



# **Building University/Corporate/State Government Partnerships for Additive Manufacturing and Printed Electronics: A Massachusetts Example**

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GUIRR Meeting  
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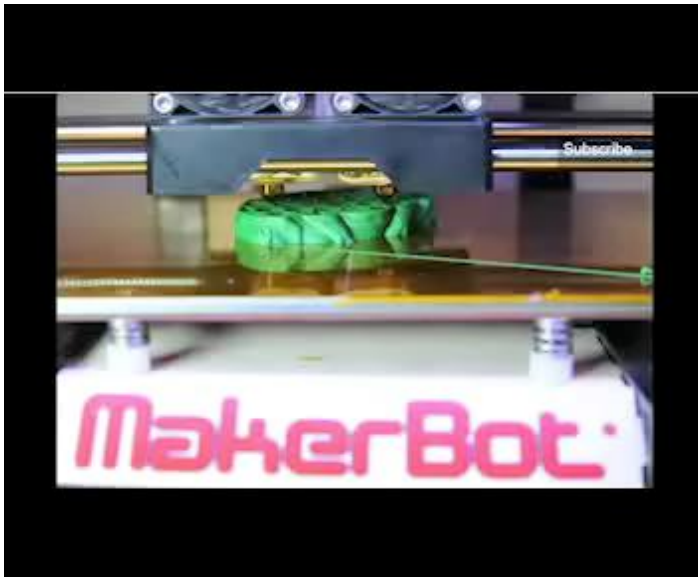
# University of Massachusetts Lowell (UML)



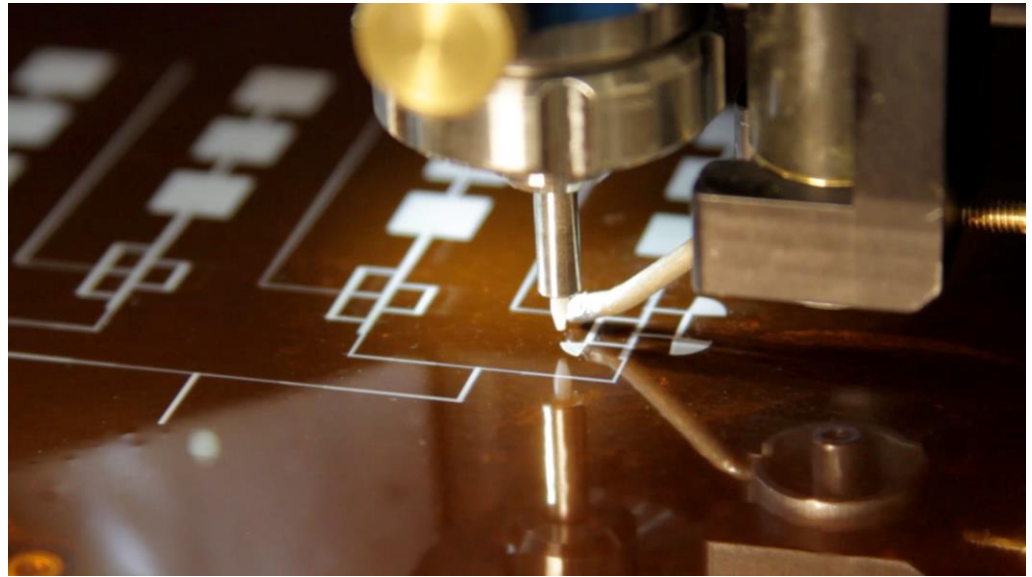
- One of 5 campuses of the University of Massachusetts system
- Comprehensive, national research university
  - More than 120 undergraduate, 36 masters and 33 doctoral degree programs
  - 600+ faculty
  - 18,000 students
  - \$70M+ in research expenditures
- Proximity to Corporate partners
  - High Tech area of eastern MA
  - Located close to many Raytheon facilities (e.g., Tewksbury, Andover)

# What is Printed Electronics ?

Printed Electronics is an additive, CAD-driven process for depositing patterned electronic materials (metals, dielectrics or active materials) onto flexible, rigid, or non-planar substrates. It's similar to 3D printing in the electronic domain.



