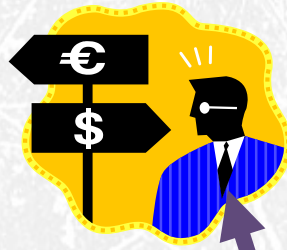


Societal Implications of Additive Manufacturing

**Thomas A. Campbell, Ph.D.
Research Associate Professor
ICTAS Associate Director for Outreach**

Economic



Environmental

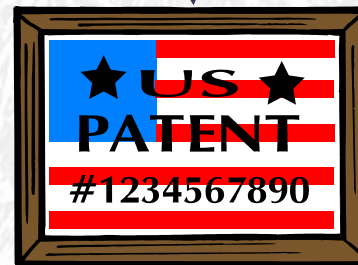


Geo-political

**Societal
Implications of Additive
Manufacturing?**



Ethics



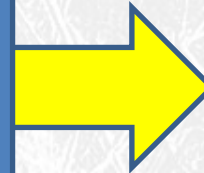
Intellectual Property (IP)



Economic Implications

TIME TO MARKET (critical due to launch costs and contractual obligations)

TIME TO VOLUME (time it takes to get a product to achieve full scale volume manufacturing; vital as it allows OEMs to fully achieve their Time-to-Market targets)



Additive Manufacturing can reduce both

Just-in-Time

Additive Manufacturing

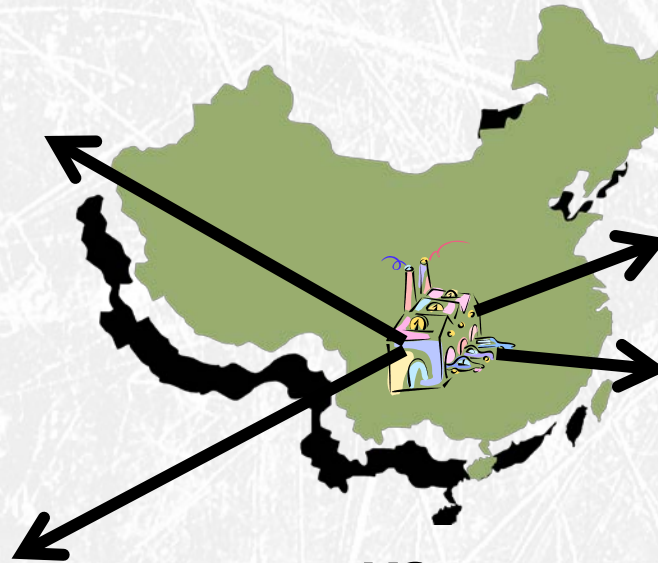


Just-in-Production



Economic Implications

**Overseas
Traditional
Manufacturing
and Global
Distribution**



VS.

**Local Additive
Manufacturing
and Local
Distribution**



Potential Advantages:

- Production closer to the consumer
- Printing on demand without build-up of inventories
- Shipping of designs instead of products
- New industry of designs for printing
- New industry for the production of AM systems and cartridges



Economic Implications

shapeways*

MakerBot Thingiverse



UPS Solutions

STAPLES

that was easy:

Will 3d printing stores become common?



Environmental Implications

Is AM *more* or *less* green than traditional manufacturing?

- + Reduces material waste and scrap
- + Limits the amount of energy used
- + More efficient use of raw materials
- + Minimal harmful (e.g., etching) chemicals needed
- + Environmentally friendly product designs possible
- + Changes to design streamlined
- + Carbon footprint of a given product reduced (via reduced waste and need for global shipping)
- But can it use recyclable materials?
- What about environment, health and safety (EHS) issues, e.g., with nanomaterials...



Geo-political Implications

U.S. does not have a lock on 3d printing



**Germany leads in metals
3d printing systems**



**China recently announced a \$242 million
investment in 3d printing over just a three
year span**

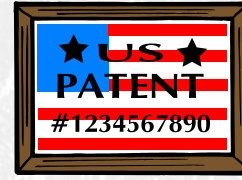
**Singapore is investing \$403 million in
advanced manufacturing, of which a part is to
create a “new 3d printing ecosystem”**



Developing World—Promises of Additive Manufacturing



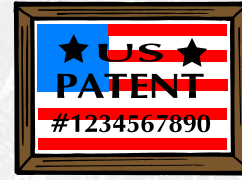
- Potential exists for:
- Disaster relief
 - 3D Printing in rural communities
 - Enablement of a 'leapfrog' in manufacturing



IP Implications

“Additive Manufacturing presents a new paradigm in speed and ease of exchange of technical information...Perhaps the time has come for the Patent Office to consider a new direction in terms of the categories of patents it issues to address the disruptive nature of AM—specifically, the *utility model*, which is now offered in many foreign countries. “

Thomas A. Campbell, William J. Cass (2013), “Additive Manufacturing (3D Printing) - New paradigms in intellectual property and anti-counterfeiting may be required,” *Scientific American*, in press.

