

# Additive Manufacturing



**GVSETS**

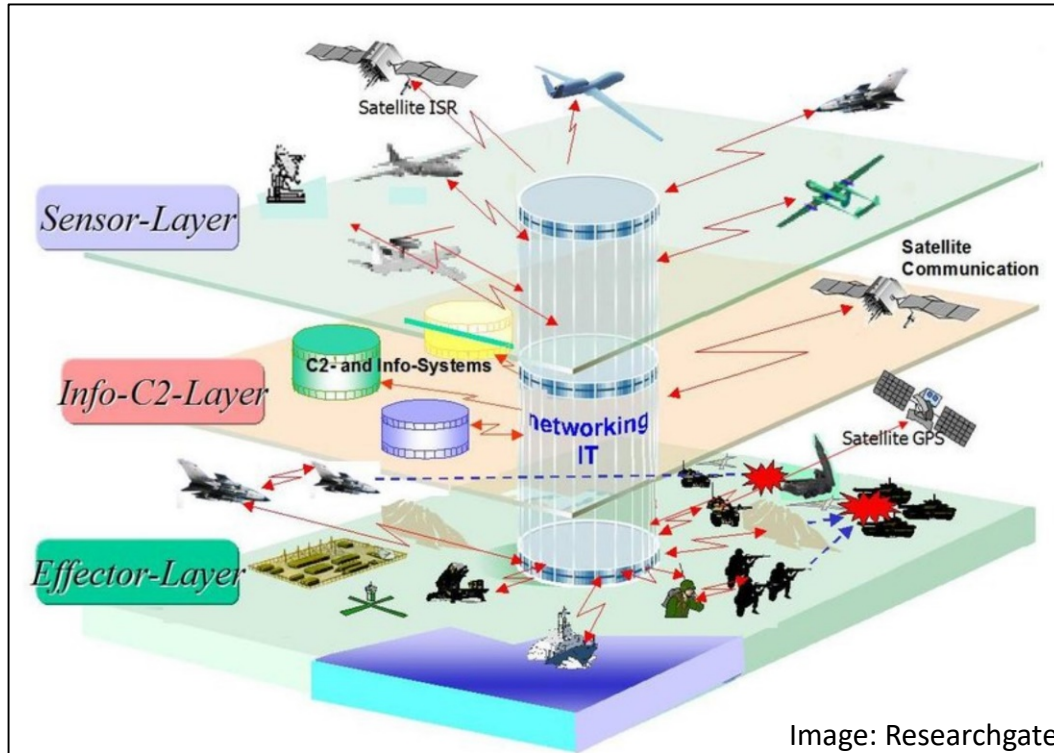
GROUND VEHICLE SYSTEMS ENGINEERING & TECHNOLOGY SYMPOSIUM  
& ADVANCED PLANNING BRIEFING FOR INDUSTRY

## Quantifying the Value of Integrating Manufacturing Platforms

Dr. Donghun Park, Dr. Yongzhang Leng, Dr. Warren Herman, Victor Yun  
3DFlexible Inc.



## System Architecture of Military IOT



### Innovative products:

- Typewriter
- PC
- Smartphone

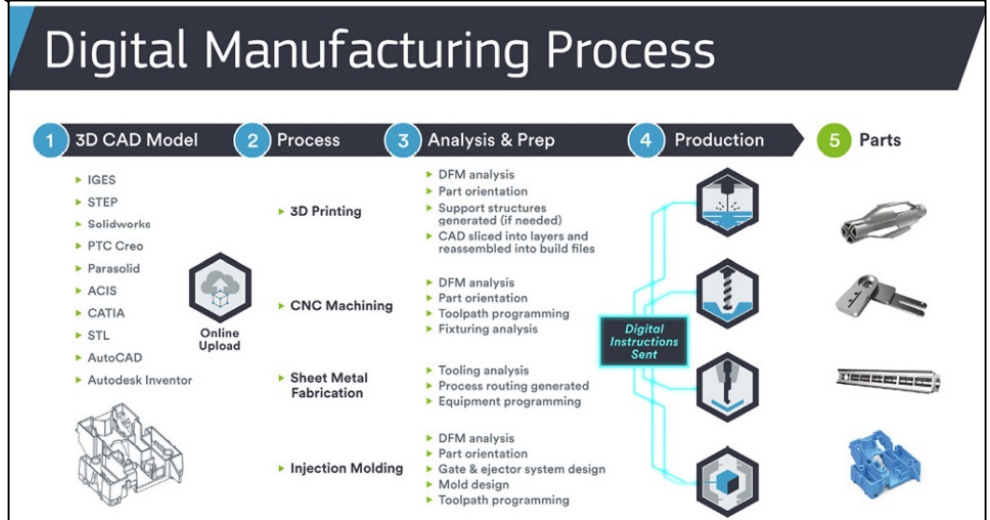
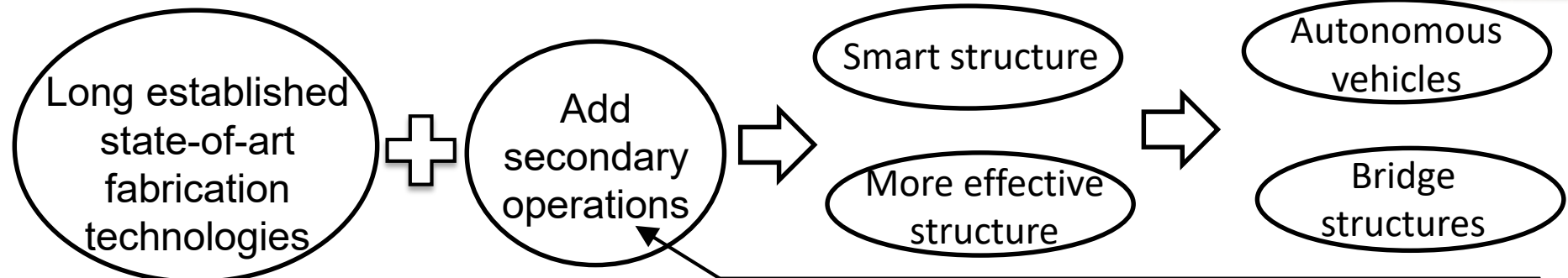
### Innovation:

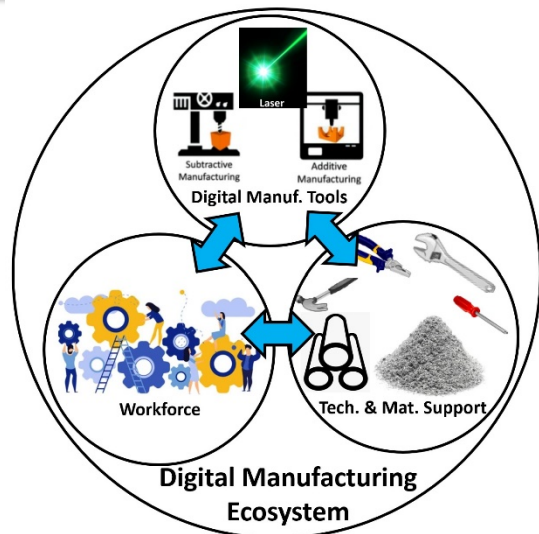
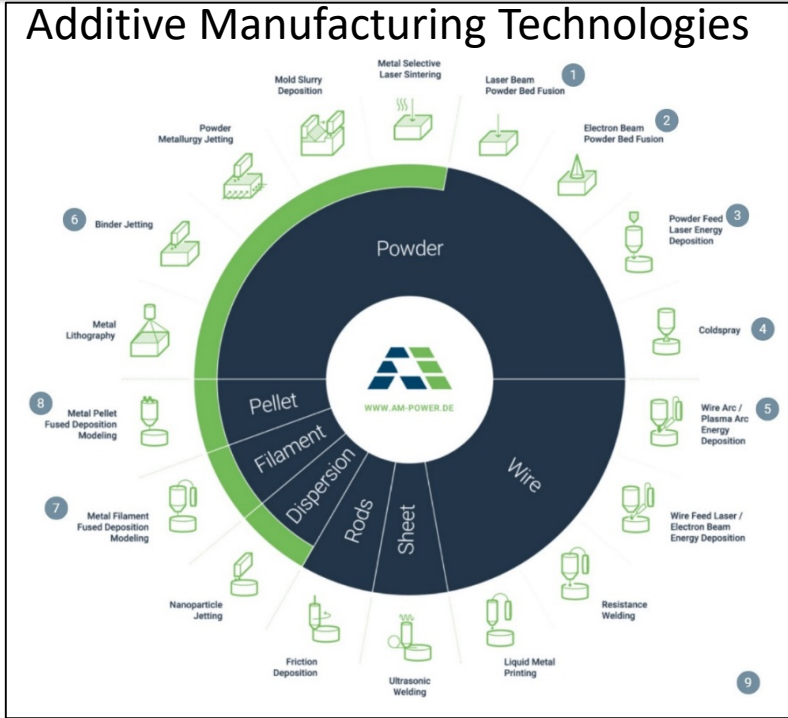
- Innovation is new and ambiguous.
- Innovation is inherently unknown.
- Innovations have long time horizons.
- Measuring innovation requires partners.

New product to accomplish any given mission and save lives

- Game changing technology from researchers and developers.
- Lower the technology threshold to increase the number of players



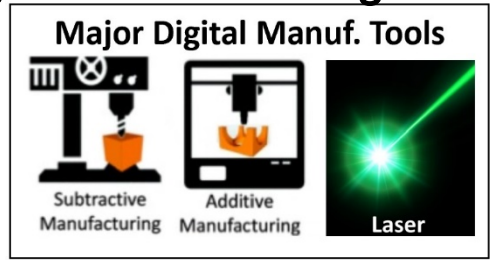




## Digital Manufacturing

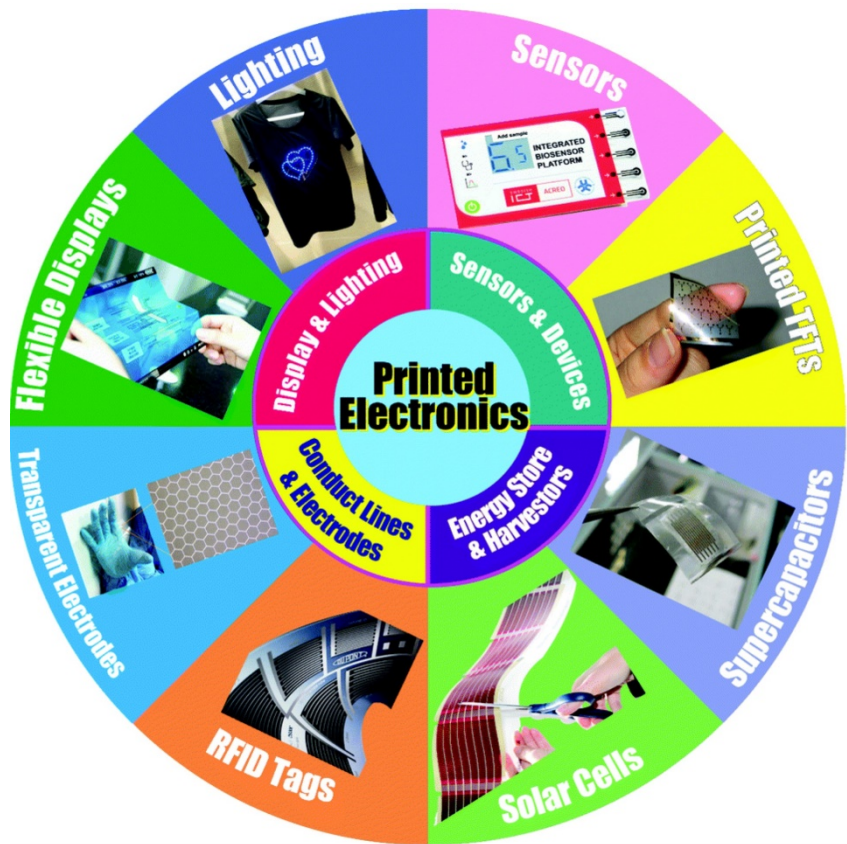
### Three key digital manufacturing technologies:

1. AM
2. CNC
3. Laser



- Many AM technology work envelopes requires:
- High temperature
  - Inert environment
  - Single function





