OAK RIDGE National Laboratory

Democratizing Advanced Manufacturing – Ensuring Prosperity and Security

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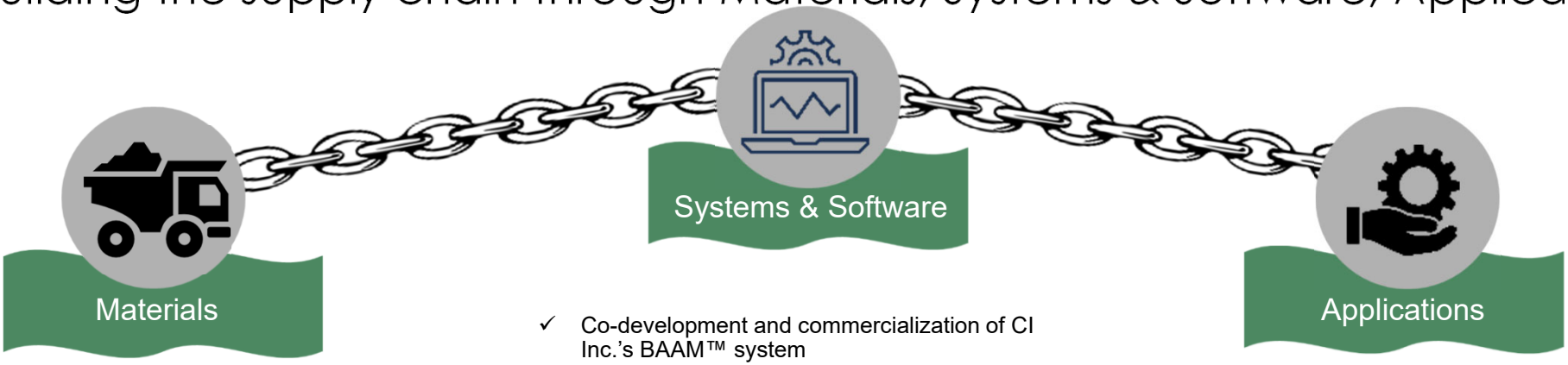
U.S. DEPARTMENT OF ENERGY

Creating an Industry:

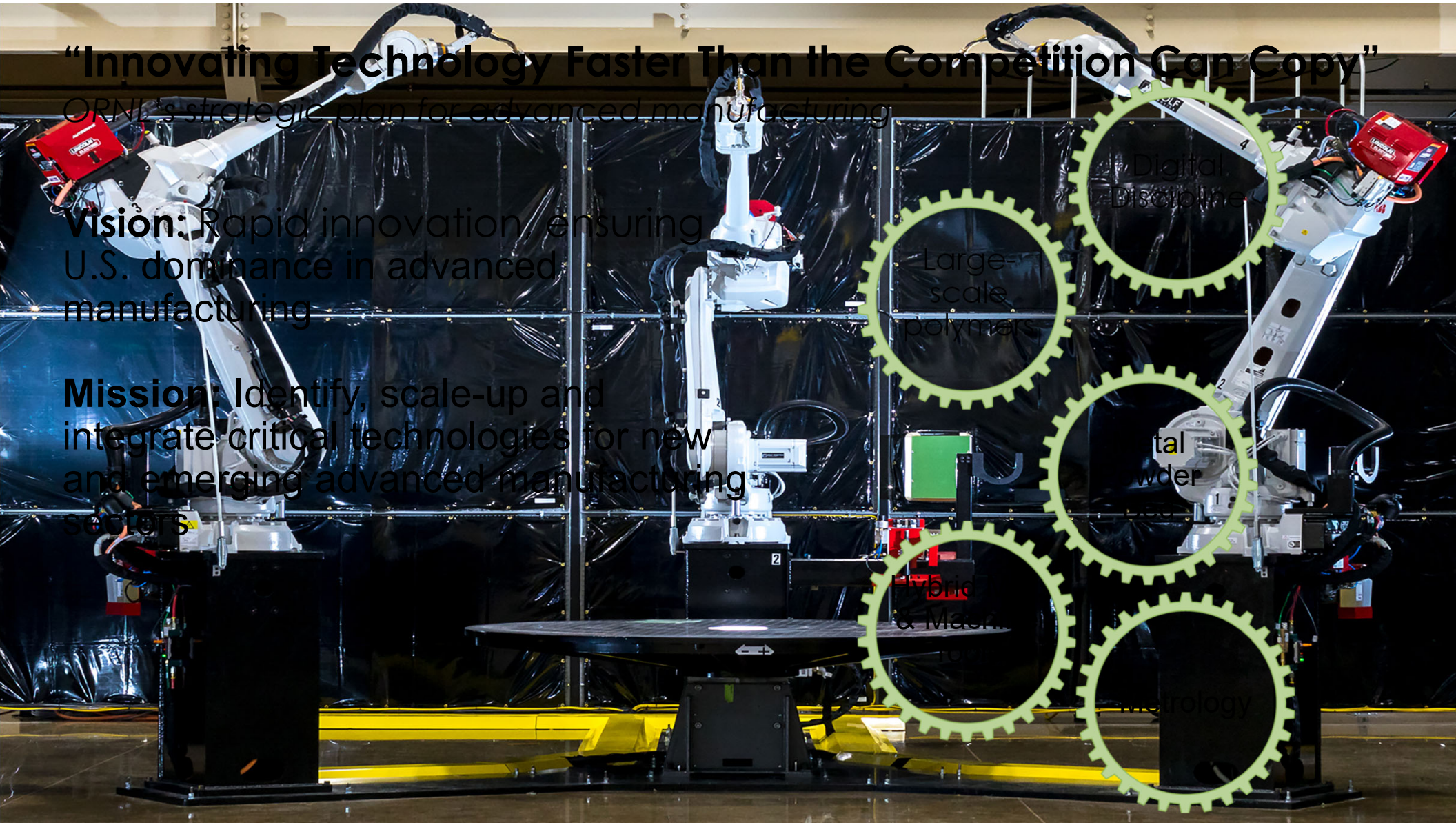
Building the supply chain through Materials, Systems & Software, Applications



- ✓ 3D printing with **>100** different material combinations
- ✓ Co-development of thermoset resins slated for commercialization
- ✓ Commercialization of thermoplastics including CF-reinforced materials and bioderived feedstocks
- ✓ Opening of new dedicated production line for additive manufacturing and injection molding

- ✓ Co-development and commercialization of CI Inc.'s BAAM™ system
- ✓ Co-develop of the world's largest thermoset system
- ✓ Commercialization of extruder technology
- ✓ Optimization of slicing software
- ✓ Augmented reality for enhanced visualization
- ✓ Enhanced modeling and simulation

- ✓ Reducing lead times for tools, dies and molds by an order of magnitude
- ✓ Rapid prototyping of CF-reinforced parts
- ✓ Direct fabrication of components for end use



"Innovating Technology Faster Than the Competition Can Copy"

ORNL's strategic plan for advanced manufacturing

Vision: Rapid innovation ensuring U.S. dominance in advanced manufacturing

Mission: Identify, scale-up and integrate critical technologies for new and emerging advanced manufacturing sectors