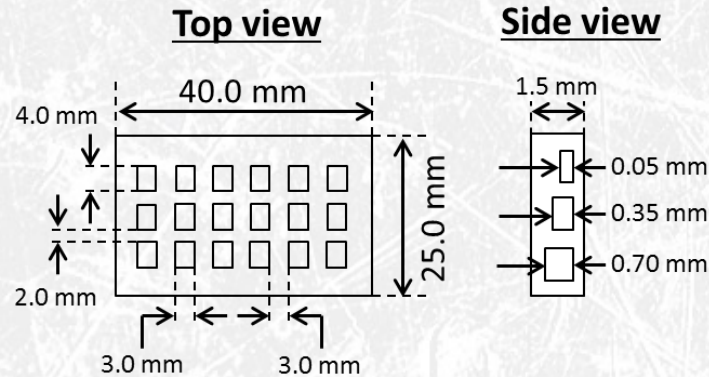


“The International Chamber of Commerce estimates that counterfeiting accounts for 5 to 7% of world trade, worth an estimated \$600 billion a year. Additive Manufacturing may facilitate even easier means for copying products; thus, anti-counterfeiting approaches for AM must be considered. “

Thomas A. Campbell, William J. Cass (2013), “Additive Manufacturing (3D Printing) - New paradigms in intellectual property and anti-counterfeiting may be required,” *Scientific American*, in press.

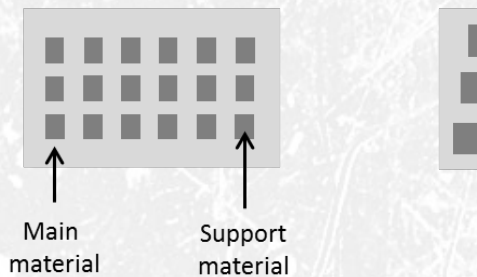
Anti-counterfeiting for Additive Manufacturing using Nanomaterials

1) PART DESIGN

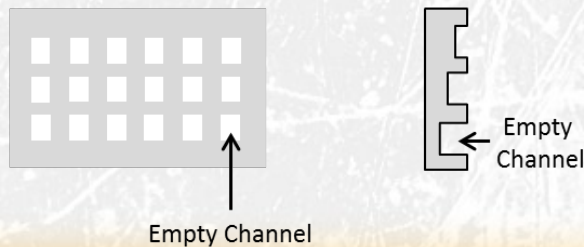


2) PRINTING AND EMBEDDING PROCESS

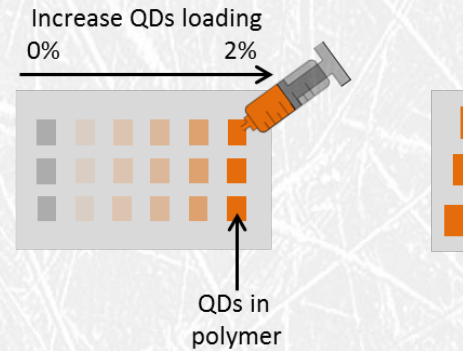
a) Printing x number of layers



b) Removing support material



c) Fill the channels with CdSe Quantum Dots dispersed in main material



d) Manually cure added CdSe/main material filling with UV light



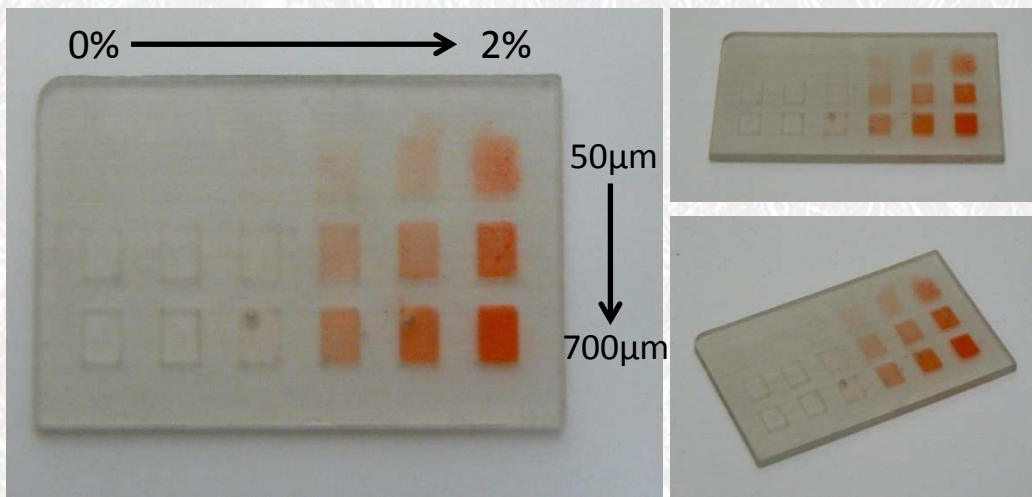
e) Resume Print to add y layers of main material on top



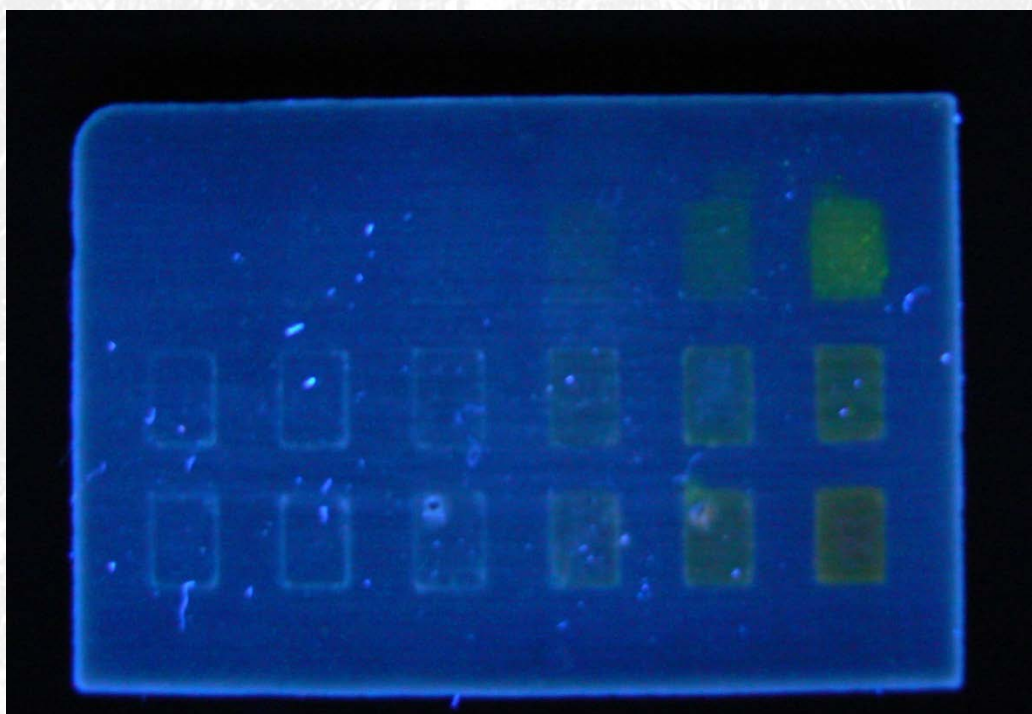
Collaboration with Dr. Christopher Williams, DREAMS Lab,

