From the GTMI Executive Director

During 2016, the Georgia Tech Manufacturing Institute (GTMI) made progress in 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 2016. I hope you enjoy reading about GTMI as much as we enjoy working to make progress in advanced manufacturing.

Ben Wang, Executive Director, GTMI

WORKFORCE DEVELOPMENT

One aspect of developing Georgia Tech’s (GT) innovation neighborhood is to ensure that we have the workforce of the future. For years, GTMI has offered numerous ways for students to gain critical knowledge and hands-on experience that is necessary to succeed in a multidisciplinary manufacturing environment. We offer: Manufacturing Education Program (MEdP) consisting of the Manufacturing Certificate, International Option, and Manufacturing Scholarships; Language, Culture and Advanced Manufacturing Summer Immersion Program; REVAMP NSF REU; and Undergraduate Research Opportunities. GTMI has also partnered with the Technical Colleges System of Georgia and the Georgia Department of Economic Development on a program to provide opportunities to technical college students to work hand in hand with Georgia Tech faculty and students. Another of our starship programs is Research Experience for Student Veterans in Advanced Manufacturing and Entrepreneurship (REVAMP). This year we welcomed 11 students representing veterans, women and minorities. Funded by the National Science Foundation (NSF) as a Research Experience for Undergraduates (REU) summer site, the program trains undergraduate students in the fundamental principles of advanced manufacturing science and technology, and entrepreneurship. Picture above right is the 2016 REVAMP/REU class.

Manufacturing Scholars Program

In 2016, two students were chosen as the first to participate in GTMI’s Manufacturing Scholars Program. The program is leveraging critical partnerships between GTMI, GT faculty, and sponsoring manufacturing companies to accelerate the development of awareness, interest, skills, and knowledge in manufacturing for GT undergraduates. Pictured at right are Adam Gordy and Rachel Beyersdorfer. Adam is working with Delta on a project called, “Surface Characterization Technique after Surface Treatment/Preparation for Composite Bonding.” Rachel is working with Sikorsky on a project called, “Augmented Reality-based Automated Fastener Inspection on Helicopter Structures.” GTMI plans to grow this program and actively recruit participants throughout the year.
Industry Partners Symposium and Distinguished Lecture - Each year, GTMI hosts a symposium devoted to addressing manufacturing challenges. In September 2016, GTMI welcomed more than 100 stakeholders to hear from this year’s Distinguished Lecturer Jeff Wilcox, Lockheed Martin’s vice president of engineering and program operations. He spoke on the “Future of Manufacturing.” The topics for the afternoon session included leveraging the GT innovation ecosystem, and the future of the makers movement. Participants also heard a keynote address on biomedical applications of additive manufacturing given by Gautam Gupta of 3D Systems. *Pictured at right is Steve Cross (on left), executive vice president of research at Georgia Tech, and Jeff Wilcox from Lockheed Martin.*

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.

Transforming world-class research into real-world value for industry partners is one of GTMI’s most important goals. Much of our 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 laboratories for demonstrations and visits prepared and scheduled through the partnership
- Meetings with GTMI faculty, students, and staff to discuss research problems
- Meetings with students to discuss opportunities for internships, co-op positions, and permanent employment
- Access to results of all non-proprietary research and to our prototyping facility

In 2016, GTMI supported more than 65 companies and non-governmental organizations, academic and government organizations.

Our Partners
- 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
- OMRON
- Siemens
- Steelcase
- ThyssenKrupp
CAIIAC, the Consortium for Accelerated Innovation and Insertion of Advanced Composites To Focus Efforts 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 nearing completion. 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 first roadmap focuses on Composite Joining and Repair since it is a highly-underserved market, but it has a significant growth momentum, a huge economic impact, as well as 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 $65 billion by the year 2020. Pictured above, center, is Chuck Zhang, a professor in the Stewart School of Industrial and Systems Engineering, working with students to inspect a composite part at a Delta Air Lines repair facility.

Cell Manufacturing

GTMI continues to support the new Georgia Institute of Technology research activities located in the Engineered Biosystems Building and Parker H. Petit Institute for Bioengineering & Bioscience (IBB) 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 center was established with a generous grant from the Atlanta based Marcus Foundation, along with funds from the Georgia Research Alliance and Georgia Tech for a total investment of $23 million. 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. Pictured at right is a small-scale bioreactor that is the model for how cell manufacturing exists on the industrial scale now. It illustrates the challenge of scaling up these revolutionary therapies for the masses.
3D Printed Heart Valves With Sensors Prove Useful for Surgeons

GTMI and Piedmont Hospital in Atlanta, Georgia, partnered on a project to create 3D printed heart valves with sensors that are made from a CT scan of the patient’s heart. The resulting valve is an exact replica of the patient's valve. Surgeons can use the printed valve to determine a plan of action for the surgery that includes selecting and positioning the appropriate sized stent. So far, the researchers have printed almost two dozen heart valve models based on actual patient imaging. They are now using images and data from patients who have already undergone the procedure to analyze how well the models can predict the success of the prosthetics. The next step will be to have the models printed before the procedure for inclusion in the pre-surgery planning phase. Pictured at right are Kan Wang, on left, a GTMI researcher; and Zhen Qian, chief of Cardiovascular Imaging Research at Piedmont Heart Institute, inspecting a printed heart valve.

Model-Based Systems Engineering (MBSE)

Researchers in GTMI’s Model-Based Systems Engineering Center have developed methods, models, and algorithms to enable a standardized description of large scale factories and supply chains, and to automate the translation from this standard description into optimization and simulation models. The approach involves the development of a comprehensive reference model (or meta-model) for the application domain, the creation of appropriate re-usable analysis component libraries, and the development of a transformation methodology based on “software factory” concepts from software engineering. Recent projects include:

- Working with NIST to develop the next generation smart manufacturing operations controller
- Applying MBSE concepts to the design and control of high volume small parts order fulfillment
- Working with Boeing to create a framework for consistency management in federated model repositories
- Working with Ford to enable automated modeling and simulation of different drivetrain configurations
- Providing short courses to help industry and government organizations accelerate their MBSE/SysML applications

Manufacturing of Additively Generated Interlaced Composites (MAGIC)

Across the world, countries are working to reduce their carbon emissions. One of the ways the United States is seeking to reduce its carbon emissions is through the Corporate Average Fuel Economy standards, which set year-over-year targets for the fleet average fuel economy of every car manufacturer that sells in the United States. High performance composites have long been used in aerospace to improve fuel economy through vehicle lightweighting, but existing composites manufacturing technologies are too slow and too expensive for automotive applications. Georgia Tech has developed a manufacturing machine that combines two batch processes, weaving and composite consolidation, into a single continuous process, resulting in high throughput and low process costs. This composite manufacturing technology will make high performance composite production fast and cost-effective, allowing automotive OEMs to meet the federally mandated fuel economy requirements. In the past year, funding from the Georgia Research Alliance was secured to build a lab-scale prototype of an alternative design that offers the potential of high throughput formation. A provisional patent on this new design was filed in May of 2016, and is expected to be converted to a non-provisional filing. Additionally, team members were awarded funds from the National Science Foundation to participate in the Innovation Corps program. This program helps university researchers assess the commercial viability of their technologies.
Additive Manufacturing
Atlanta-based DDM Systems continues evolving the LAMP™ System CPT6060, a commercial tool that makes ceramic parts directly from a computer-aided design file. The machine uses advanced 3D printing technology specifically designed to make ceramic cores and molds used by foundries to cast highly demanding and complex parts such as aircraft turbine engine components. The company was lauded by international industrial technology leaders for the device’s faster and less costly method of making such parts. In 2016, it was one of five finalists, and the first and only one from the United States, nominated for the prestigious HERMES Award presented annually at the Hannover Messe international industrial fair. Pictured above is Suman Das, Professor of Mechanical Engineering and co-founder of the company, holding a piece made by the LAMP System CPT6060.

Internet of Things for Manufacturing (IoTfM)
The second annual GTMI Internet of Things for Manufacturing (IoTfM) Workshop in November 2016 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. Participants heard from major industry contributors to IoTfM, including AT&T IoT Solutions, Continental Automotive GmbH, Corning, DecisionIQ, JTEKT North America, Nestlé Purina Atlanta, PricewaterhouseCoopers, Siemens USA, Stanley Black and Decker, Thyssenkrupp and Wipro. At an industry roundtable discussion the next day, participants discussed opportunities and challenges in implementing IoT. The group agreed that, among other things, there is great revenue potential in IoT, it will take great investment to fully implement it, the cloud will have an enormous influence and that security is a concern. Pictured at right is Thomas Felis, Thyssenkrupp, explaining the company’s global IoT efforts.

Tribology
A $400K Defense University Research Instrumentation Program (DURIP) grant is enabling research to identify problem areas that may arise within a launcher from the cyclic loading of repetitive fire. New equipment provided by the grant is being used as a basic research tool to understand the wear of materials under cyclic loading, where extreme pressure, temperature and acceleration are present. It will also offer guidance into the development of wear prevention and control criteria of materials experiencing extremely high current densities.

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.
Facilities

GTMI is making progress as the leader of the Georgia Tech manufacturing innovation neighborhood, consisting of academic and interdisciplinary labs for basic research, and a pilot facility for translational development. These basic research labs are led by faculty, powered by bold ideas, focusing on Technology Readiness Level (TRL)/Manufacturing Readiness Level (MRL) 1-3 challenges. The other component of the GT manufacturing innovation neighborhood is the Advanced Manufacturing Pilot Facility (AMPF), where faculty, students, and GT industry partners are co-located and developing and testing solutions to TRL/MRL 4-7 challenges.

Financials

(Five-Year Averages FY2012 - FY2016)

Industry Partnerships = 71.2% of budget

Federal Funding = 15.4% of budget

State Funding = 13.4% of budget

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
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Jeannette Yen - Professor, School of Biology

All members of the IAB are Georgia Tech faculty.
GTMI partners with the Enterprise Innovation Institute, including the Advanced Technology Development Center, Minority Business Development Agency, Georgia Manufacturing Extension Partnership, and Venture Lab. