

Direct Digital Manufacturing for Next Generation Electrically Functional RF Structures



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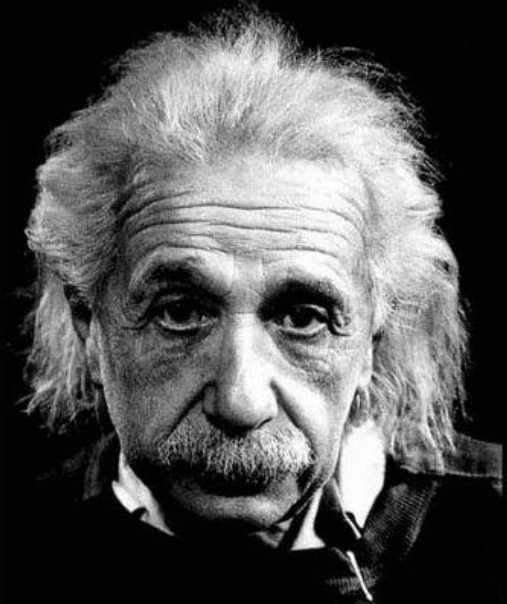
Define Direct Digital Manufacturing

Printing Examples

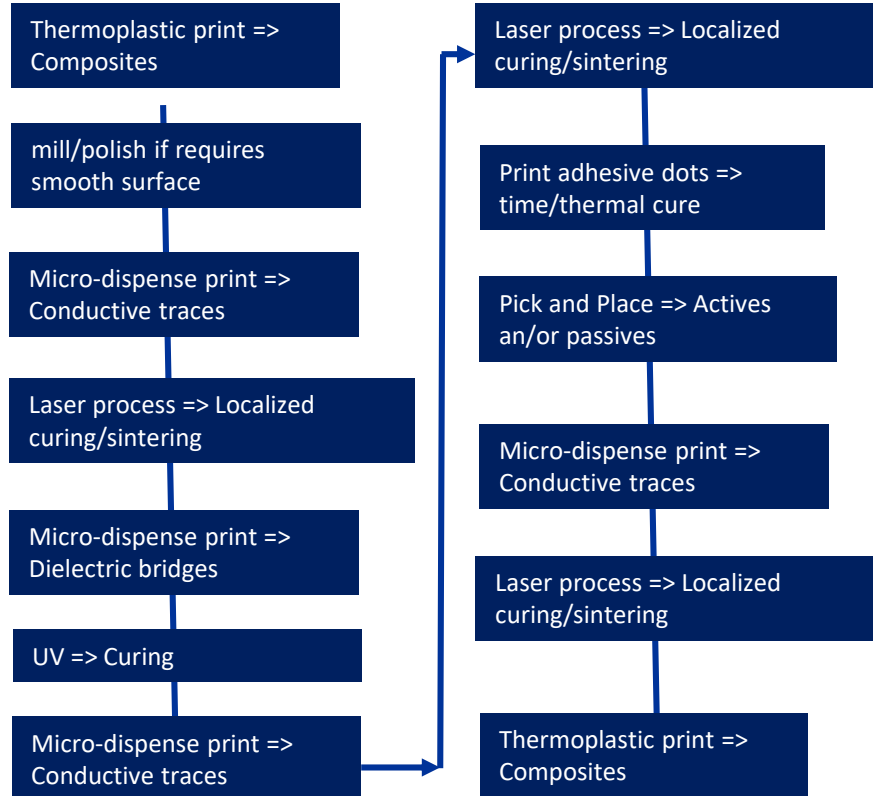
Requirements for DDM to Succeed

“Everything should be made
as simple as possible,
but not simpler.”

Albert Einstein



Direct Digital Manufacturing => No Retooling Required

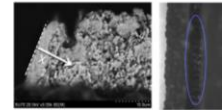


This can be done today using a multi-head system. This is still a 2.5D approach.

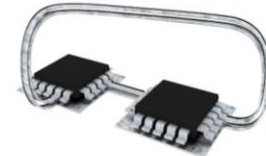
Next generation is 2.5D Conformal

Next next generation is true 3D.

