Manufacturing the Future – Ensuring Prosperity and Security

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Innovating technology faster than competition can copy

**Vision:** Rapid innovation, ensuring US dominance in advanced manufacturing

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

- Hybrid manufacturing and Machine Tools
- Metal powder bed
- Large-scale polymers
- Digital discipline
- Metrology
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
- Sensors
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
Big Data Generation – On Board Sensors

• Website for accessibility
  – List of machines with images as links
  – Review machine programs
  – Graphs plotted from near real time data
Hybrid Manufacturing

- Combination of additive (Deposition), subtractive (Machining), and inspection in a single machine tool
- Achieving Higher Productivity & Better Surface Finish
Hybrid Manufacturing

Easily Reconfigured

Various Feedstock

- Additive:
  - Blown-powder (~0.5 lb./hr.)
  - Wire-feed (~5 lb./hr.)
- Subtractive: Traditional machining

Lower Cost

Traditional: $90,000
Hybrid: $2,500
97% Material Cost Reduction

Hybrid Toolpath Planning

Chord Slicing - Autodesk

Non-Uniform Layer Slices – Open Mind
COVID19 Manufacturing Demonstrations at ORNL

- Face Shields
  - DeRoyal

- Test Tubes
  - Denso
  - Coca-Cola

- N95 Material
  - Hills Inc.

- Masks
  - DeRoyal
Face-Shield Mold
Face-Shield Mold
Feedback Control
Flow Architecture

Edge-driven system level control
- G-code drip feed process
- Parameter and macro modification

Modular components and interface access
- Standard, industry accepted protocols
- Goal, capabilities applicable to any system
Feedback Mechanisms for Closed-Loop Control

In-situ Process Modifications

**Thermal Imaging**
Thermal monitoring during print operations

**Automated Geometric Inspection**
Continuous inspection during cooling to monitor distortions over time
Feedback Mechanisms for Closed-Loop Control
Enhanced, Data-Driven Operations

**Dynamic Dwell for Thermal Control**
Fabrication of thin-wall structures with dynamic thermal control

**Multi-Part Thermal Operation**
- Fabrication of 2 independent components with thermally-driven closed-loop control architecture
- Allows hybrid fabrication of N independent components within single build space
The Building Blocks for Democratization

- Securely get the design and production information from the 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 data 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)