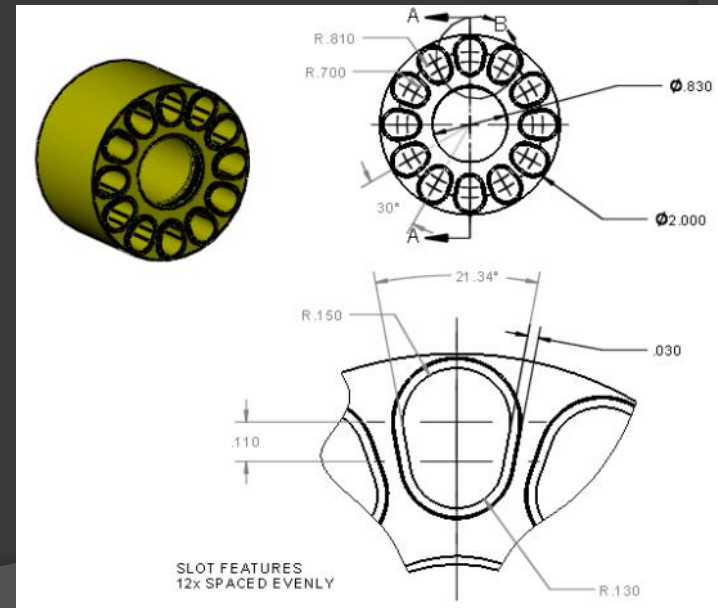
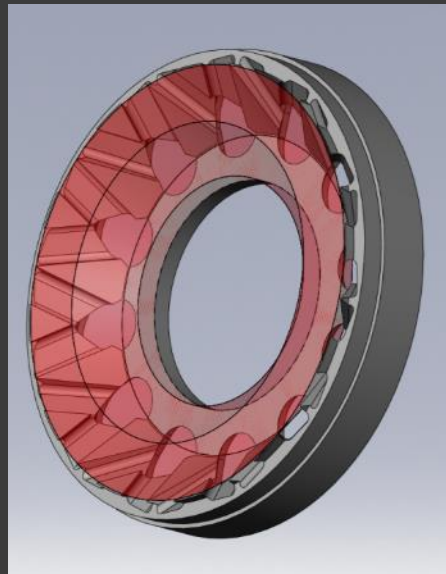


Prototyping complex nozzles & thermal insulators

High temperature

Abrasion resistance

See 3D Printing a concrete house  
-Needed on small part scale with  
finer tolerance and better ceramic





# C. Energetic Materials

- Main working material
- Pyro compositions / low explosive / high explosive
- EM Solids (powders or grains)
- EM Liquids/slurries/pastes

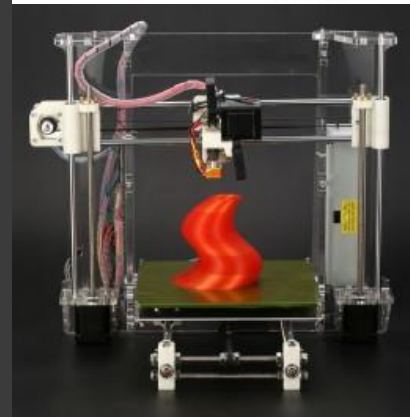
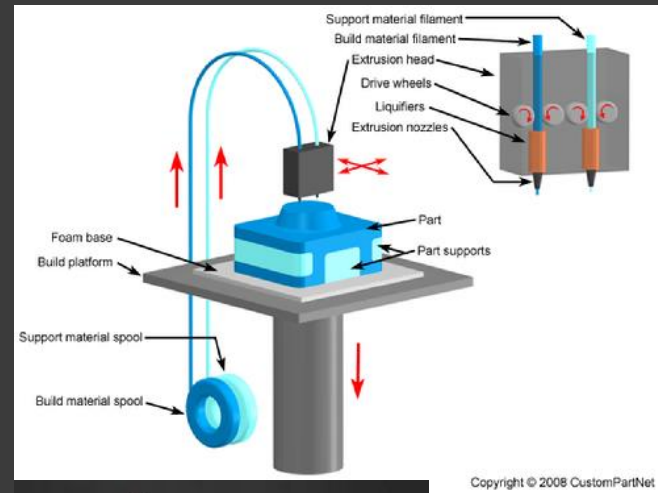
## Critical Elements

- Material strength [extreme requirements for warheads | minimal requirements for consumer items (i.e. door breach charge)]
- Temperature capability (polymers withstanding high and low temperatures)
- Maximize EM mass
  - Minimize polymer binder/matrix
  - Minimize print voids



# EM Powder in a Filament – FDM

- Temperature balancing
  - Low temp polymer
  - High  $T_{ign}$  EM
- How thin can the filament wall be (maximizing RM mass to maintain reaction)
- Beneficial filament materials (PTFE)

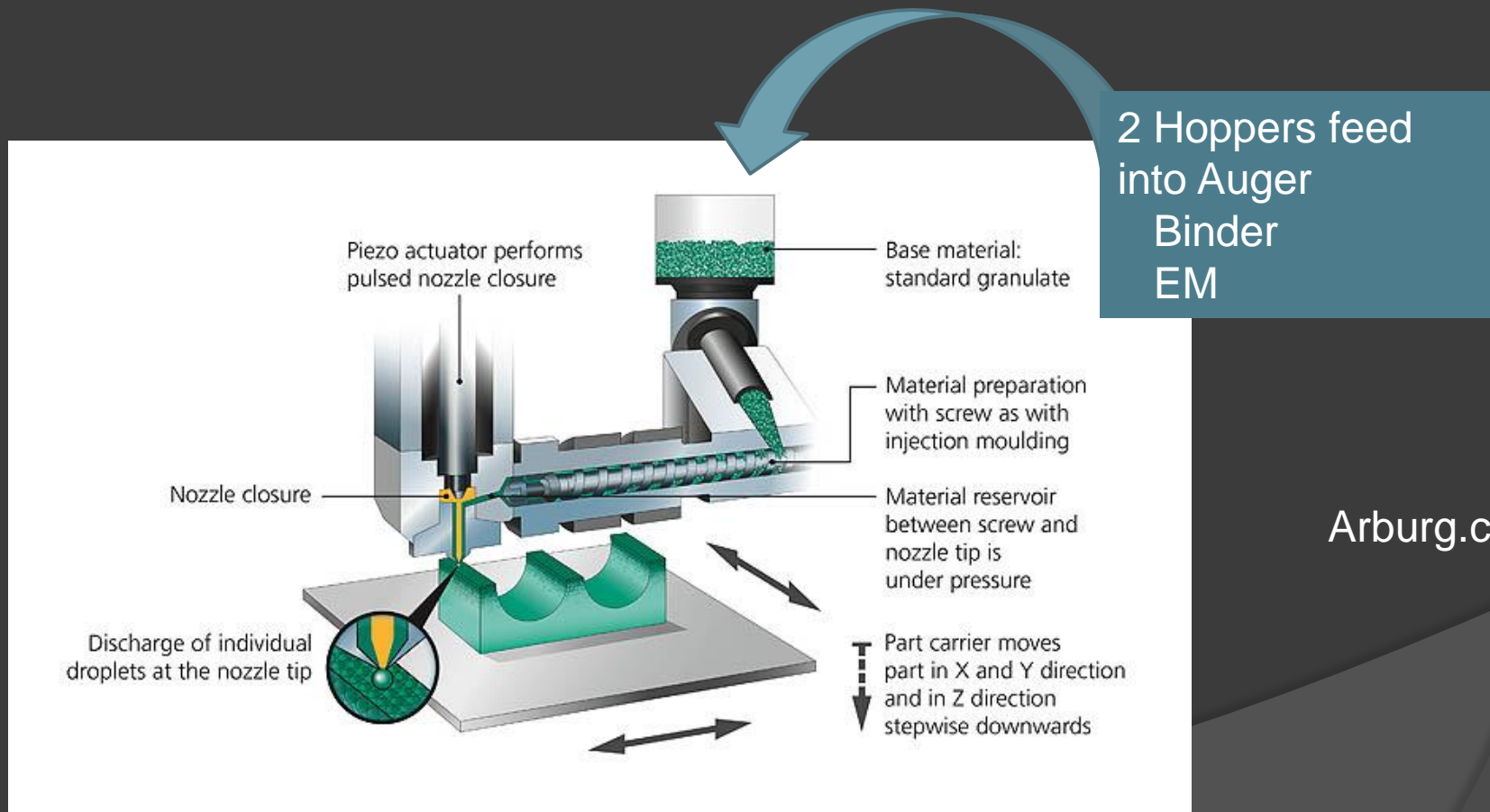






# Powder EM in Plastic Freeforming

## ➤ EM + polymer binder



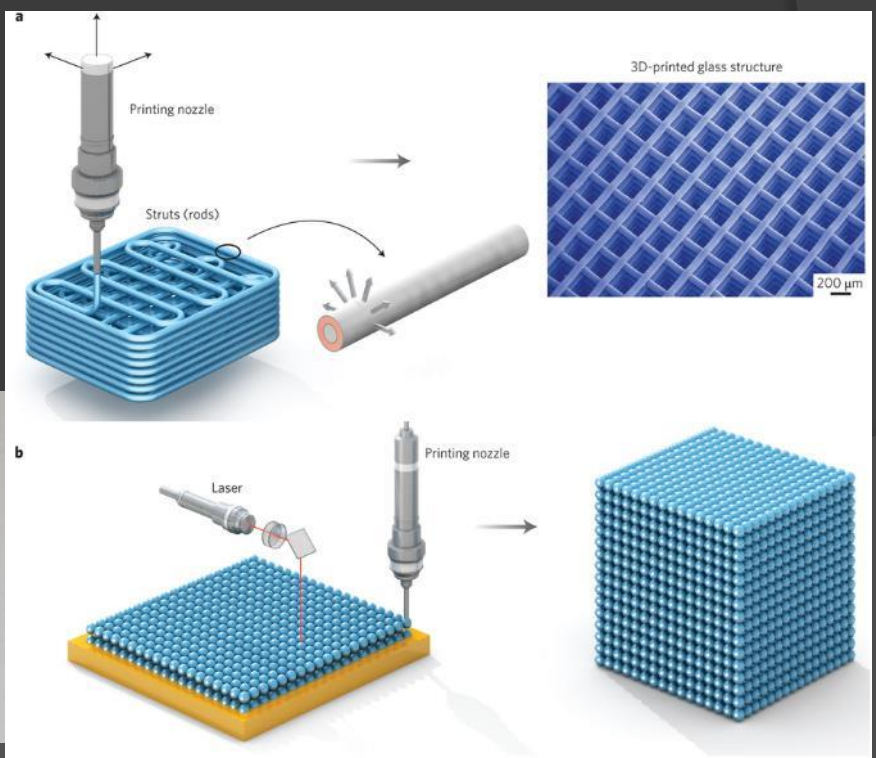
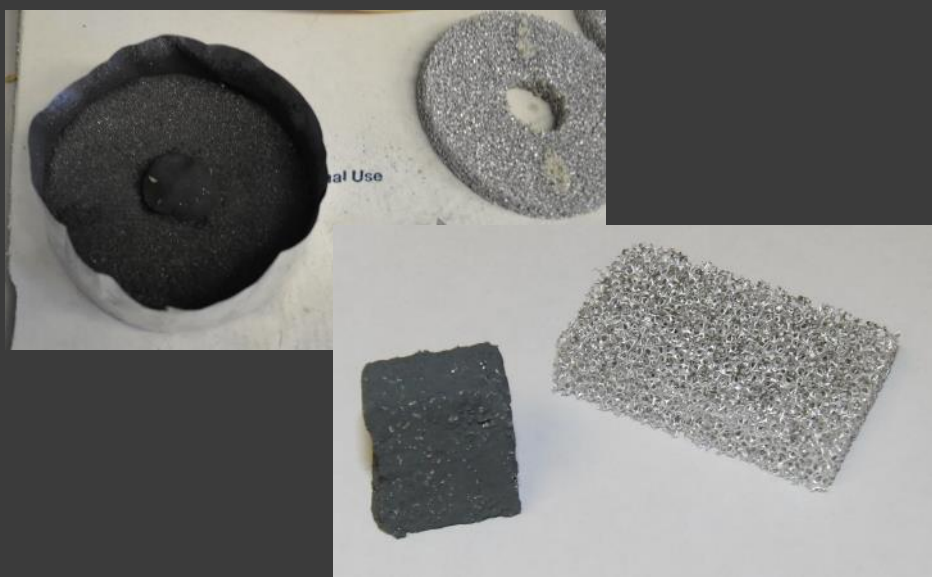
Arburg.com