Electrical Interconnects

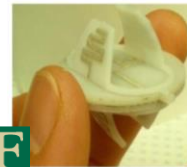


High-Frequency Transmission Lines

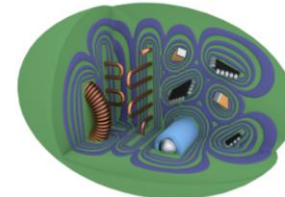


Thomas Weller, USF

Milling



Raymond Rumpf, UTEP
Electromagnetic Devices



USF



Direct Digital Manufacturing=> No Retooling Required



**Direct Digital
Manufacturing (DDM)**



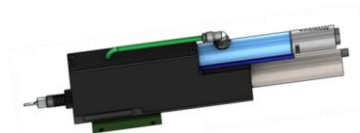
Precision micro-dispensing



Thermoplastic extrusion



Precision micro-machining



Pick and place

Many Processes

Direct Digital Manufacturing=> No Retooling



**Direct Digital
Manufacturing (DDM)**



In situ thermal heating



In situ photonic



In situ UV curing

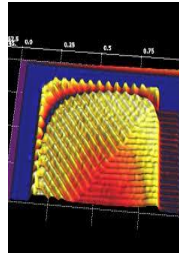
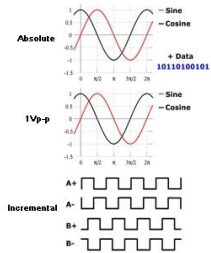


In situ lasers

Many Processes

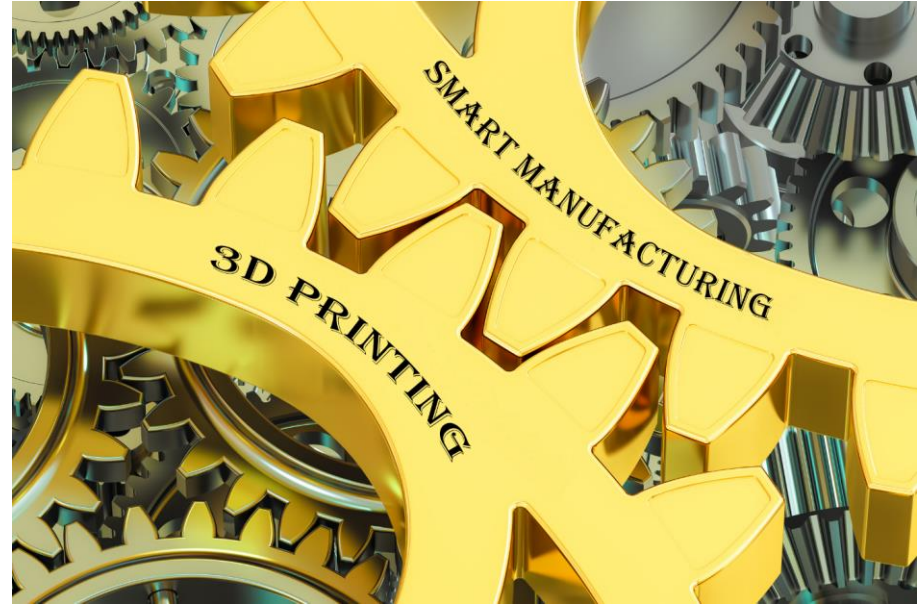
Connecting DDM to Smart Manufacturing

- Sensor feedback during prints
- Sensor feedback during processing
- Real time in situ adjustments



Feedback

**Is it smart to put DDM in
Smart Manufacturing?**

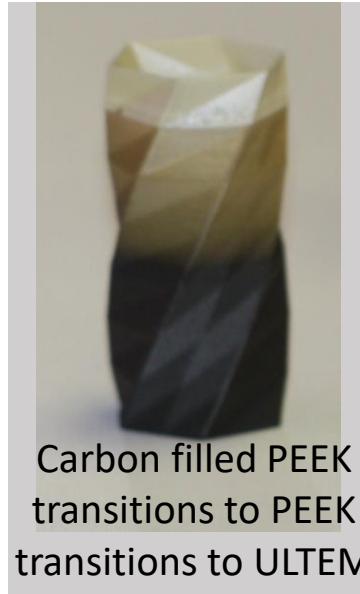


**Is it smart to put Smart
Manufacturing in DDM?**

Performance => Materials and Process

We must expand, we must do better

- Material options
 - Wide range of thermoplastic
 - Wide range of thermosets
 - Composites
 - Metals
 - Gradients
- Process options
 - Nozzles
 - Material delivery
 - Temperature range
 - Other processes
 - Feedback