<http://www.dreams.me.vt.edu>, Virginia Tech

Visible light

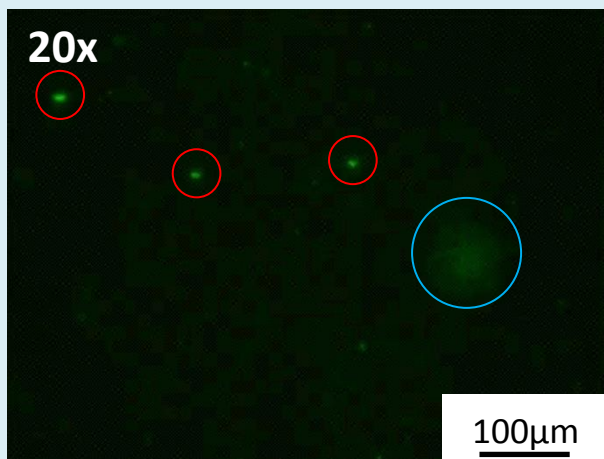
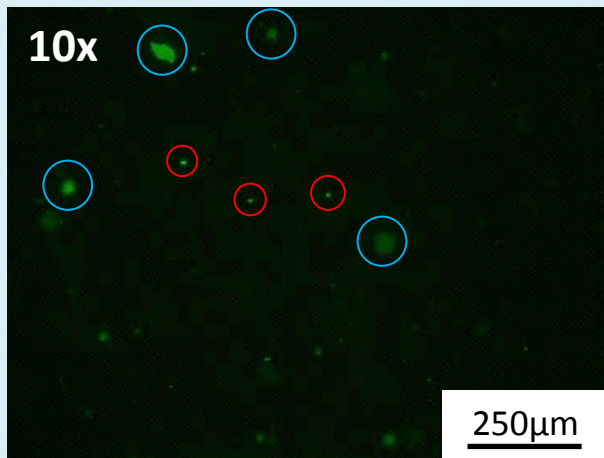
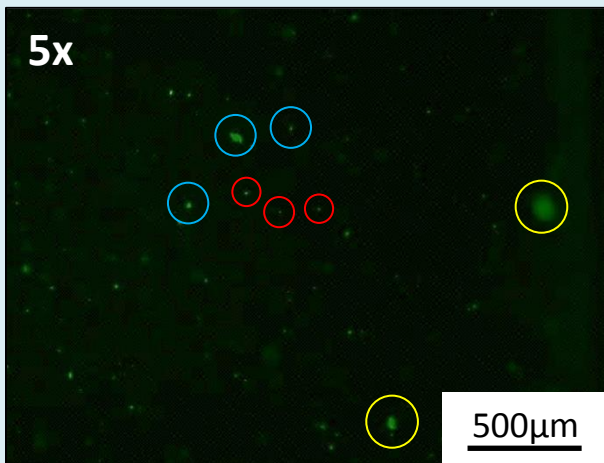


UV-light



3D printed part with embedded CdSe quantum dots under visible light and 365nm ultraviolet (UV) light

Thomas Campbell, Christopher Williams, Olga Ivanova, Amelia Elliott, "Fabrication of Physically Unclonable Functions via Additive Manufacturing," US Patent Application # 61/704,197, filed August 7, 2013.



Fluorescence microscopy images of 700 μm channel filled with 0.005wt.% quantum dot nanosuspension under various magnifications—note no quantum dots are visible to the naked eye under visible light

Potential exists to embed nanomaterials into 3d printed objects, map them, and later detect them for anti-counterfeiting validation



Ethics Implications

Already here or on the horizon is 3D Printing with:

- **Prosthetics**
- **Organ bio-printing**
- **Stem cells**



- **Who benefits?**
- **Will such capabilities become standard medical practice?**
- **How will medical insurance be affected?**



Are we considering moral and ethical implications of these new medical capabilities?

Potential Implications for Military Ethics

- **Small arms** – “completely uncontrolled and unlimited ability to produce small arms on demand”
- **Major military hardware** – “...as the ability of purchasers to create their own replacement parts dramatically increases, the ability to regulate violent action by regulating the supply of replacement parts commensurately decreases.”
- **New concepts in war-making equipment** – “Additive manufacturing could render altogether obsolete the big, bulky machines of the kind that have typified military equipment.”
- **Catastrophic weapons** – “Emerging advances in nanotechnology coupled with emerging additive manufacturing technologies may make possible the production of chemical or biological warfare agents using micro-reactors.”

John Mark Mattox (2013) Additive Manufacturing and its Implications for Military Ethics, Journal of Military Ethics, 12:3, 225-234. DOI: 10.1080/15027570.2013.847534

Coming Convergencies

- **Cyber-infrastructure**
- **Internet of Everything**
- **Programmable Matter**