# Bimolecular Reactions

- Print scaffold of fuel or oxidizer
- Dual head printing
- Impregnate by oxidizer or fuel by slurry or liquid

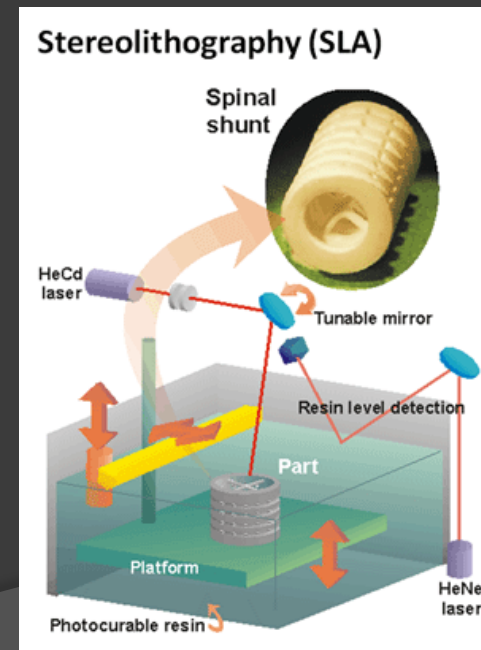
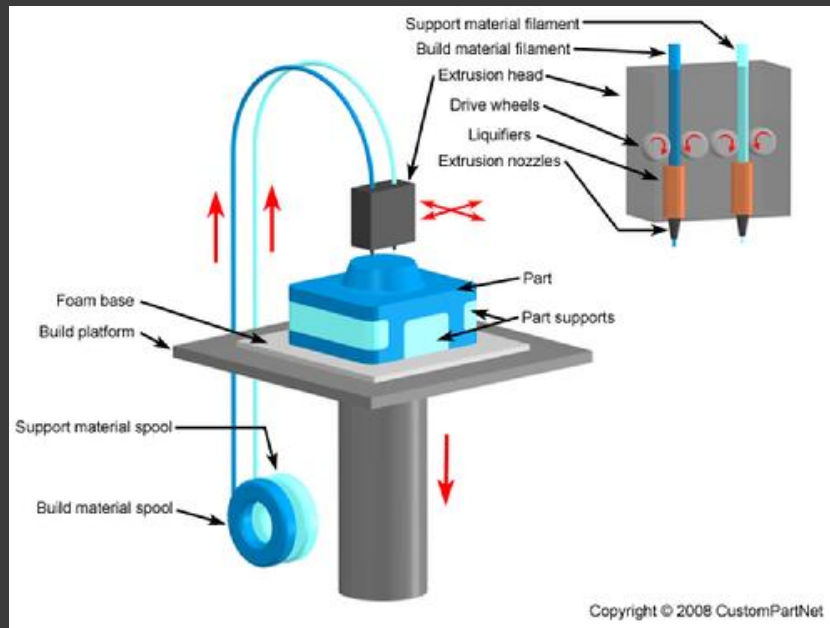
## RM Filled Aluminum Foams





# Extrudable EM place & Cure

- EM 'towpreg': b-stage binder
  - UV cure binder
  - thermoset
  - O2 exposure cure binder
  - Maximize EM/binder ratio
  - Minimize void volume ratio





# Additive EM Manufacturing

- EMPI selectable effects warheads
  - Based on multiple EM fills
    - Could be manufactured at same time by layers
  - Based on complex architectures
    - Fuze positioning
    - Advantageous mach-stem interactions
    - Currently limited to moldable geometries
  - Based on multiple initiation points
    - fuzing positions simultaneous or unique



Questions?