Ubiquitous Sensing, Big Data & AI

- Embedded computing platforms
  - Arduino (Real-Time DSP)
  - Raspberry Pi (LINUX Platform)
  - Particle Photon (Cloud-Based Platform)
- Low cost / disposable / rapidly upgradable
- Sensors
- Sensors
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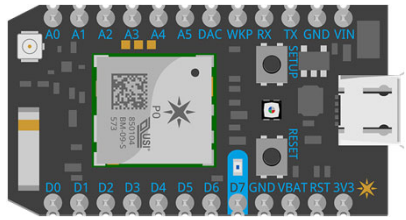
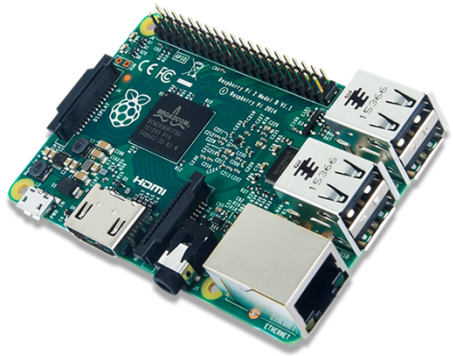
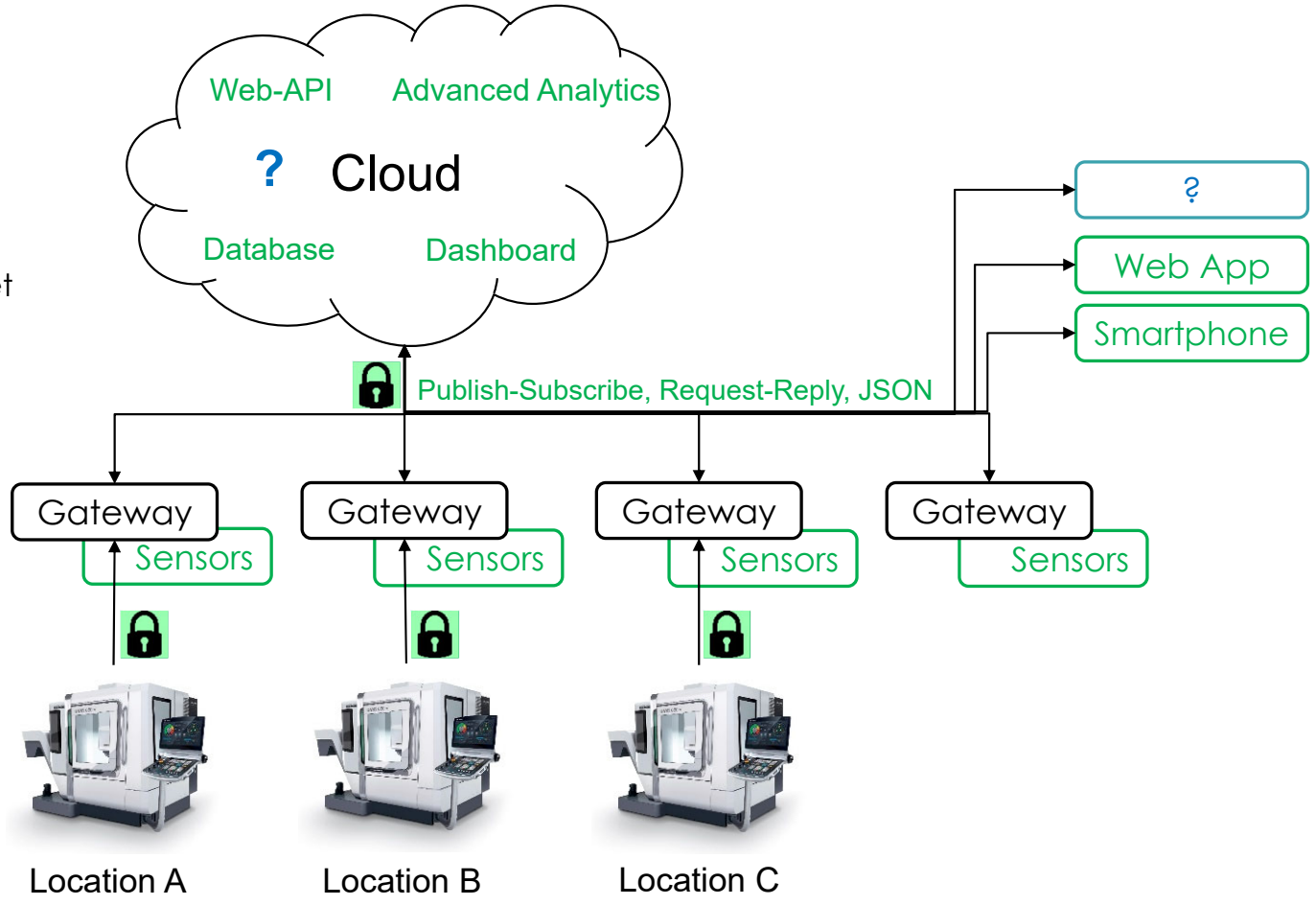




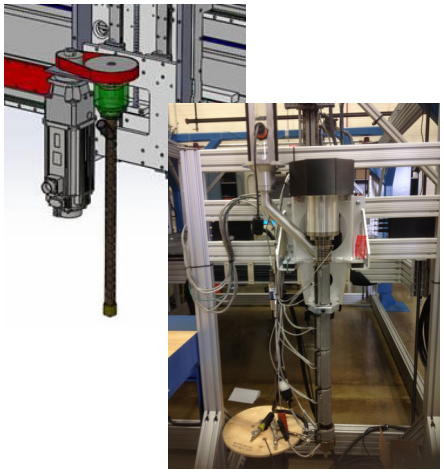
Next Generation Architecture

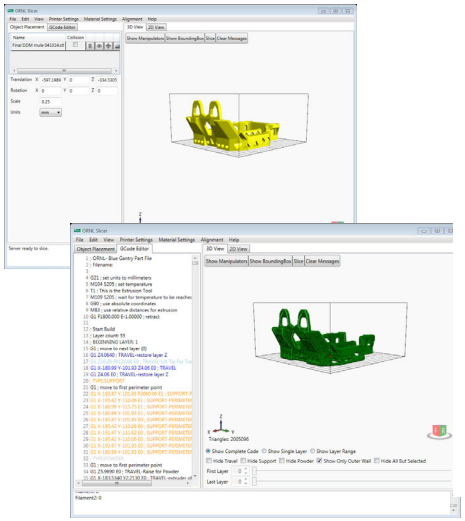
- **Secure, efficient, and real-time cloud operations**
- Integration of **REST/HTTP (request-reply)** and **MQTT (publish-subscribe)**
  - Compatible with majority of Internet services
  - Allow **machine-to-machine** and **machine-to-cloud** communication
  - Access with **no need of static IP** address
- **Integration of Web-APIs**
  - Twilio, GoogleScripts, IFTTT, AWS Lambda (Alexa)
  - Shock monitoring system (HFDA)
- **Fog computing and cloud computing**
  - Machine utilization
  - Number of parts and cycle time computation

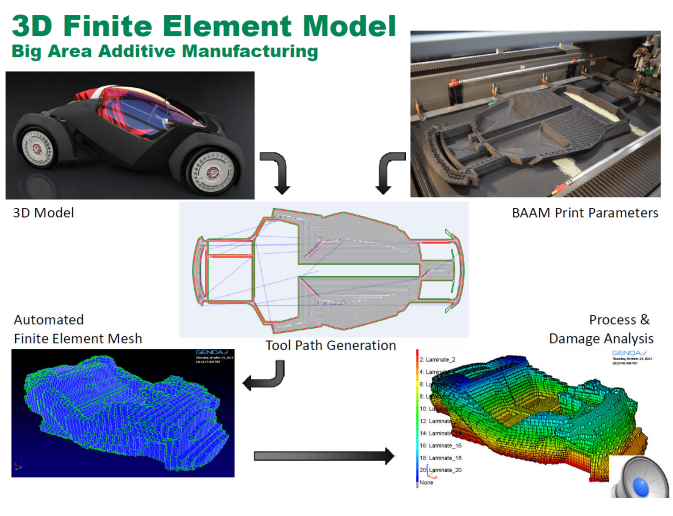


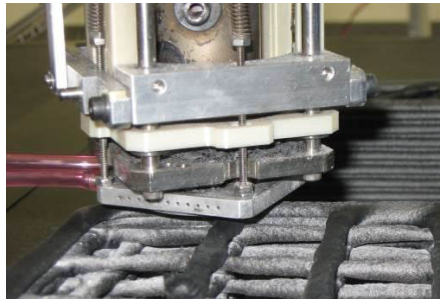
Advancing System Science and Engineering

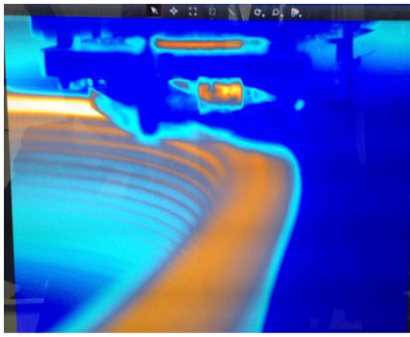
- ***Developing systems, components and controls***











