From the GTMI Executive Director

During 2017, the Georgia Tech Manufacturing Institute (GTMI) continued building Georgia Tech’s manufacturing innovation neighborhood. From bold steps in advancing research in composites and cell manufacturing to answering important questions about the Internet of Things for Manufacturing, our team continues to step up and work on the challenges facing manufacturing in the United States and Georgia.

This report provides highlights of our work during 2017. I hope you enjoy reading about GTMI as much as we enjoy working to solve grand challenges facing manufacturers.

Ben Wang, Executive Director, GTMI

STRATEGIC PLAN

In February 2017, a strategic planning committee was named to revise and update the GTMI strategic plan. Committee members represent faculty, staff, government partners and industry leaders. The committee looked at new external drivers such as the new National Network for Manufacturing Innovation (NNMI), emerging technologies, and macro-economic trends that will impact manufacturing in the next five to ten years. They also looked at internal changes such as the Advanced Manufacturing Pilot Facility (AMPF), manufacturing of biological and stem cells, and incorporating the revised GT IRI objectives. Moving through the process, the committee analyzed GTMI through a deep Strengths, Weaknesses, Opportunities and Threats (SWOT) exercise.

The SWOT analysis allowed the committee to synthesize the information and derive a set of signature initiatives that can assist GTMI in meeting its goals and its mission.

**Vision:** GTMI will be the world’s premier institution anticipating needs and providing solutions on the frontiers of manufacturing research, application, and deployment.

**Mission:** To pursue knowledge and skills that accelerate the translation of manufacturing-related research into high impact products and manufacturing systems.

**Strategic Goals**

Goal #1:
Establish and sustain GT as a premier technology university for manufacturing related research, education, and thought leadership.

Goal #2:
Champion and support GT excellence in multi-disciplinary manufacturing research & innovation.

Goal #3:
Create and deploy transformative capabilities across GT to identify and collaboratively solve systems-level, high impact manufacturing challenges.
GTMI is constantly demonstrating its thought leadership position by organizing workshops on topics such as the Internet of Things for Manufacturing and holding weekly luncheon seminars as part of the Manufacturing Luncheon Series. GTMI staff are also active in national and international trade associations, with several holding leadership positions within these organizations. The Industry Partners Program (IPP) provides numerous opportunities to build relationships with manufacturing experts in academia, government and industry. In addition to these activities, GTMI researchers are often sought out as speakers for topical workshops and they also publish papers singularly and in collaboration with others.

**Distinguished Lecture** - GTMI hosts an annual Distinguished Lecture devoted to addressing manufacturing challenges. Perhaps best known as the inventor of the Segway, 2017 GTMI Distinguished Lecturer Dean Kamen lectured to a crowd nearing 130 on October 12. Kamen’s lecture was hosted by the Georgia Tech Manufacturing Institute (GTMI) and the Petit Institute for Bioengineering and Bioscience (IBB).

**Manufacturing Luncheon Seminars** - Each fall and spring semester, GTMI hosts weekly “lunch and learn” seminars on a variety of issues affecting manufacturers. A number of companies that present also conduct student recruitment sessions while they are on campus. The sessions are free, a light lunch is provided and attendance is usually around 35 participants. The following are the speakers GTMI hosted during FY17:

- **Paul Babin**, Director, Technology, Innovation & Sustainability, thyssenkrupp
- **Reid Bishop** and **Kan Wang**, GT ISyE, “Cell Manufacturing Supply Chain”
- **Celine Cabana**, Technical Account Manager, Fluid Design Group, “Dynamic Simulation”
- **David Dukes**, Fiat Chrysler Automotive
- **Chris Eonta**, Molyworks, “Additive Manufacturing of Landing Gear Components”
- **Xiao-Yan Gong**, President & CEO, Medical Implant Mechanics
- **Lishan Mu**, Markforged, “Disrupting the Production Line with Additive Manufacturing Technology (A closer look at Composites and Metal)”
- **Eric Parker**, CEO, Sumo Robot League
- **Steve Ritchie**, Director of Operations Tech & Support; **Chris Taylor**, Director of Operation Engineering; **Erik Selander**, Director of Operations Tooling & Tech; and **Arun Saini**, Operations Program Manager; Gulfstream Operations
- **Chris Schier**, Technical Training Aids, “Latest Innovations from Desktop Metal and Stratasys 3D Printing with Live Demonstrations”
- **Jeff Smith**, Autodesk, “Design and 3D Printing”
- **Jeff Stein**, Boeing, “Automation in Aerospace”
- **Bryan Stewart**, Morris, Manning, and Martin, LLP, “Intellectual Property”
- **Diego Tamburini**, Principal Industry Lead - Manufacturing, Microsoft, “How can manufacturing benefit from the cloud?”

Pictured above, from left, Don McConnell, Georgia Tech vice president of industry collaboration; Steve Cross, Georgia Tech executive vice president for research; Gil West, Delta’s senior executive vice president and chief operating officer; David Garrison, senior vice president for engineering, quality, planning and logistics for Delta; Tad Hutcheson, senior vice president of the Delta Air Lines Foundation; and GeorgeTech President G.P. “Bud” Peterson cut the ribbon on the new Delta Air Lines Advanced Manufacturing Pilot Facility at Georgia Tech.
CAIIAC, the Consortium for Accelerated Innovation and Insertion of Advanced Composites, Publishes Roadmap on Composites Joining and Repair

Work on a first-of-its-kind roadmap by the Consortium for Accelerated Innovation and Insertion of Advanced Composites (CAIIAC, pronounced “KAYAK”) is complete. CAIIAC’s mission has been to create an innovative domestic manufacturing ecosystem to significantly shorten the time required in manufacturing development cycles, and provide “right-the-first-time material yields” for broad-based composite processes. The consortium’s roadmap focuses on composite joining and repair because it is a highly-underserved market with significant growth momentum, and has transportation and safety implications. The worldwide maintenance, repair, and overhaul market (MRO) is expected to grow at a compound annual growth rate (CAGR) of 3.8% reaching about $66 billion by the year 2020. The roadmap was published and copies are available online at www.manufacturing.edu. Pictured on right is a technician completing a scarf repair on an Airbus 350. The CAIIAC roadmap focuses on composite joining and repair because it is a highly-underserved market with significant growth momentum, and has transportation and safety implications.

Cell Manufacturing

GTMI continues to support the new Georgia Tech Marcus Center for Therapeutic Cell Characterization and Manufacturing and the NSF-funded Engineering Research Cell for Manufacturing Technologies that will develop processes and techniques for ensuring the consistent, low-cost, large-scale manufacture of high-quality living cells used in cell-based therapies. The therapies developed by the center will be used for a variety of disorders such as cancer, lung fibrosis, autism, neuro-degenerative diseases, autoimmune disorders and spinal-cord injury – as well as in regenerative medicine. Cell therapy is the fastest growing segment of regenerative medicine and also the largest. Globally, the stem cell therapy market is expected to be worth US $180 billion by 2030. The T cell therapy market alone will be worth US $30 billion by 2030. The emerging cell therapy industry is challenged to enable scalable manufacturing of therapeutic cells as an effective, safe, reproducible, and affordable pharmaceutical product with standardized characterization and quality control. A necessary condition for fast growth and significant impact of this emerging industry is robust end-to-end supply chains. In fact, a key barrier to such growth identified by industry in the National Cell Manufacturing Consortium, an industry-academia consortium funded by the Advanced Manufacturing Technologies program of the National Institute for Standards and Technologies, is the absence of supply chain management and process modeling for cell therapy products. Pictured on right, the NSF Engineering Research Center for Cell Manufacturing Technologies (CMaT) held an official kick-off meeting on November 13-14, 2017. There were over 130 participants including NSF, industry partners, and faculty and students from the partner institutions: Georgia Tech, University of Georgia, University of Wisconsin-Madison, University of Puerto Rico at Mayaguez, University of Pennsylvania, Emory University, Gladstone Institutes, and Michigan Technological University. Get more information at: http://cellmanufacturingusa.org/
3D Printed Left Heart Phantom with Soft Robot Grips to Simulate Heart Pumping