CAD File of Helmet
Shrink in CAD
12.5 micron nozzle



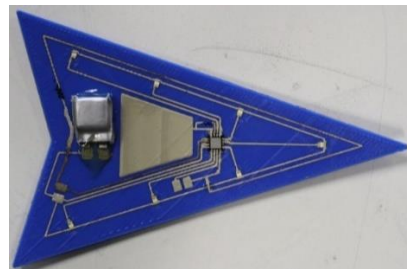
Printed Circuit Structures (PCS)



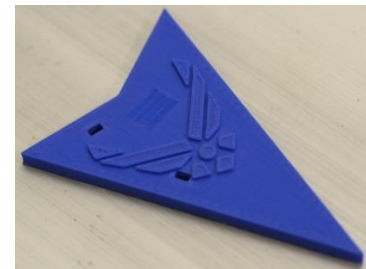
Timing circuit heart



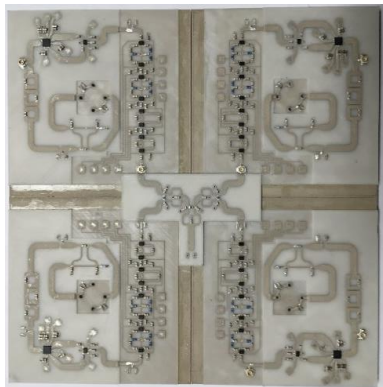
Embedded circuit heart



Micro-controller



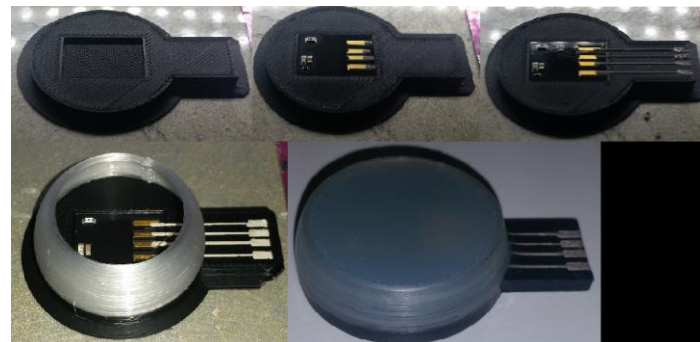
Embedded micro-controller



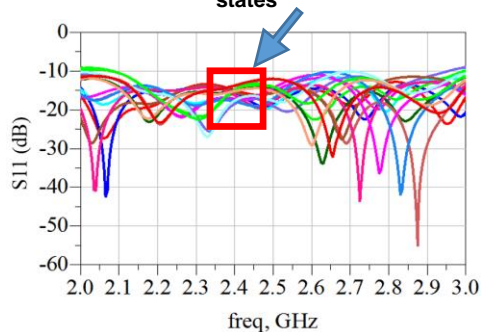
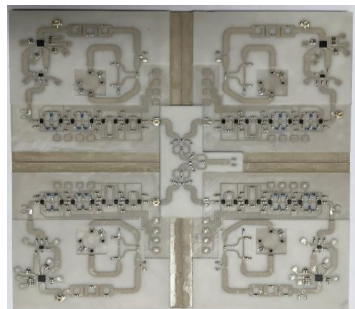
4 Element Phased Array
Antenna



Simon Says with embedded micro-
controller

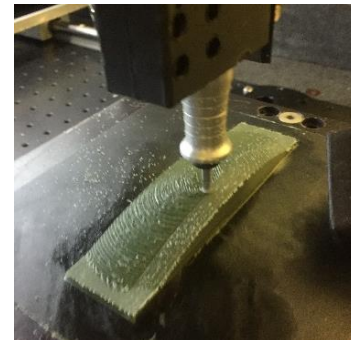


Progression of Embedded USB Device

[illegible]

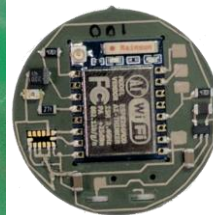
2.4 GHz Phased Array Antenna. Multiple elements printed and tested. 7 RF functional layers in each element, no solder.