Process control

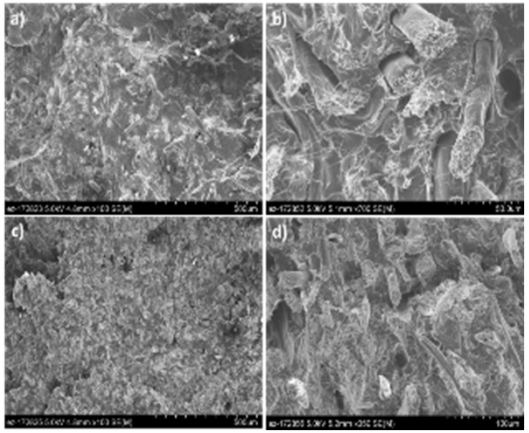
Graph Theory for scan strategies

In-situ process monitoring

- ***And transitioning to industry***

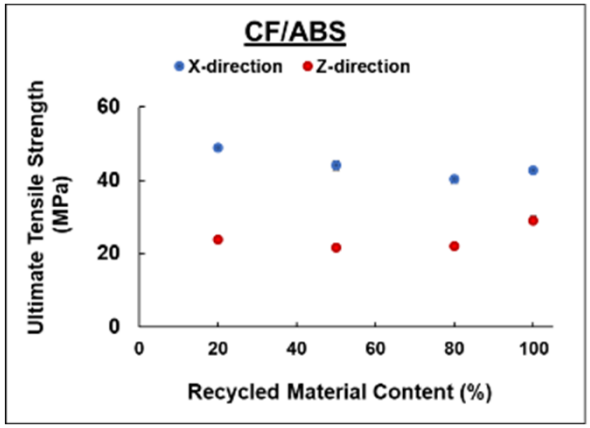
Future of Sustainability – Recycling and Bio-Derived Materials

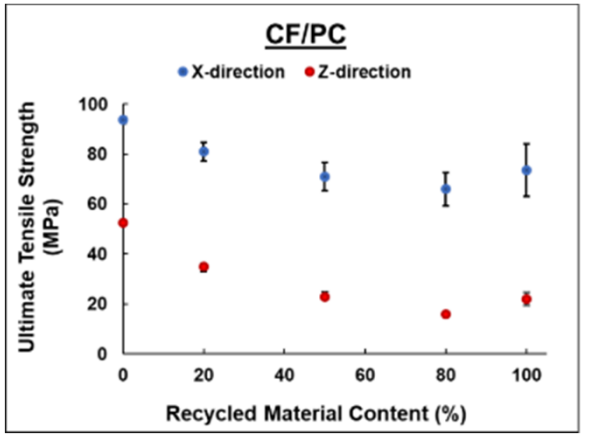
Industrial Size Recycling Equipment



Microstructure of Bio-derived Materials

Properties of Recycled Materials





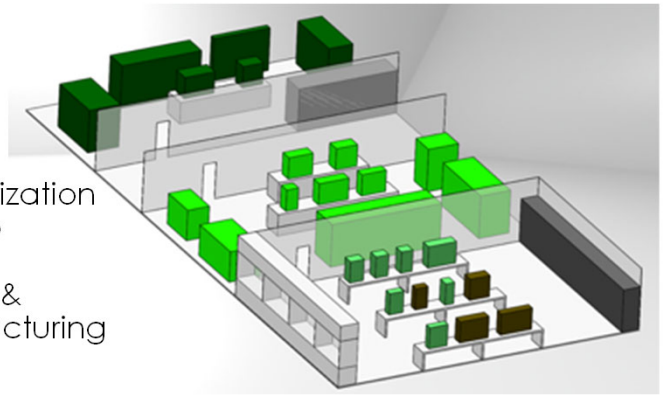
Additively Manufactured Pavilion with Bio-derived Materials

Rapid Innovation and Commercialization Lab Floor Plan

No other currently available open research facility with the combined capabilities