GTMI and Piedmont Hospital in Atlanta, Georgia, partnered on a project to create 3D printed left heart phantoms with soft robot grips that are made from a CT scan of the patient’s heart. The resulting phantom is an exact replica of the patient’s left heart. The soft robot grips are designed to press and twist the left ventricle like the real cardiac muscles. Researchers can use the printed left heart to simulate the blood flow within the left heart under different physiological conditions. For example, the phantom can be used to predict the Left Ventricular Outflow Tract (LVOT) after Transcatheter Mitral Valve Replacement. The next step will be to have the models printed before the procedure for inclusion in the pre-surgery planning phase. *Pictured on right is the inside of the 3-D printed model of a human heart valve. Black regions represent the location of actual calcium deposits.*

New Composite Forming Technology Saves Time and Money

The WEAV3D composite forming machine combines weaving and composite consolidation into an automated, continuous process that reduces waste, cycle time, and material handling costs. The WEAV3D composite forming machine is designed to scale through integration with existing high-volume composite processes, including continuous lamination, D-LFT compression molding, and injection molding. The composite lattice coming off of the WEAV3D machine can be trimmed and overmolded in a continuous production line, enabling cycle times of five minutes or less. Composite parts fabricated using this technology can reduce part cost by up to 50 percent when compared to carbon fiber composites formed using traditional methods. The WEAV3D composite forming machine can process a wide range of continuous fiber-reinforced thermoplastic tapes, with melt temperatures up to 400° C. The machine allows the user to vary weave pattern, lattice density, and tape-type (carbon, aramid, and glass), enabling complete control over the strength, stiffness, and cost of the final part. *Pictured above is the WEAV3D composite forming machine prototype and the composite lattice material.*

Additive Manufacturing for Bio-Engineering Research (AMBER) Lab

The mission of the AMBER Lab is to leverage the most recent additive manufacturing technologies to accelerate and scale up existing bio engineering applications and innovate new designs and methods that are unachievable via conventional methods. The lab is housed at the Advanced Manufacturing Pilot Facility located on the Georgia Tech campus. *Pictured on right is the AMBER Lab where researchers are working on projects like “Voxelated Tissue Engineering with 3D Bioprinted Auxetic Metamaterial.”*
Additive Manufacturing

The Direct Digital Manufacturing (DDM) lab continued to make advances in Scanning Laser Epitaxy (SLE), a metal 3D printing technique developed at Georgia Tech for advanced high-temperature nickel-base superalloys. The research was performed in a project titled “Cyber-enabled direct digital manufacturing of gas turbine hot-section components” sponsored by the Office of Naval Research under a program titled Cyber-enabled Manufacturing Systems for Direct Digital Manufacturing (CeMS-DDM). The focus of this effort is on investigating the science and technology necessary for producing crack-free and defect-free structures through laser powder bed fusion (LPBF) additive manufacturing techniques across a range of nickel-base superalloys used in the manufacture of turbine engine hot-section components such as blades, vanes and shrouds. Such alloys were previously known to be non-weldable and highly crack-prone when processed through conventional welding or powder bed fusion techniques. This research, however, successfully demonstrated the capability of producing fully dense crack-free structures through careful control of processing parameters. The alloys investigated included popular hot-section alloys such as equiaxed IN1001 and MAR-M2472, and single-crystal CMSX-43 and René N54. Extensive microstructural characterization of the alloys processed through SLE showed highly refined microstructures with significantly reduced elemental segregation compared with conventionally cast counterparts, resulting in superior compositional homogeneity and hardness properties.