PAAs we print next...

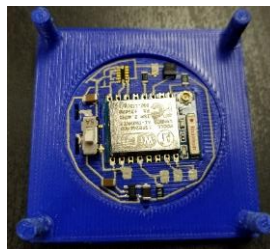
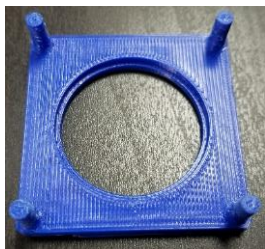


8 to 12 GHz Conformal Phased Array Antenna. 64 elements. Improving RF designs.

Wearable vs 40 mm comparison



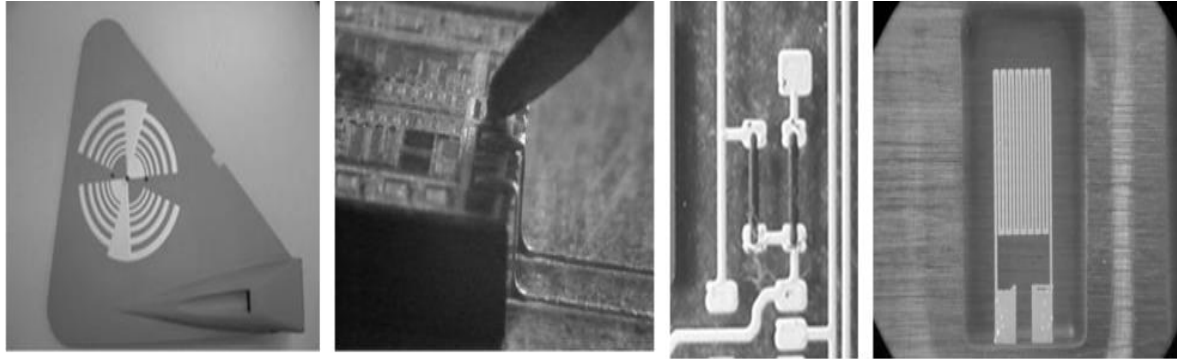
- Printed dummy 40 mm round with accelerometer
- Shot it out of an air cannon several times
- Worked for several shots....until it didn't....battery came lose



- Printed wrist wearable with accelerometer
- Wore it for no good reason

Where to next?

Print reliably, repeatably, easily and speedily:



- Antennas on any curved surface
- To bare die
- Passives
- Sensors
- Any structure
- Multi-material and including disparate materials...metals/plastics

Make a wireless, printable platform, add any sensors, make any shape, make any function.

Qualifying printed parts



Timing circuit heart



Embedded circuit heart



Solar Cell



Printed Circuit Board

Advantages

- Rapid product change
- Conformal
- Flexible
- 3D structural
- Waterproof
- Rugged
- More available
- Green technology

Needs

- In situ monitoring
 - Imaging
 - Resistance
- Qualified material set
- Qualified process set
- Built in test points for post testing

Can we qualify during print???

Mass Customization

A Factory in a Tool

Direct
Digital
Manufacturing
3D Fabricating

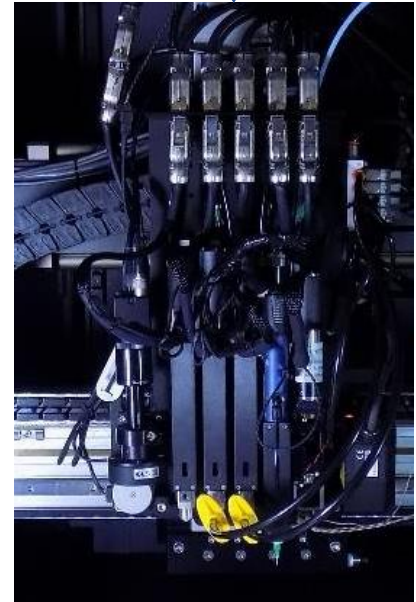
- Printing
- Micro-dispensing
- Micro-spraying
- Micro-milling
- Digital Polishing
- Pick and place
- Post processing
- In situ monitoring

The motion platform

- industry standard nanometer resolution
- precision required for quality parts
- includes biological parts.