Rapid Innovation Capability

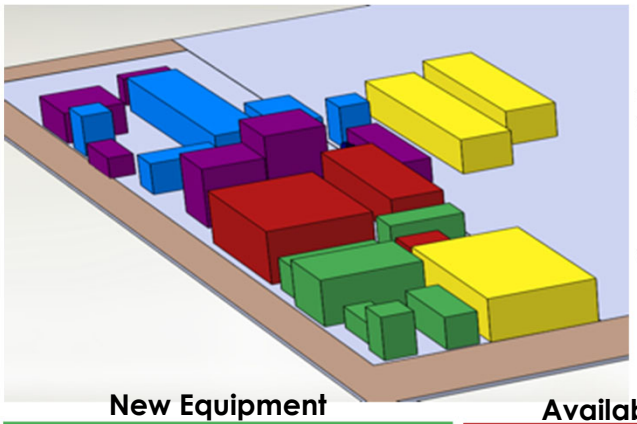
Low Bay
50' x 100'
- Characterization
- Bench Top Feasibility, Recycling & Remanufacturing



New Equipment

- Lab-Scale Recycling & Recovery
- Manufacturing
- Characterization

Scale up Capability



High Bay
50' x 200'
- Commercial Scale Manufacturing Systems
- Recycling & Recovery Equipment

New Equipment

- Recycling & Recovery

Available Equipment

- Thermosets
- Thermoplastics
- Additive Manufacturing
- Automation and Molding

Inside 110,000 square foot Manufacturing Demonstration Facility

Circular economy supporting capabilities:
- **Green** boxes are new equipment
- Other colors are MDF existing capabilities

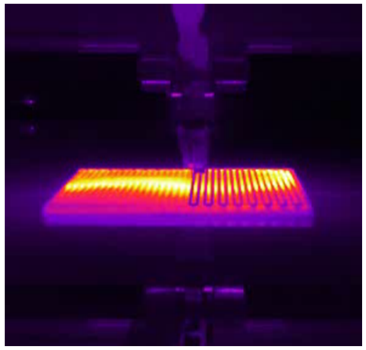
Scale-up Science of Polymer Additive and Composite Manufacturing

Large Scale Reactive Polymer Printer Unveiled at ORNL by Magnum Venus Products

- Developing technology from concept to commercialization
- Coordinated R&D of Systems, Materials and Applications
- Sustainability Focus with Recycling and Bio-derived Materials
- Implementing Digital Factory Platform
- Products Introduced by Industry Partners

Benchtop to Industrial Scale Manufacturing Capability:

- Thermoplastic Extrusion Deposition
- Reactive Polymer Additive Manufacturing
- High Rate Composite Manufacturing
- Recycling of Polymer Composite Material
- Composite Intermediate Material Manufacturing



De-coupled Print Toolpath and Exotherm in Reactive Additive Manufacturing

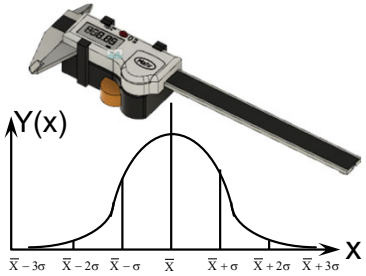
6 R&D100 Awards, 3 Awards for Composites Excellence, JEC Innovation Award, ASM Engineering Materials Achievement

Engaging SME's and Workforce (Current & Future)

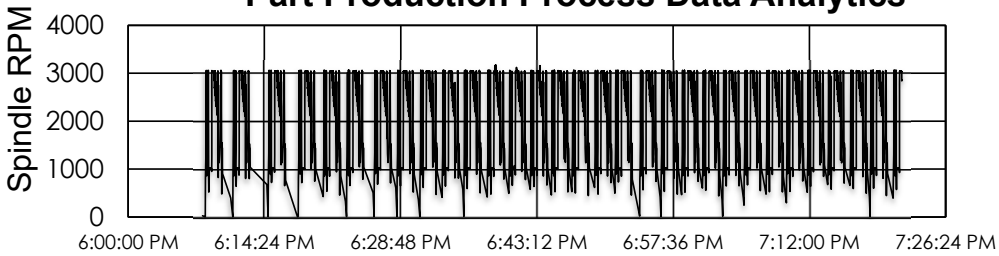
Wireless Machine Monitoring System

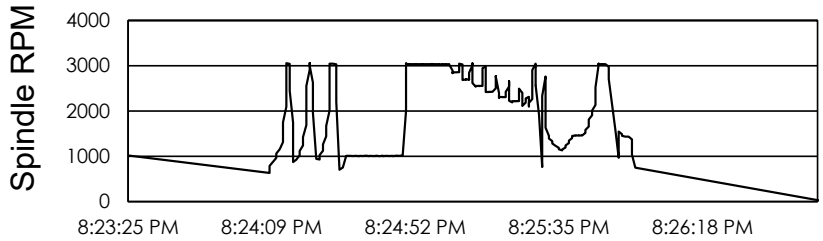
Low-cost sensors:
- Vibration based PM
- OEE
- Coolant health

Wireless calipers and instruments

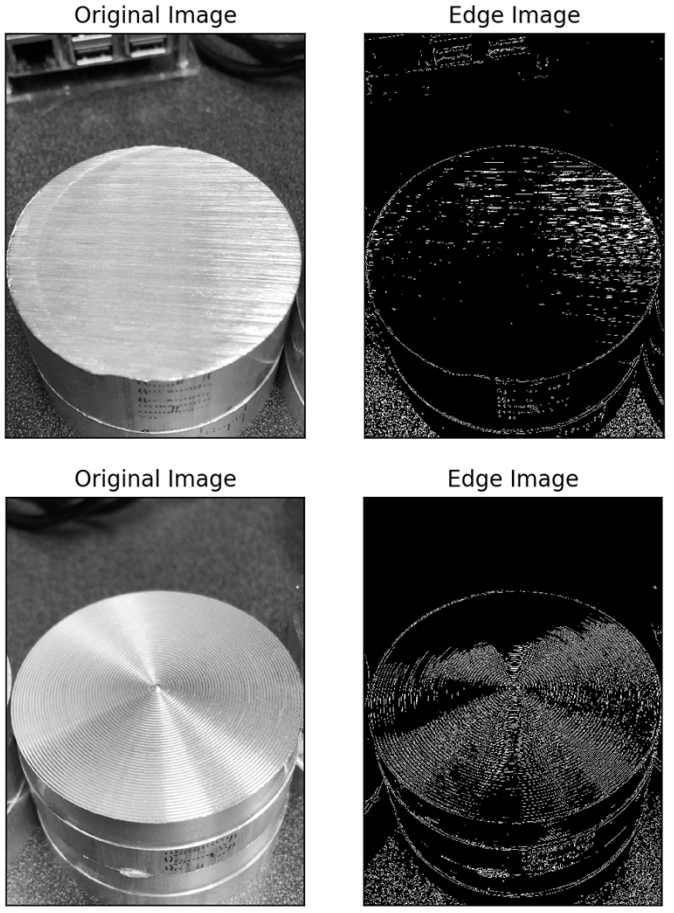


Part Production Process Data Analytics





Surface Finish Inspection with Mobile Phone



OAK RIDGE National Laboratory | MANUFACTURING DEMONSTRATION FACILITY

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Secure, Resilient & Adaptable Manufacturing Ecosystem

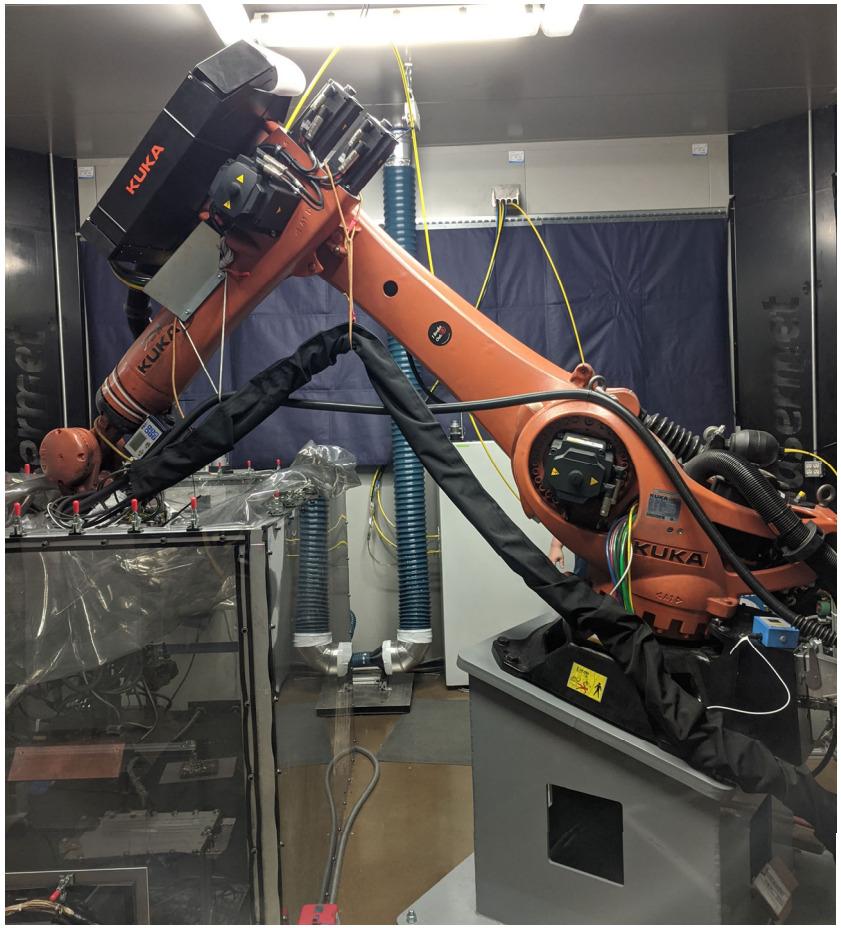
The Building Blocks

- Securely get the design and production information from customer
- Collect production data for digital passport, and for process validation and improvement.
- Make the part in a secure fashion and ensure that it has a valid digital passport
- Enable legacy systems
- Leverage XR to ensure safe and secure operations
- Control/store critical information in a secure location
- Create the recipe, and it is not a unique recipe
- Enable next generation production operations
- Perhaps a new business mode…

The Ride Share Example

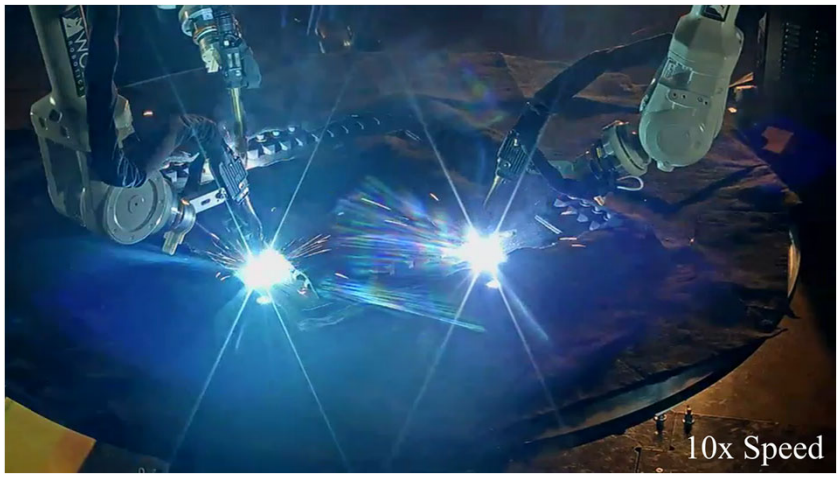
- Connecting the customer to the supplier
- Born qualified / digital passport
- Leveraging and extending the capabilities of a well-trained workforce

When am I Going to Lose my Job?



Back to the Big Picture

- Digital thread is a two-way street
  - Getting date for ML/AI
  - WFD capabilities (especially VR/AR/XR)
- Must deploy rapidly (faster than the competition)
  - Learning from production and field deployment
  - Generative design and manufacturing
  - Human providing the starting point



- Leverage Cloud/Fog/Edge for Compute/Communicate/Storage
- Must weave in cybersecurity
- Protection of proprietary and classified information
- Must support the ecosystem (SME/Middle class)

"In times of change, learners inherit the earth; while the learned find themselves beautifully equipped to deal with a world that no longer exists." (Eric Hoffer 1902-1983)