Opportunities and Challenges

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GTMI Strategic Planning: Additive Manufacturing with Metals

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GTMI is to:

• Engage faculty from across schools and GTRI labs to develop a portfolio of interdisciplinary research that will maintain Georgia Tech’s leadership status in advanced manufacturing technology

• Convene interested faculty to define strategic initiatives to achieve its mission, often in conjunction with other interested IRI

• Establish focused initiatives: align resources and opportunities

• Inform College and School curricula of emerging industry trends and needs
GTMI Strategic Initiatives
2017-2018

Digital Factory of the Future
• Additive manufacturing\(^1\) Suman Das
• Composites manufacturing\(^1\) Chuck Zhang
• Precision machining Tom Kurfess
• Robotic manufacturing\(^3\) Shreyes Melkote

Cell & Tissue Biomanufacturing
• Cell Bio-manufacturing\(^2\) Krish Roy

Manufacturing Neighborhood Stewardship
• Delta Advanced Manufacturing Pilot Facility
• Boeing Manufacturing Development Center
• Georgia Advanced Bio-Manufacturing Center \(^2\)

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1 Joint initiative with Materials Institute + Data Analytics & Informatics Institute
2 Joint initiative with Petit Institute for Bioscience and Bioengineering
3 Joint initiative with Institute for Robotics and Intelligent Machines
The Digital Factory of the Future:
Strategic Initiative Focus Areas

➢ Additive Manufacturing Systems: Joint with IMAT
  o Design for additive manufacturing
  o Integrated design /analysis / process control systems
  o Materials development & integration
  o Real time process controls

• Composite Joining and Repair
  o National roadmap
  o Digital, predictive MRO

• Precision Machining
  o Real-time interactive machine tool feedback intelligence
  o Shop floor prognostics and diagnostics

• Robotic Manufacturing: Joint with IRIM
  o Human robot integration: Getting robots out of their cage
  o Flexible automation
Basic Strategic Initiative Criteria

Opportunity Attractiveness
- Growth potential
- Sustained demand
- Major engagement opportunities
- Key client potential
- Attractive market terms
- Strong innovation drivers
- Significant IP potential
- Strategic fit with Institute goals

Ability to Compete
- Strength of capabilities vs. competitor with largest market share
- Distinctive competency / IP position
- Depth and strength of leadership
- Access and ability to influence client decisions makers
- Adequacy of resources to serve clients
- Ability to attract and retain key resources
AM broadly recognized as a “game changer” for digital manufacturing

AM for Metals acceptance is lagging the polymer systems

Applications limited by lack of confidence in repeatability/reliability of critical / certified parts

Aerospace use focused on tooling expanding with DOE-ORNL support

Key government AM – Metals R&D funders are ONR & AFRL ($25M – $40M/ yr.)

America Makes funding flows to industry primes & their university partners

Expanding applications interest in AM from DOD MRO community

GE Additive, Siemens positioning as dominant forces through aggressive investment & acquisition

Major corporations are investing in in-house capabilities, including Enterprise Alliance partners Ford & Boeing
DOD MRO Community is Being Driven to Incorporate AM Technologies into Depot and Field Operations

- Digitally integrated manufacturing has advanced to the point that limited run / “lot size one” production is possible
- Marine Corp directive mandates AM adoption except for mission critical parts
- Army adopting modular field deployed additive parts production
- AF Logistics Complexes acquiring AM for metals equipment, but have limited skills to use effectively
- AFLMC establishing AM support centers adjacent to ALCs
  - UDRI funded to establish centers in Dayton, Warner Robins, Oak City, & Ogden
- MRO system lacks “expert engineering support” to enable “form-fit-function” replacements for MRO parts production
• Tech’s AM efforts have market credibility and recognition largely as *individual faculty* efforts, not a GTMI signature

• Penn State is the dominant university player with both DARPA & America Makes center funding

• Multiple universities establishing government / industry funded prototyping and process development labs:
  – Ohio State, UC-Berkley, Texas A&M and Arizona

• Expanding capability at National labs: ORNL, LLNL, BNL

• Establishing a GTMI signature in AM—M requires competitive differentiation against the benchmark academic AM center (Penn State)
Additive Manufacturing of Metals
Initial Observations

Opportunity Attractiveness
✓ Rapidly growing marketplace based on emerging technology
✓ Significant technology challenges / innovation drivers:
  ▪ Design methods & tools
  ▪ Predictive process-structure-property relationships for complex thermal processes
  ▪ Scalable, fast material processing
  ▪ Real time process control & defect correction
  ▪ Common reproducible data sets
✓ Major engagement opportunities
  ▪ ONR, AFRL, Army, America Makes
  ▪ Aircraft engine manufacturers
  ▪ Aircraft maintenance and remanufacture
✓ Key client potential
  ▪ High value / low run manufacturing
  ▪ Aerospace
  ▪ Medical
✓ Significant IP potential
✓ Strategic fit with Institute strengths: Materials, direct digital manufacturing, data analytics, supply chain analytics

Ability to Compete
✓ Strength of capabilities vs. competitor with largest market share
  ▪ Top 5 Leaders: Penn State, Univ. of California, Fraunhofer, Ohio State
  ▪ Over 2016-2017 GT ranks 12th in number of publications on AM for Metals
✓ Distinctive competency / IP position
✓ Depth and strength of leadership
✓ Access and ability to influence client decision makers
✓ Adequacy of resources to serve clients
✓ Ability to attract and retain key resources
✓ Ability to sustain investment in initiative
Critical Competencies Essential to Additive Manufacturing: NSF 3 Plane Diagram