One motion platform with multiple nozzles for multiple materials producing complex products.

Personalized will come from next generation materials, processes and factories.



Mass Customization



A Factory in a Line

The industrial tools are made to be put in a line....

10 nozzles per machines...

5 machines....

50 times reduction in time.

If a large, complex product took 10 hours to print....this would reduce that to 12 minutes.



A Factory in a Box

Smarter Manufacturing

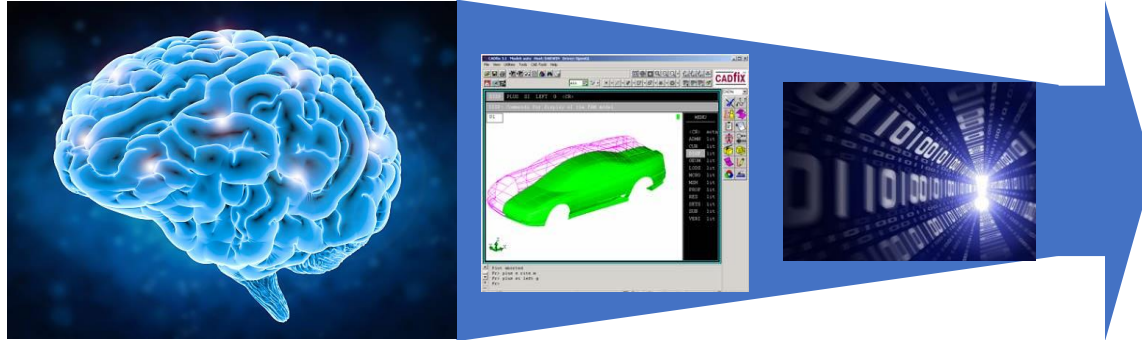


It's not just about connecting from one machine to another, it's about making adjustments on the fly when corrections need to be made.

Smarterer Manufacturing

Is smarterer a word? Is DDM a thing?

The Internet of Things, connects things together.



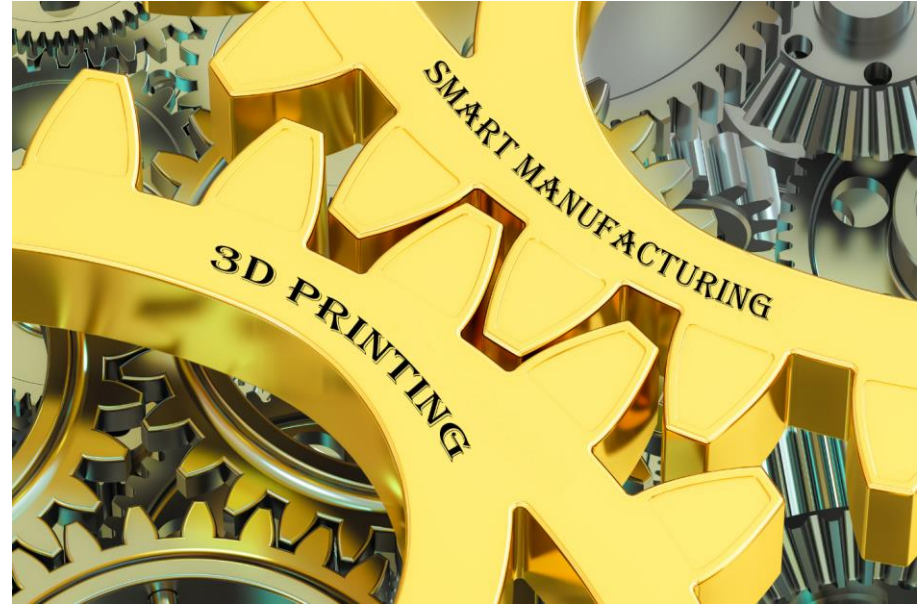
DDM will connect your brain to things.



Conclusion

- Digital Manufacturing is not new
- Feedback in Manufacturing is not new
- Direct Digital Manufacturing => coming
- DDM without Feedback is not Smart

Is it smart to put DDM in
Smart Manufacturing?



Is it smart to put Smart
Manufacturing in DDM?

Who is working on DDM?



U.S. AIR FORCE



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