## Equipment

Spinner

UV lithography

Hot plate

Chemical bath 1

Chemical bath 2

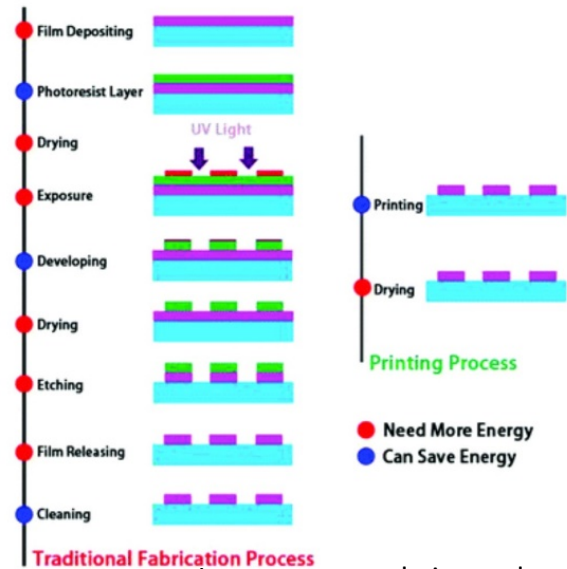


Image: nanoscale journal

## Advantages of AM: Fewer equipment

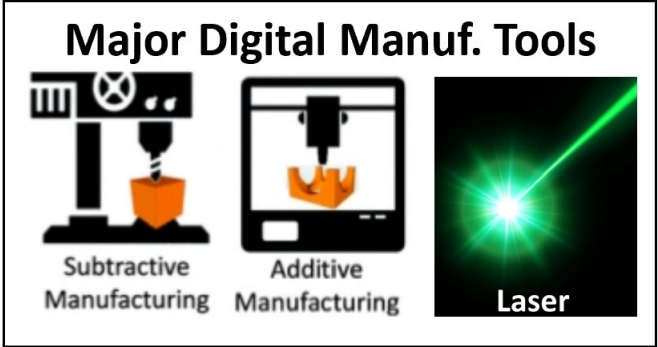
The various application fields of the PE technologies (image: Nanoscale journal)





Product innovation is defined as:

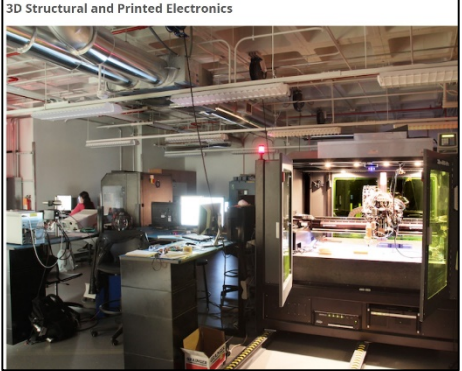
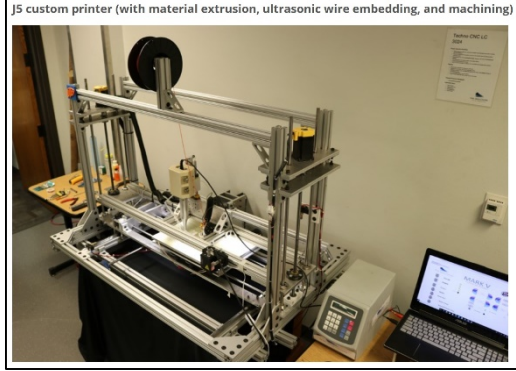
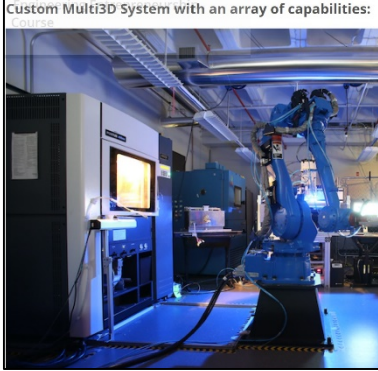
- The development of new products
- Changes in design of established products.
- Use of new materials or components



UTEP/Keck center

America Makes Laboratory

Con: Initial and support cost. Stand-alone tools.



The future of manufacturing is digital...from fragmentation to integration.



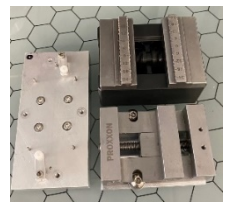


## Intuitive...robust...industry standard...affordable...popular...customize...

**Hardware:** Scalable and interchangeable  
Motion platform: Industry proven  
Print heads: Syringe, Aerosol, Inkjet  
Laser: UV, visible, IR  
Subtractive: Automatic tool changer

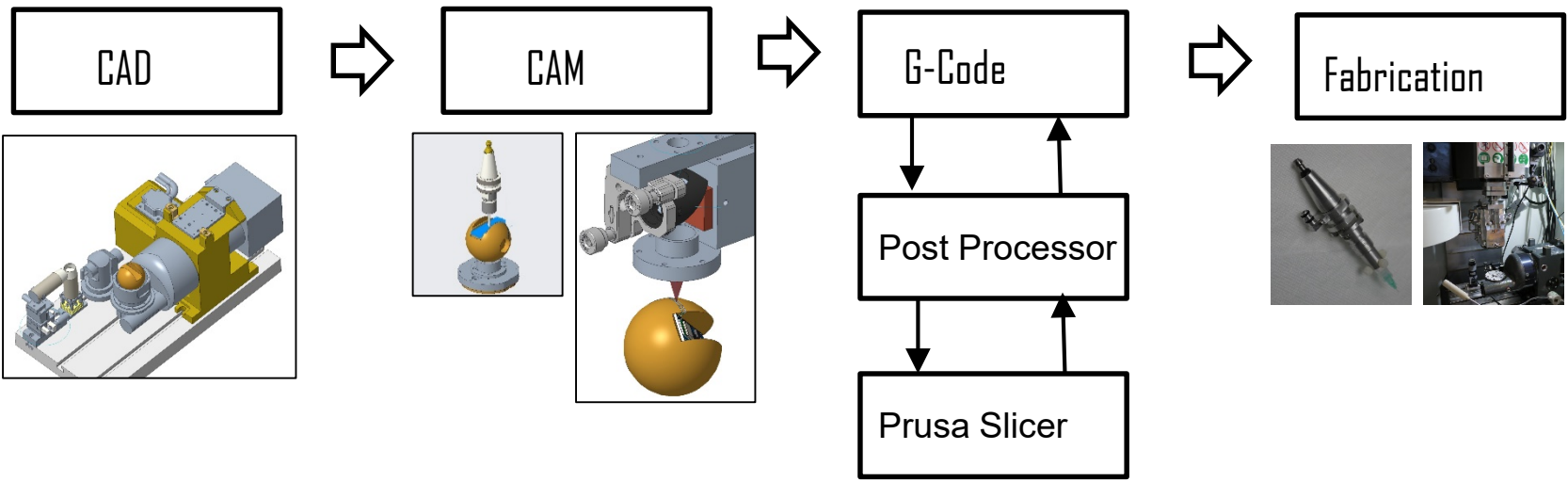
**Software:** Industry standard and intuitive  
CAD: Top tier, supported, intuitive  
CAM: Milling, Printing, Shutter control, G-code

**Accessories:** Affordable  
Vision: Telecentric, wide angle, zoom  
Vise: Machining, vacuum, clips



- Hardware list:**
  - Mill: Haas CM1
  - Lasers: IPG 532nm, BKTel 1070nm
- Software list:**
  - Creo Parametric CAD
  - Creo Manuf. CAM
  - Prusa Slicer
- AM tools:**
  - EFD syringe system
  - Nanojet aerosol
- Accessories:**
  - EO telecentric camera
  - Plugable zoom camera
  - GoPro camera
  - All-in-one computer
  - Vacuum pumps
  - Probes
  - Stages

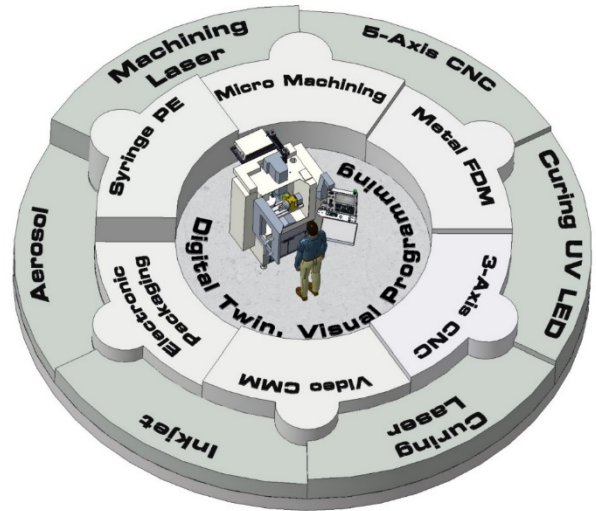
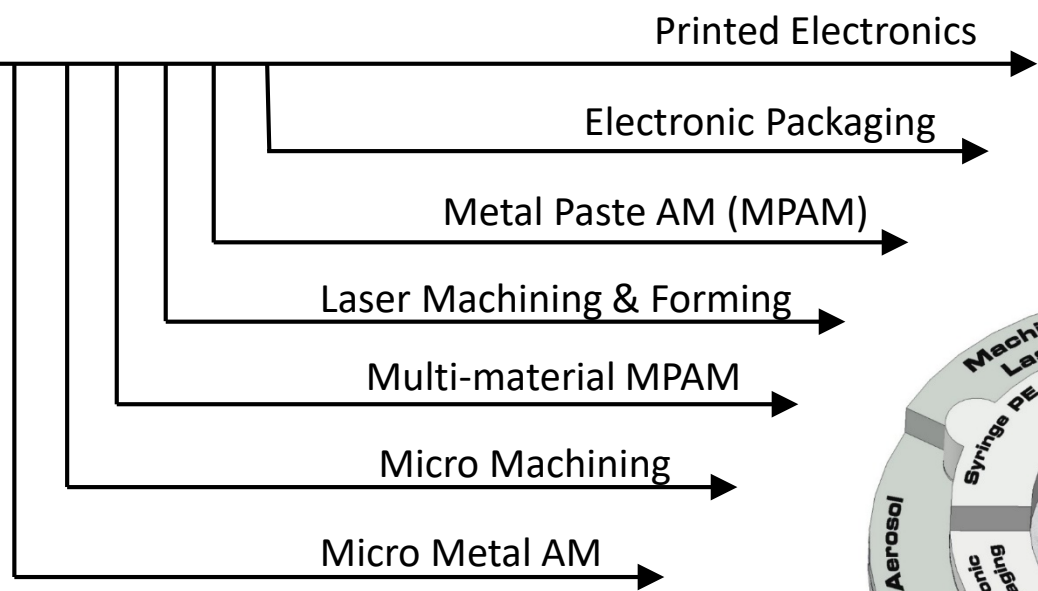
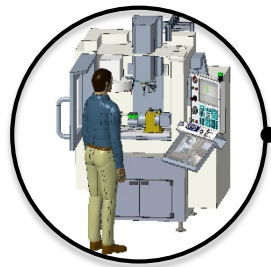


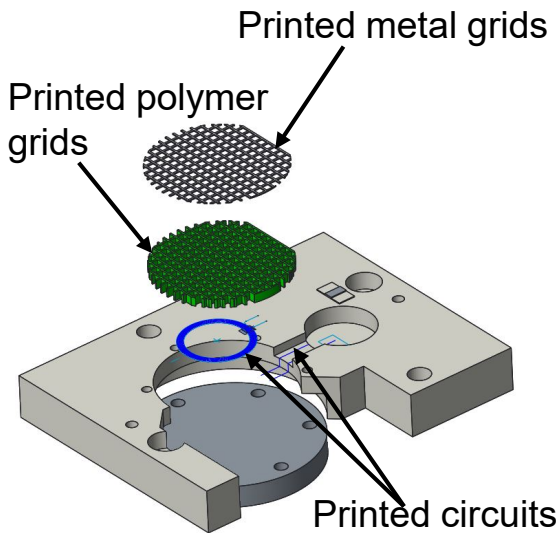


Visual base programming

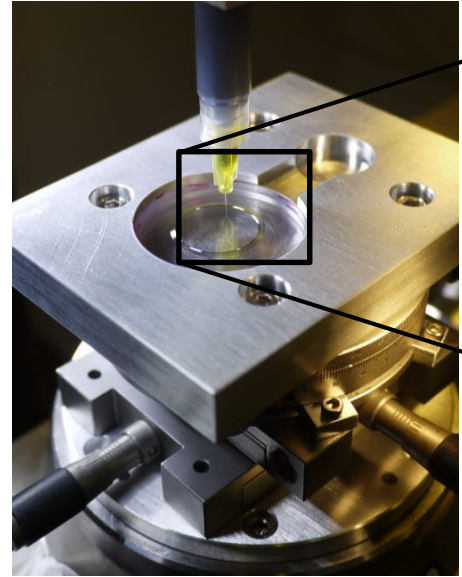
Virtual Reality training...in the future



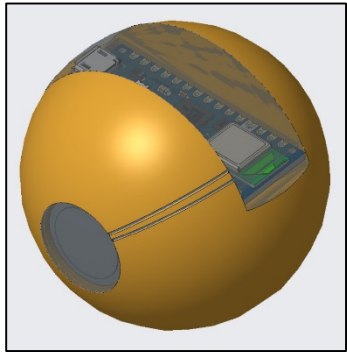
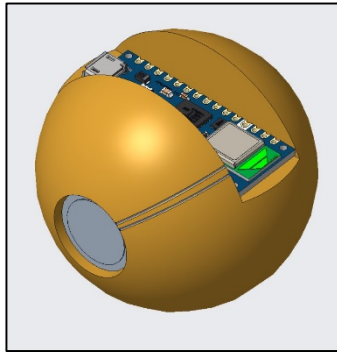




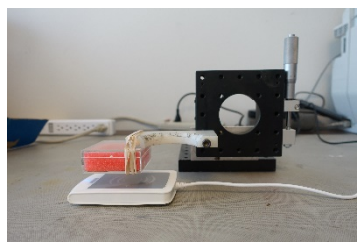
Lite digital twin.



Printing RFID coil

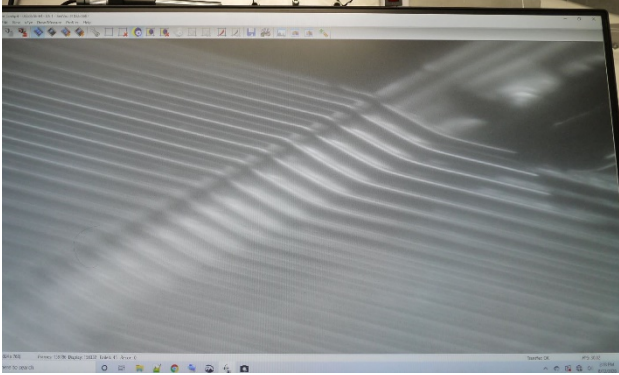
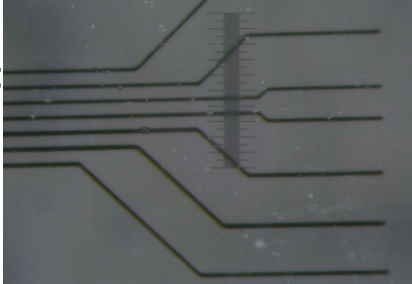
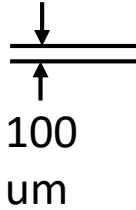
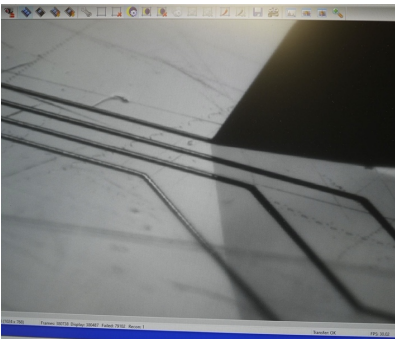
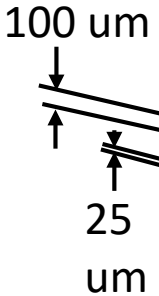


Embedding Arduino Nano inside the billiard ball.

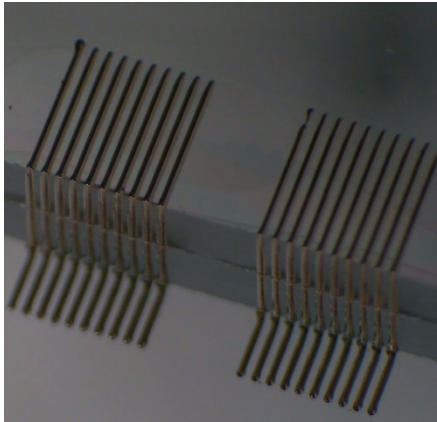


Printed RFID test





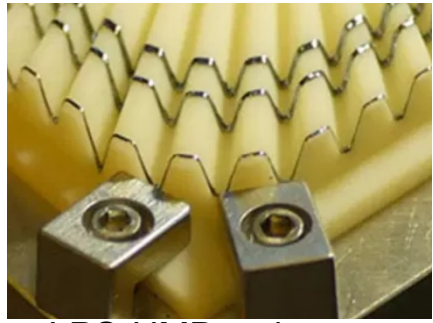
- 100 um pitch
- 30-degree ramp



200 um pitch printed DOWA ink conductive traces. 2mm vertical wall



Practice circuits on 1" dia. Delrin ball.

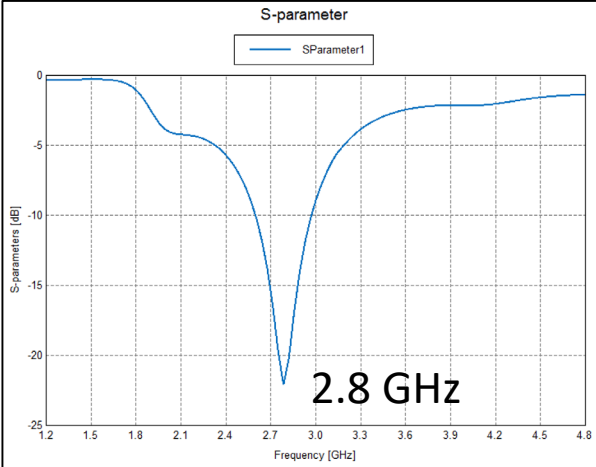
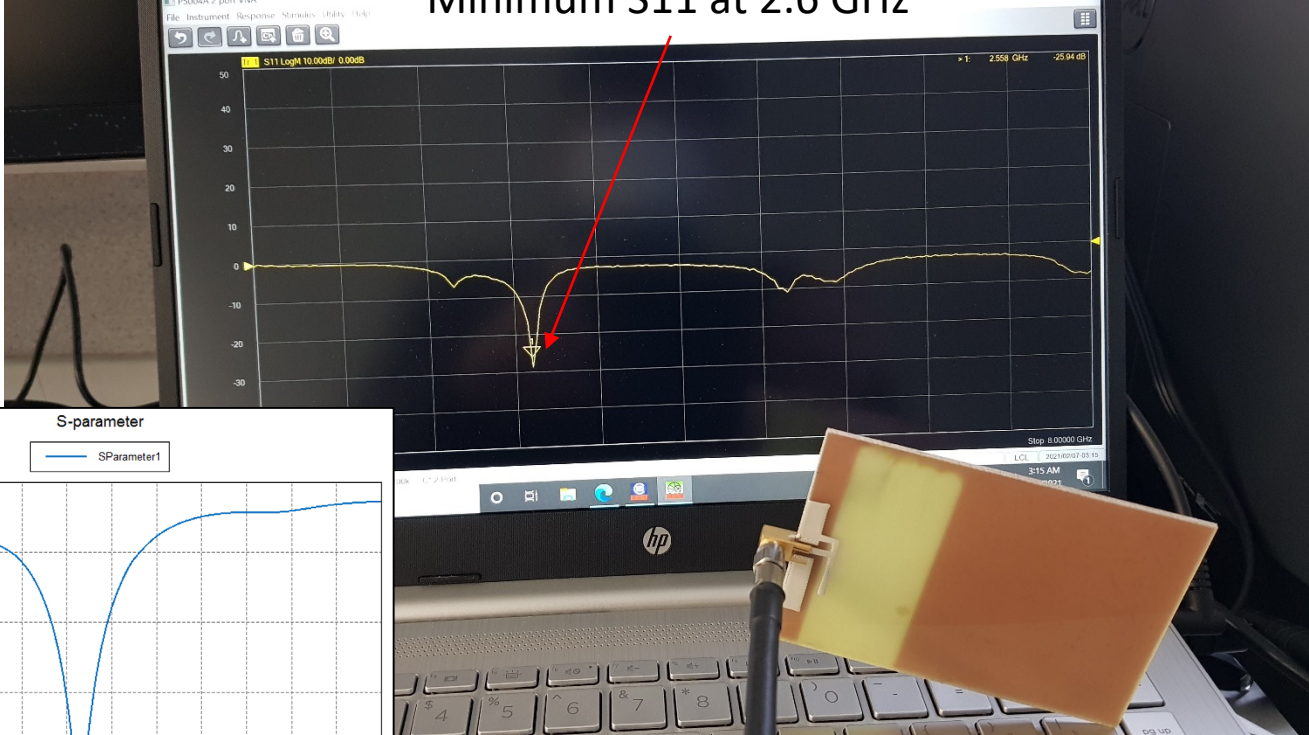


LPS-UMD webpage



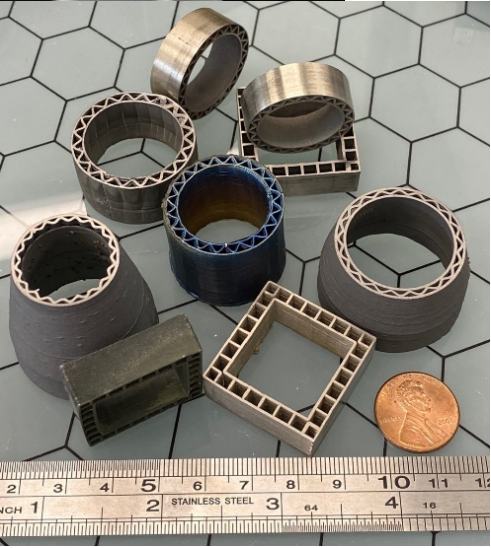
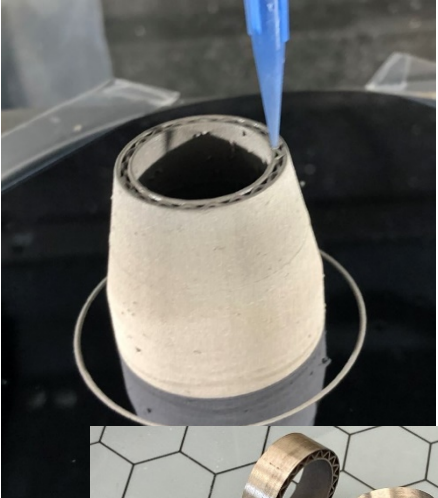


### Minimum S11 at 2.6 GHz



Printed antenna testing result

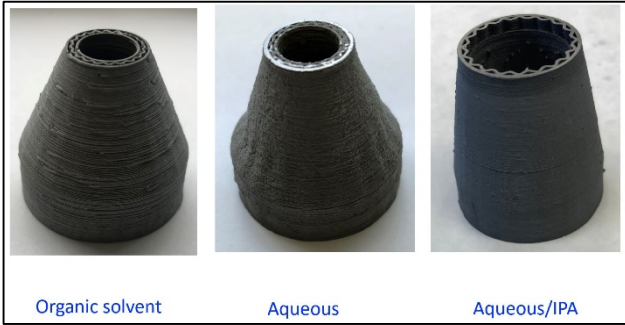




Info: from 2019	Rapidia	Desktop Metal Studio System+	Markforged Metal X	3DFlexible
Technology	Metal paste	Binder Jetting	Fused Filament Fab.	Metal paste
Debind Bath *	None	✓	✓	None
Sintering shrinkage *			20%	<5%
Inconel 625	✓	o	o	✓
17-4 Stainless Steel	✓	✓	✓	?
316 L Stainless Steel	o	✓	o	?
A2 Tool Steel	x	x	✓	?
Maraging Steel	o	x	x	✓
Titanium	o	x	o	✓
Cobalt Chrome	x	x	x	?
Ceramics	o	x	x	?
✓ Available    o In Development    x No information    ? Plan to develop selected material in Phase II				

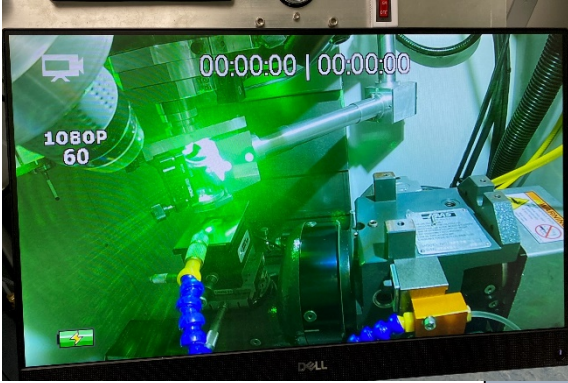
Freedom to explore

- Paste (no loose powder)
- Room temperature printing
- Breathing air atmosphere
- Many nozzle size
- No laser
- No cleanup
- No safety issue

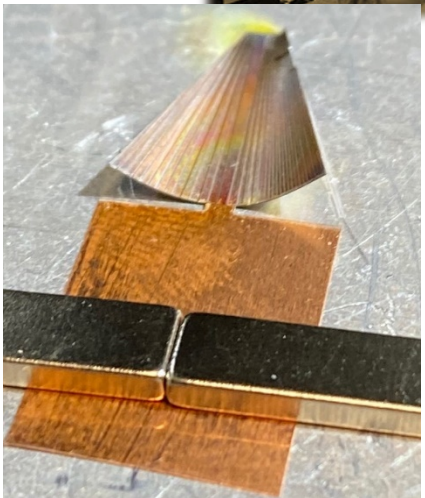
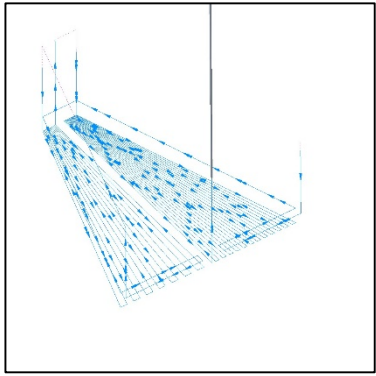
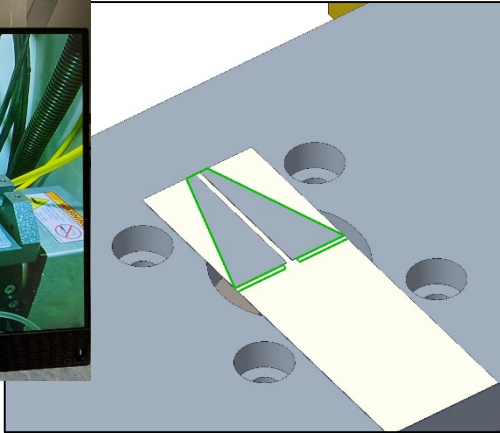


\* Initial result.  
<https://markforged.com/resources/learn/design-for-additive-manufacturing-metals/metal-additive-manufacturing-introduction/metal-additive-manufacturing-process>





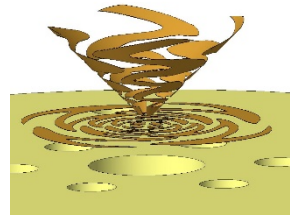
532nm pulsed laser



Conical four-arm sinuous antenna

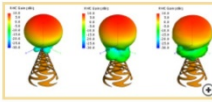


Image of the Conical four-arm sinuous antenna.



The *Four-arm sinuous* is a two-port dual-linearly polarised, multi-octave bandwidth antenna which is also physically compact. It is well suited to applications that require instantaneous polarisation diversity. The sinuous antenna provides good broadband characteristics but has the added advantage that it is capable of simultaneously receiving signals of different polarizations in the same aperture with good isolation between the ports.

The *Conical sinuous* provides unidirectional radiation (as shown below) without the need for a bandwidth limiting cavity backing. The structure is generated by projecting the outline of a planar sinuous onto a cone.



Typical RHC gain radiation pattern -  $f_{min}$ ,  $f_0$  and  $f_{max}$ .

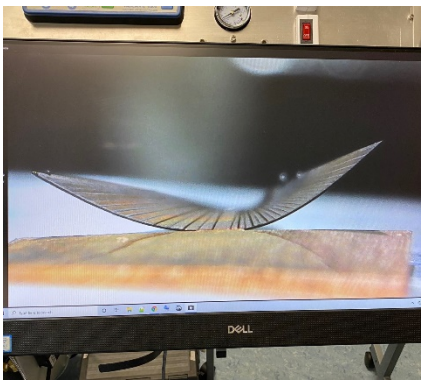
On-going ARMY SBIR project.

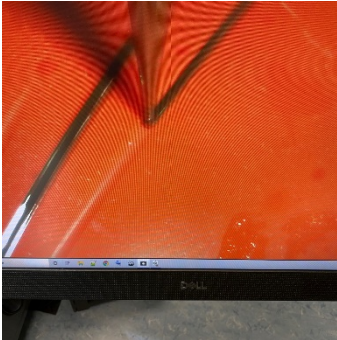
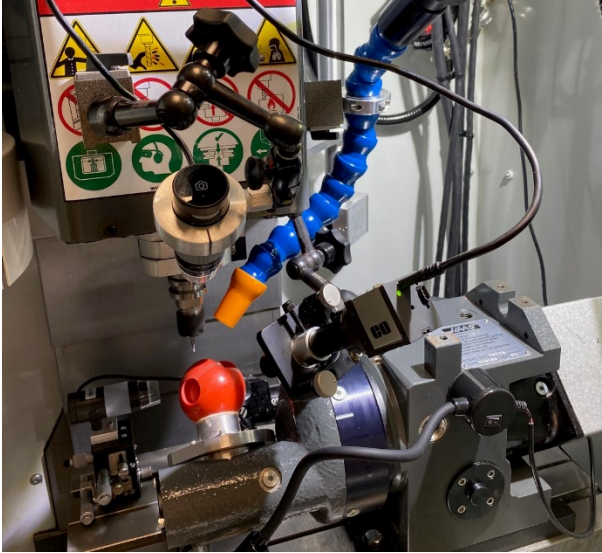
Problem:

- Laser energy absorption rate.
- 1064nm CW couldn't touch copper.
- Need customization.
- Laser safety.

Solution:

- Select a proper wavelength laser.
- Class 1 laser: Enclosed, safety interlocks.





Milled surface ready for printing without a cleaning step .



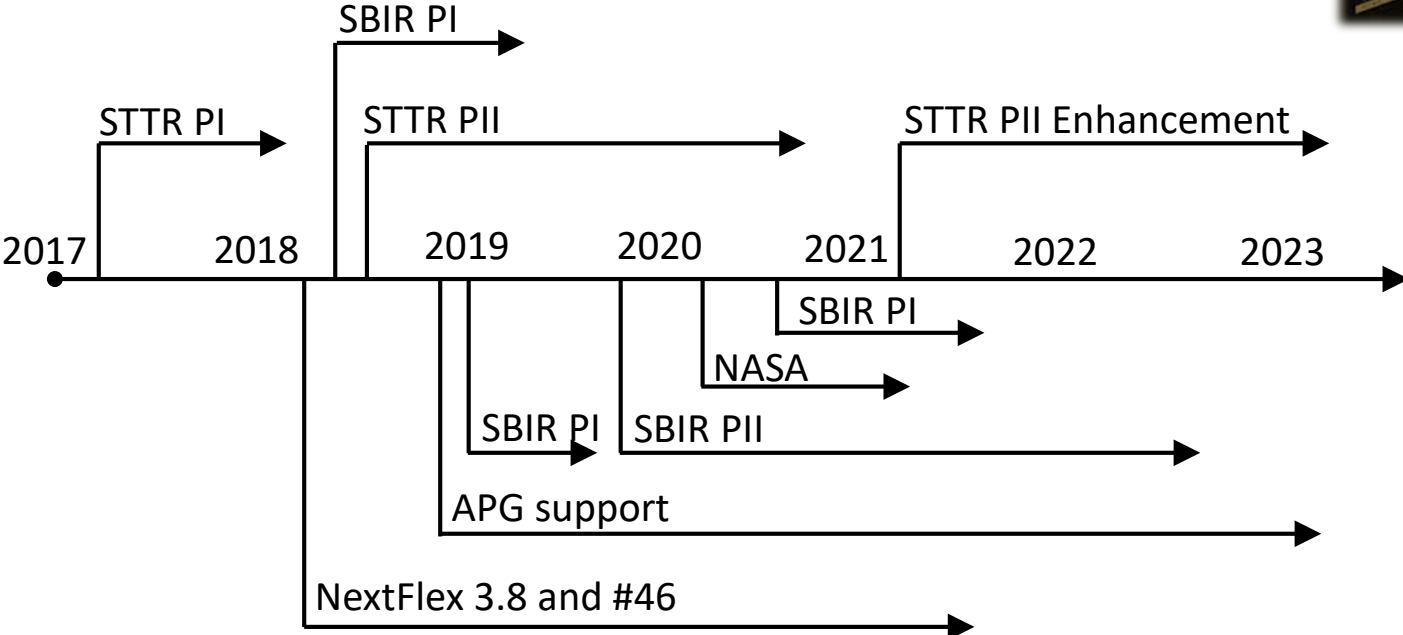
**Problem:**

- Contaminated work envelope.
- Rigid debris containment structure.

**Solution:**

- Add vacuum nozzle near the mill bit.
- Surround the base with vacuum.
- Use commercial parts.





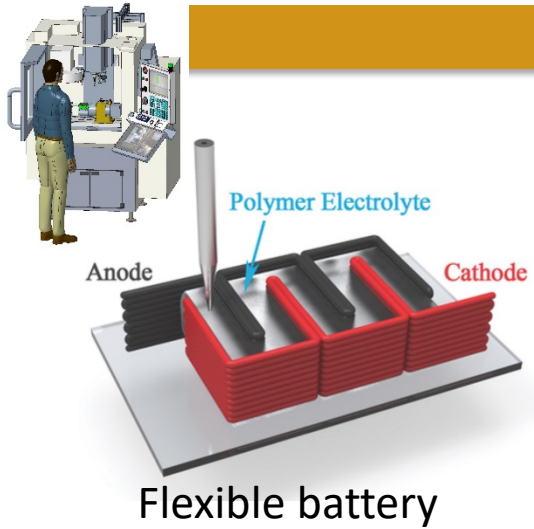
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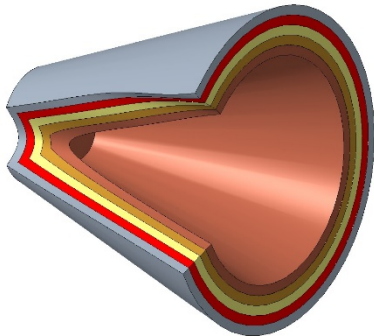
### Future work:

- Merging of AM and Printed Electronics.
- Standardizations.





Possible innovative products



Multi-material shaped charge liner

Example 1: slotted nozzle with free formed external geometry, variable cross-section and squared lattice structure with 100 µm wall thickness; material 1.4404 (316L)

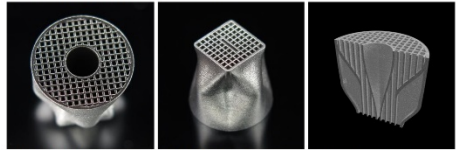


Figure 1: bottom view Figure 2: inclined top view Figure 3: section view (CAD)

Example 2: hexagonal grid structure with 100 µm wall thickness; material 1.4404 (316L)

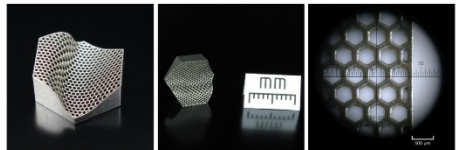
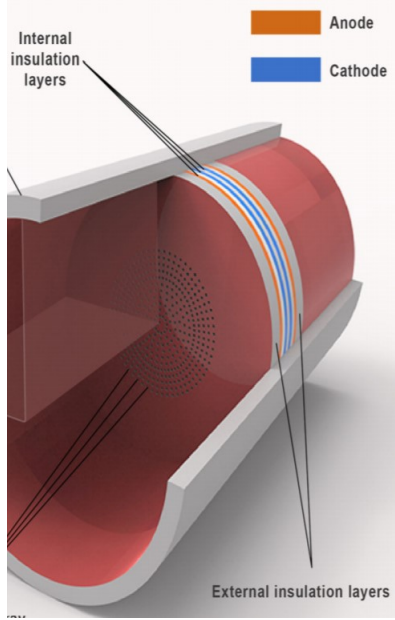
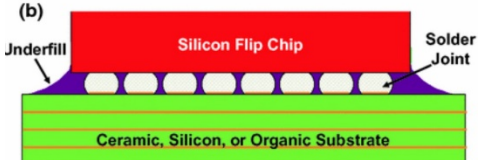
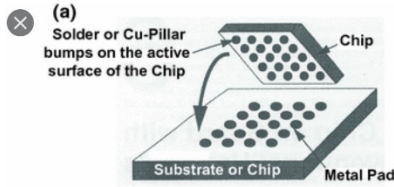


Figure 4: inclined top view Figure 5: comparison 10mm scale Figure 6: microscope view

Micro parts (image: 3Dmicroprint)



Transducer

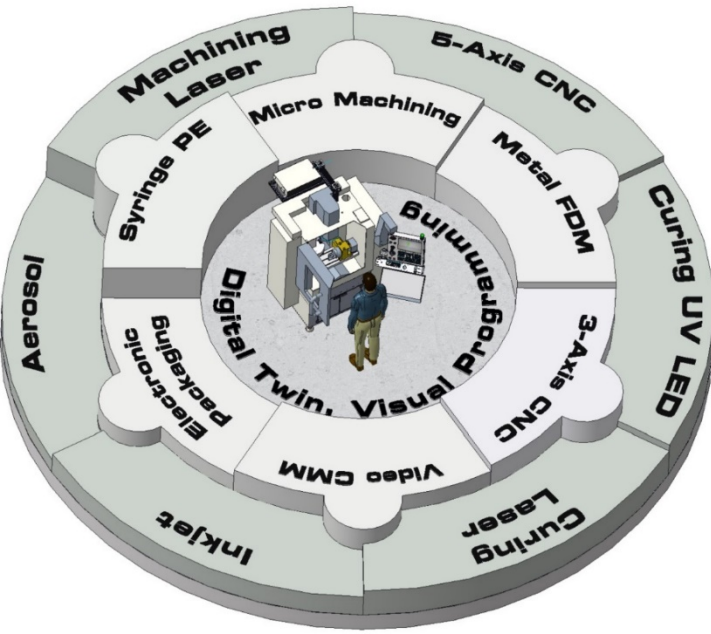
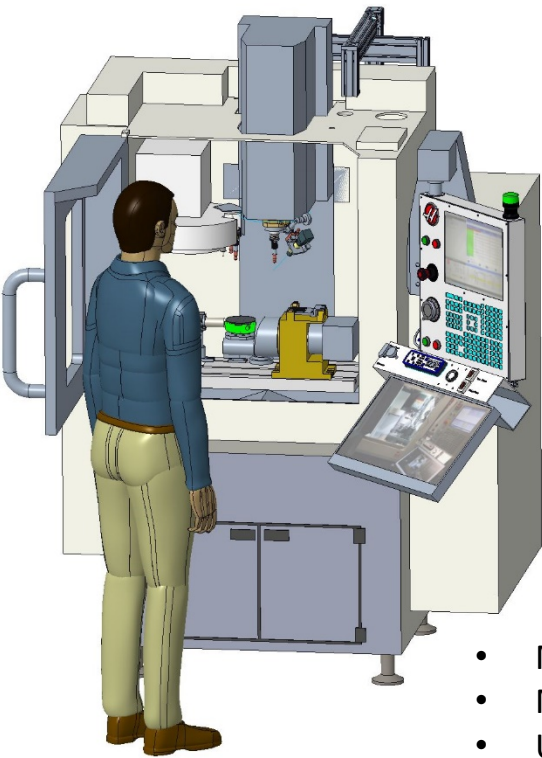


Micro metal bumps or lens array





### 3DFlexible Digital Manufacturing Ecosystem



- Manufacturing flexibility
- Multiple manufacturing technology
- Unified operating system
- Endless type of tools and support accessories
- Affordable manufacturing ecosystem