Conventional 3D Printing



Printed Electronics

Printing electronics enables fast prototyping and new form factors for electronic products

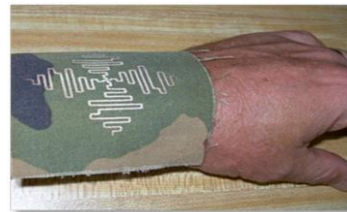
# The Potential of Printed Electronics

## *Accelerating Product Development*

- Products are manufactured directly from CAD - no lithography/masks required
- Rapid prototyping reduces the time to market and faster design iterations
- Rapid prototyping encourages more risk taking in design

## *Changing the Form Factor*

- Electronics can be implemented over large areas – e.g., printed displays
- Additive (printed) processes put materials only where needed – no waste
- Substrates can be low cost and don't have to be rigid
- Electronics can be **flexible, conformal, wearable and embedded into 3D objects**
- Electronic products can be expanded to include companies that manufacture paper and plastics !



Printing of electronically-functional materials will change the form factor for electronics, accelerate the product development cycle and change the way we interact with electronics

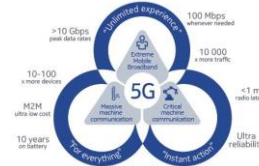
# Applications/Industries that will Use Printed Electronics?

- **Anything that's wireless (with an antenna)**

- IoT, RFID

- **Next Generation 5G Cell Phones**

- 30 GHz, 64 element antenna arrays



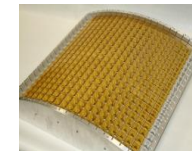
- **Medical Devices**

- Smart drug delivery systems – send patient data to physicians
- Health monitoring



- **Defense**

- Low cost, flexible radar systems
- Monitoring the soldier/pilot (health, communications)



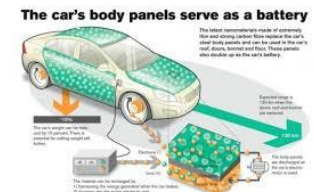
- **Wearable Electronics**

- Active textiles



- **Automotive**

- Car radars, moldable electronics, printed batteries, light weighting





# What Are the Opportunities for Printed Electronics ?

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- Expected to become an enabling technology for a new generation of electronic products
  - Will impact many industries and provide entry for new entrants
- Printed Electronics is in the early stages of development
  - Like the IC industry in the mid-70's
  - Need to develop the supply chain
- There is an opportunity for state economies to get ahead of the curve and cultivate a regional ecosystem in printed electronics
  - Pull existing industries/suppliers into the PE space
  - Encourage startups
  - Workforce training

# Raytheon-U Mass Lowell Research Institute (RURI)

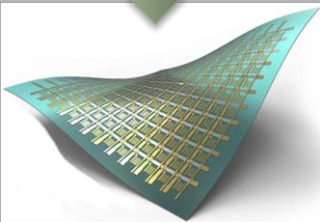


Saab Emerging Technologies Building

- Joint research research center between Raytheon and UMass Lowell (UML)
- R&D for Raytheon on Printed Electronics
- Occupies the entire 4<sup>th</sup> Floor Saab Emerging Technologies Building on the UML campus
- Moved into facility January 2015

## What is Unique about RURI is:

- New concept in university-industry collaboration
- Raytheon employees are co-located with UML faculty, students
- The only Raytheon facility located on a university campus
- The only UMass facility with a corporate partner
- Internal Raytheon projects on additive/printed electronics
- Manufacturing technologies to develop radar systems with lower cost, and different form factors
- Partner on federal funding pursuits
  - Millions of \$ working with federal manufacturing institutes, ONR, Army, Air Force
- Train the next generation of Raytheon engineers



Changing the form factor and reducing cost for radar systems

# How/Why did RURI Happen?

- **Strategy**

- Identify companies that:
  - Need R&D to stay competitive
  - Do not have a dedicated research organization
  - Are local to the university – proximity counts!

- **Opportunity (circa 2011)**

- New state-of-the-art research building was in planning stage
  - Available space... 3<sup>rd</sup> and 4<sup>th</sup> floors would not be built out due to lack of funds
- Raytheon was not active in Printed Electronics
- Major Raytheon facilities are located within a 15-20 minute drive of campus
- Expertise on UML campus in plastics, nanomanufacturing

- **Challenges**

- Raytheon had never had a physical footprint on any campus
- UML had never had a company using space on campus
- Raytheon is a conservative, risk adverse company
- Logistics (finances, ITAR, etc)

- **Tactic**

- Embed– took a sabbatical at Raytheon
- Confirm their need, “sell” the idea, convince working engineers and executive management



# Printed Electronics Research Collaborative (PERC)

## PERC Mission:

Develop the supply chain for printed electronics in Massachusetts (and NE)

## State Funding: Massachusetts Tech Collaborative (MTC)

- \$4M committed based on 1:3 match of corporate investments and federal funds
- Kicked Off in January 2015
- Funds to be used for equipment only
- PERC has raised over \$7M in corporate and federal funds
- Preposition teams for federal funding opportunities
  - ONR, Army, America Makes, NextFlex
- 14 companies have joined PERC as members so far... more coming

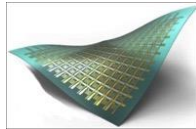


Governor Baker at UML  
announcing state investment



# Developing the Printed Electronics Supply Chain

## Systems



Flexible Phased  
Array Radar

**Raytheon**

**BAE SYSTEMS**

## Subsystems

Phased Array Antennas	AM-Based Printed Circuit Boards	Frequency Selective Surfaces
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## Components

Thin ICs with Printed Interconnects	Printed Transistors	Antennas	Metamaterial Based Devices
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## Processing Equipment

3D structural printers	Functional ink printers- 2D	Functional ink printers for 3D objects	Pick & Place die mounting on flex substrates	Optical & thermal sintering
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## Modeling & Design for AM

Modeling Tool Integration; Structural, EMag, thermal...	EMag Design & simulation	Software for 2D to 3D circuit layout	Materials modeling & engineering
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## Printable Materials

Electrically Conductive Inks	CNTs & graphene	Flexible low loss Substrates	Dielectrics	Ferroelectric materials	Thermally Conductive Inks
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**PERC/RURI has been visited by over 100 companies and organizations**

# PERC/RURI Integrated Facility

## • Printing Lab

- Optomec Aerosol Jet
- nScript Micropen Dispenser
  - 4-head and single head
- Sonoplot Picoliter Dispenser
- Three 3D printers
- Photonic Curing
- Keyence Digital Microscope
- 4-point probe, profilometer

## • Modeling Lab

- ANSYS Multiphysics bundle

## • Microwave Test Lab

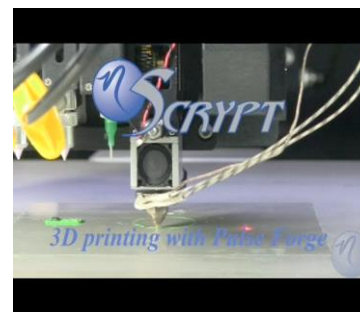
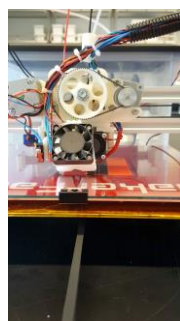
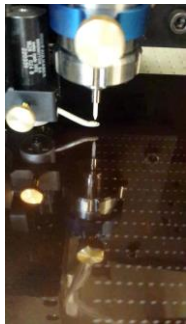
- Keysight Network Analyzers (26 GHz, 50 GHz)
- Three Wafer Probers
- Rhodes & Schwartz Spectrum Analyzer, VNA

## • Antenna Characterization Lab

- Anechoic chamber

## • Packaging and Subsystem Integration

- Robotic Arm for printing on 3D objects








8000 sq. ft. - Access Controls in place by floor, lab and office for ITAR Projects

# PERC Value Proposition

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- **Provide R&D through sponsored research projects**
  - Leverage university expertise and integrated PERC facility
  - Advanced design tools, extensive printing systems (2D and 3D) and broad range of characterization equipment
  - Enable fast prototyping of new design concepts
- **Create teams to pursue federal funding**
  - Most funding requires an integrated team
  - Short deadlines on proposals – it helps to have an existing relationship
- **Support building out the PE supply chain**
  - Help connect system integrators, material suppliers, equipment vendors, etc
  - Expanding from DoD to Commercial-Medical devices, telecommunications
- **Faculty: Enabling research in multiple disciplines**
  - All engineering disciplines, physics, chemistry, medical, business
- **Workforce Training**
  - Developing talent for MA companies

# Use Federal Funding to Expand Capabilities

	Title	Sponsor	Partners	UML Value	Total Value
	<b>FEDERAL AWARDS/PROPOSALS</b>				includes cost share
	Novel, Low-Cost Phased Arrays Manufactured by 3D Printing	ONR- Phase 2 STTR	SI2, RTN	\$200,000	\$749,000
	Printed Materials with Embedded Electronics	Army-SBIR Phase 1	SI2, RTN	\$20,000	\$60,000
	Printed Materials with Embedded Electronics	Army-SBIR Phase 2	SI2, RTN	\$125,000	~\$625,000
	Multimaterial 3D Printing of Electronics and Structures	America Makes	RTN, GE, nScript, Rogers Corp, USF	\$188,000	\$2,000,000
	Multi-Functional Substrates and Printing Integration for RF Devices	NextFlex 1.0	RTN, CST, Rogers, Flexcon, Daussalt Systems	\$1,820,000	\$1,820,000
	Flex-Hybrid Electronic X-Band Antenna Arrays for Next Generation of Deployable Antennas	NextFlex 2.0	SI2, RTN	\$320,000	\$1,467,000
	Additively Manufactured Phased Array for Airborne Applications	AFRL	RTN	\$50,000	\$150,000
<b>TOTAL</b>				<b>\$2,723,000</b>	<b>\$6,871,000</b>

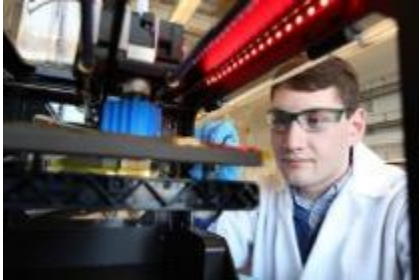
Army Natick funding coming through HEROES for functionalized materials

Federal projects enable PERC to hire staff and students and collaborate with industry



# Workforce Training

- One PhD and 2 MS students graduated from PERC within last year
- 4 Completed capstone teams over over 2 academic years
- Current students
  - 5 Ph.D. students
  - 8 M.S. Students (E.E. and M.E.)
  - 14 undergrad students (3 capstone teams)
- All students and Staff are U.S. Persons
- 6 students hired by Raytheon in the last year



James Benedict-MED



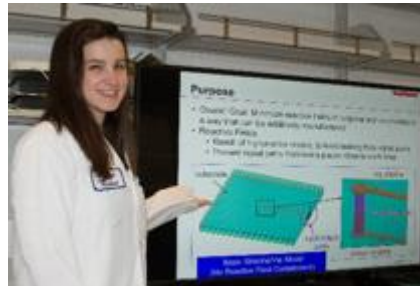
Elicia Harper-MET



Rocco Vigorito- Hardware  
Integration center (HWIC)



Jarrod Vaillancourt-MET



Carolyn Reistad –EDD, Antenna



Brian Morrison- MET



- **RURI** is a new model for academic-corporate R&D partnership based on co-location
- **PERC** is a model for coalescing corporations, universities and state government to develop a regional economic ecosystem in an emerging technology and a talent pipeline to feed these companies.

## My Advice

- **Need champions on both the academic and corporate sides**
  - Champions must have credibility within their respective organizations
- **Proximity Counts!**
  - Co-location creates more synergy
- **Timing is important**
  - Need companies with an urgent technology pull and concern of a capability gap
  - Need a local academic institution with requisite expertise, availability of modern campus facility and talented students to develop a talent pipeline
  - Need a state government willing to seed an unproven technology and support development of a new ecosystem in the region

See our video on YouTube – search for “Printed Electronics Lowell”