Internet of Things for Manufacturing (IoTfM)

The third annual GTMI Internet of Things for Manufacturing (IoTfM) Workshop in November 2017 welcomed over 100 participants for a day of important updates on current industry projects, research and news about how the Internet of Things continues to impact manufacturing. According to this year’s presenters most people have a general idea of what IoT is, but there still exists challenges in how to effectively implement an IoT plan. The reason, they say, points to deciding what data to collect and how to use it to improve efficiencies in process and quality in products. Several speakers also called for improved collaboration between IT departments, engineering staff and those on the shop floor to successfully implement an IoT strategy. Participants heard from major industry contributors to IoTfM, including AGCO, the Air Force Research Laboratory, BMW, EATON, EXIDE Technologies, Georgia Tech Research Institute, Intel, National Instruments, Rockwell Automation, Shaw Floors and Universal Robots. The workshop also included ample time for attendees to network and get to know their peers in other areas of industry. The day after the workshop, representatives of various manufacturing sectors were invited to a roundtable to share issues and ideas on how to move IoT to the next level.

Precision Machining

Research on Precision Machining is built around the technical expertise and interests of involved faculty members. Research activities in this topic area include basic research aimed at the fundamental understanding of material behavior in machining of advanced materials such as aerospace alloys, modeling and simulation of material removal processes, applied research in novel low-cost sensors and process monitoring, and new process development for advanced materials systems. Recent advances in high performance computing, low cost sensing and high bandwidth connectivity have enabled the precision research to extend into the realm of digital manufacturing, specifically focusing on big data, advanced prognostics and diagnostics, cyber-enabled manufacturing, and the digital twin for machines and processes. Research in these areas is funded by industry and government sponsors.
Advanced Manufacturing Pilot Facility Now in Operation

GTMI continues to make progress as the leader in expanding the Georgia Tech manufacturing innovation neighborhood. The Advanced Manufacturing Pilot Facility (AMPF) opened officially in June 2017 as a place that enables teams of academic, industrial and government experts to develop, scale and deploy next-generation technologies that promote innovation and allow technical, business and economic strategies to evolve in strengthening and growing the manufacturing ecosystem. It provides opportunities for student engagement via internships and cooperative work positions. As a pilot facility, pre-commercial production systems that employ new technologies can be realized, producing small volumes of new technology-based products, mainly for the purpose of learning about the new technologies. Delta and Boeing were the first to establish a presence at AMPF. Delta provided generous funding to refurbish the facility prior to its opening.

FY2018 Financials

<table>
<thead>
<tr>
<th>Source of Funding</th>
<th>Percentage of Budget</th>
</tr>
</thead>
<tbody>
<tr>
<td>State Funding</td>
<td>30%</td>
</tr>
<tr>
<td>Federal Funding</td>
<td>14%</td>
</tr>
<tr>
<td>Industry Partnerships</td>
<td>56%</td>
</tr>
<tr>
<td>Industry Partnerships</td>
<td>56%</td>
</tr>
</tbody>
</table>

GTMI External Advisory Board (EAB)

- **Lane Ballard** - Vice President, Materials and Manufacturing Technology, Boeing Research and Technology
- **Gretchen Corbin** - Commissioner, Technical College System of Georgia
- **Wayne Eckerle** - Vice President, Corporate Research and Technology Integration, Cummins, Inc.
- **Thomas Felis** - Vice President of Innovation, ThyssenKrupp Elevators Americas
- **David Garrison** - Senior Vice President, Engineering, Quality Planning and Logistics, Delta
- **Theresa Kotanchek** - EAB Chair - Chief Executive Officer, Evolved Analytics, LLC
- **Rob Maskell** - Chief Scientist, Cytec Engineered Materials/Solvay
- **Michael McGrath** - Consultant and Technical Advisor, McGrath Analytics, LLC
- **David Morgan** - Executive Vice President Operations, Shaw Industries, Inc.
- **John D. Russell** - Technical Director, Manufacturing and Industrial Technologies Division, Air Force Research Laboratory
- **Charles Wessner** - Faculty, Georgetown University

GTMI Internal Advisory Board (IAB)

- **Chris Downing** - President, Enterprise Innovation Institute
- **Karen Fite** - Director, GaMEP, Enterprise Innovation Institute
- **Hamid Garmestani** - Professor, Materials Science and Engineering
- **T. Russell Gentry** - Associate Professor and Coordinator of M.S. and Ph.D. programs in the School of Architecture
- **Soumen Ghosh** - Professor, College of Business
- **Diana Hicks** - Professor, School of Public Policy
- **Shreyes Melkote** - Morris M. Bryan, Jr., Professor, Mechanical Engineering
- **H. Douglas Nation** - Principal Research Engineer, Electronic Systems Laboratory, GTRI
- **Krishnendu Roy** - Carol Ann and David D. Flanagan Professor, Director of the Center for Immunengineering
- **Massimo Ruzzene** - Professor, Aerospace Engineering
- **Chelsea White** - IAB Chair - Schneider National Chair in Transportation and Logistics, School of Industrial and Systems Engineering
- **Jeannette Yen** - Professor, School of Biology

All members of the IAB are Georgia Tech faculty.
Much of GTMI’s success comes from active collaboration with industry partners who help drive research outcomes to produce results that are readily implemented in the industrial sector. GTMI works with companies of all sizes on short- and long-term projects, ranging from several months to a few years. Our partners provide vital financial support and play an active role in GTMI’s strategy to efficiently deliver innovative concepts from the laboratory out into the marketplace. In addition to strategic involvement in projects, GTMI’s industry partners enjoy many benefits, including:

- Access to lab demonstrations and visits prepared and scheduled through the partnership
- Meetings with GTMI faculty, students, and staff to discuss research problems
- Networking events to recruit students for internships, co-op positions, and employment
- Access to results of all non-proprietary research and to our prototyping facility

In 2017, GTMI supported more than 65 companies and non-governmental organizations, academic and government organizations. Our partners are:

- Association of Manufacturing Technology
- Autodesk, Inc.
- The Boeing Company
- Clean Hands Safe Hands
- Cytec Solvay Group
- The Coca-Cola Company
- Ford Motor Company
- Georgia Automotive Manufacturing Association
- Generation Orbit Launch Services, Inc.
- General Dynamics
- IronCAD
- Molyworks
- OMRON
- Siemens
- Steelcase
- ThyssenKrupp
- Tongtai
- Warner Robins Air Force Base

Strategic University Partnership Provides Model for Multi-Disciplinary Work

The Georgia Tech-Boeing Strategic University Partnership is a multi-disciplinary program that funds early-stage basic and applied research projects in manufacturing-related topics of interest to Boeing. The Strategic Universities program is run out of Boeing Research & Technology in Missouri. The partnership was established in 2007 and is managed by GTMI. To date, this $14.3M+ program has supported research on a broad range of manufacturing topics, including systems-based design for manufacturing, advanced manufacturing processes, robotics, automated material handling, sensing, and materials aspects of manufacturing. Faculty from units in the College of Engineering, College of Computing, and the Institute for Robotics and Intelligent Machines participate in the program. The program has also supported faculty from Civil Engineering, Electrical and Computer Engineering, GTRI, and GTMI. Georgia Tech and Boeing recently initiated a translational research project on Accurate Robotic Machining for Large Scale Assemblies at the Delta Airlines Advanced Manufacturing Pilot Facility (AMPF). The project involves GTMI-affiliated Georgia Tech faculty and students, GTRI researchers, and Boeing engineers stationed at the Boeing Manufacturing Development Center located in the AMPF.