**Implications in
Additive
Manufacturing?**

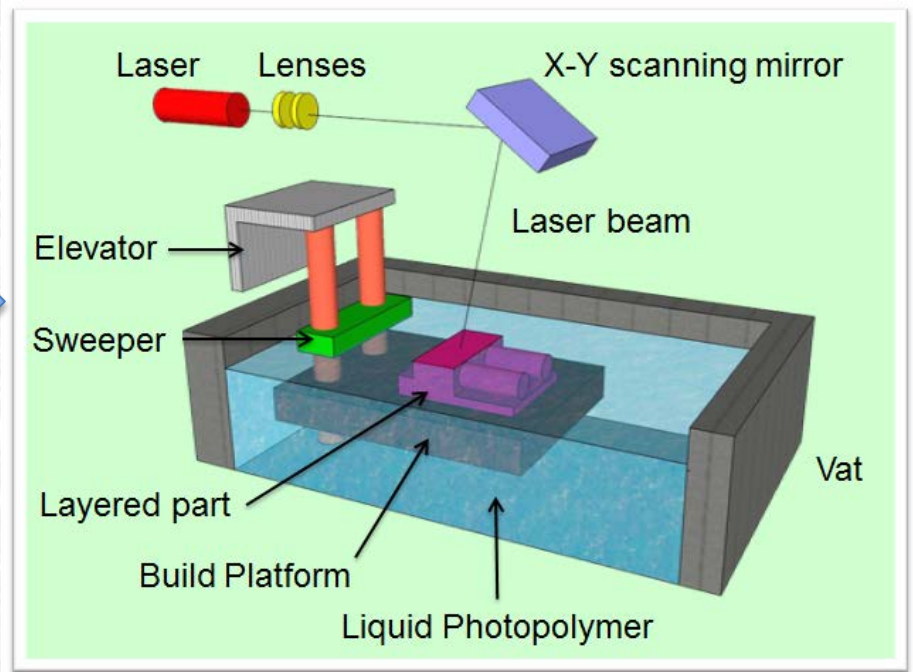


**“The future ain’t what it used to be.”
- Yogi Berra**

Cyber-infrastructure



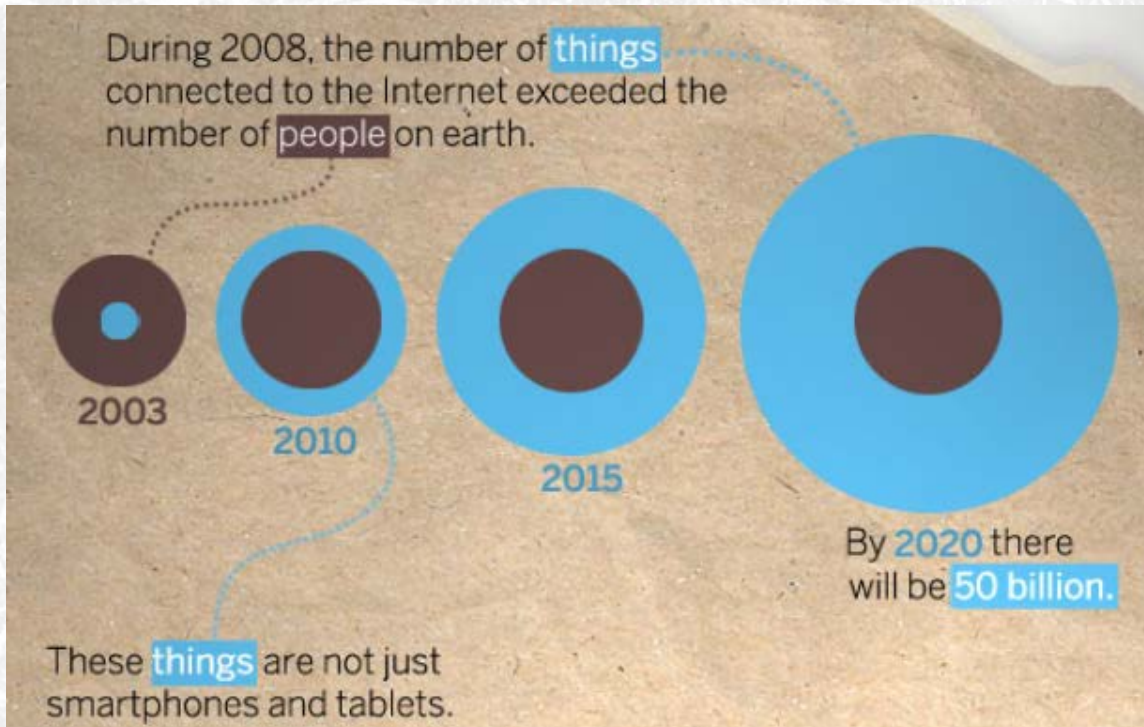
How will
cyber affect
3d printing?



Concern exists about protecting Additive Manufacturing systems from cybersecurity attacks

- ✓ Are Additive Manufacturing systems safe from cyber-attacks?
- ✓ How can we protect CAD software from cyber-mischief?
- ✓ How can we ensure finished products are printed to the intended design?

Internet of Everything



<http://blogs.cisco.com/news/the-internet-of-things-infographic/>

What could the IoE mean for Additive Manufacturing?

- ✓ High demand for embedded sensors in 3d print jobs
- ✓ More complex, multi-material objects
- ✓ Greater challenges in design as more diverse objects are fabricated

Programmable Matter

Programmable Matter is the science, engineering and design of physical matter that has the ability to change form and/or function (shape, density, moduli, conductivity, color, etc.) in an intentional, programmable fashion.

Self-folding furniture

Morphable Wings

ADAPTIVE CLOTHING

Additive Manufacturing has significant societal implications, but also a great future. We must understand and address implications, while working to harness the promising future applications.

“You’ve got to be very careful if you don’t know where you are going, because you might not get there.”

- Yogi Berra

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