- Functional Requirements
  - Model Based Certification
    - Statistical Process Control
    - Certified Material Supply
    - Integrated Design Tools
  - Real-Time Hybrid Process Control
    - Certified Parts Production
    - Production Applications

- Controlled Process
  - On-line Process Monitoring
    - Material Control
    - Certified Material Supply
    - Integrated Design & Analysis Tools
    - Design Guidance

- Functional Tools
  - Process Equipment
  - Fusion Process
  - Quality Assessment
  - Material
  - Process
  - Structure
  - Properties
  - Design Tools
  - Analysis Tools
  - Process Control

- Fundamental Knowledge
  - Metallic Parts Production
  - Polymer Parts Production
AM for Metals Requires an Integrated "Digital Thread" Toolset to Merge Simulation & Experimental Data

Initial Design
- Design Modeling (CAD)
- Printer System Interface

Design for AM
- Topology Optimization
- Lattice Generation

Design Verification
- Design Analysis & Verification

Design & Process Refinement
- Process Simulation
- AM Materials Data Base

Production Process Automation & Control
- 3D Printer System
- Parts Production
- Post Processing

Post Processing
- Process / Defect Monitoring
- Thermal Cycle Properties Impacts

Power Characterization & QA
Critical Elements of a GTMI Additive Manufacturing for Metals Strategy

1. Expand & link foundation of enabling core capabilities:
   - Design methods and tools,
   - Extend MATIN materials design efforts for metallurgical properties prediction & tracking,
   - Process equipment & controls
   - Real time Q/A techniques
   - Data provenance

2. Expand core capabilities development funding sources and routes:
   - AFRL, ONR, DARPA, DOE-EERE/MTC & ORNL, America Makes

3. Establish a GTMI regional leadership position as platform for national reputation

4. Establish applications development base with lead users
   - Aerospace / Automotive tooling production: Boeing, Delta, Ford
   - MRO replacement parts design and remanufacture: AFMC-ALCs, NAVAIR

5. Establish pathway to integration of AM into GT’s manufacturing curriculum
1. EXPAND & LINK FOUNDATION OF CORE CAPABILITIES

• Integrated design and analysis systems
  – Faculty leader in development of both software suite and design practices
  – Access to state-of-the-art software vis-à-vis GEAdditive or Siemens PLM

• Metallurgical engineered materials in key alloy systems
  – Faculty leader in metallurgical engineering: process, structure, properties, performance
  – Application of materials by design simulation, experimental and data analytics systems

• Contemporary AM production hardware
  – Access to state-of-the-art systems via collaboration agreement
  – Dedicated process facility lab

• Data provenance capacity
  – Extension of GT- MATIN systems for design, simulation and test data capture & analysis

• Core applications engineering capacity
  – Research faculty base to engage with lead users
GTMI AM for Metals: Enabling Building Blocks

Integrated AM Design
- Convergent modeling
- 3D Simulation
- 3D Printing

Materials By Design
- Properties & Performance
  - High-Throughput Characterization
  - Low-Cost, Robust, Metamodels
- Hierarchical Structure & Interfaces
  - High-Throughput Prototyping
  - Low-Cost, Robust, Metamodels
- Synthesis and Processing

Direct Digital Manufacturing Lab
2. Expand Core Capabilities Development Funding Sources

Office of Naval Research
- Awarded over $30 million in 53 grants to universities and research institutions in 2016 – 2017; $1.1 million to GT researchers (McDowell & Das)
- Typically two to three year awards at $500k to $3M
- Includes support for equipment and software acquisition

Air Force Office of Scientific Research
- $6 million in grants over period
- Strong focus on process-property investigations

Other DOD (OSD, ARMY, DARPA)
- Award of $1 million in 7 research awards
- Army focus on prosthetics

America Makes (Manufacturing USA)
- Industry led teams cofounding efforts
- Dominantly aerospace led with core universities
3. Establish GTMI Leadership of a Regional Government – Industry-Institute Alliance for Active Players in AM Development

- **GT Corporate Partners**
  - Siemens: Turbine systems development
  - Boeing: Tooling
  - Ford: Tooling
  - Delta
  - United Technologies: UTRC & Pratt & Whitney

- **Government Agencies**
  - ONR
  - AFRL
  - AFMCC- WR
  - DARPA

- **DOD Logistics Agencies**
  - AFMC ALCs
  - NAVFAC
  - Marines Logistics Centers
4. **Establish applications priority development strategy with lead users**

- Finalize Georgia Tech “Point of View” on key challenges and priorities in Additive Manufacture of Metals
- Vet the Point of View with the current cadre of Tech’s Alliance partners, both government and industry
- Distill feedback into a priority challenges roadmap, identifying potential collaborators
- Select specific topics for investigation of potential collaboration, including third party funding sources
- Develop internal / external funding strategies
- Sustained engagement with core cadre of collaborators via an AM of Metals “steering group” to advise and critique GTMI progress
Defense MRO / Field Systems Could Find Common Ground with a GTRI Manufacturing Technology Branch

- Established relationships with Warner Robins ALC as a value added partner
- Potential for joint support of a applications design capabilities vis-à-vis Boeing AMDC
- Pursuit of new DOD program development vis-à-vis the AFMC Competitive Engineering Program across all three ALC: WR, Ogden, Oak City
- Potential State support to establishing an “AM Center of Design Excellence” to build a GT role in the AFLCMC-UDRIAM Center at Warner Robins
- Develop a role for the Marine Corp Logistics Base, Albany GA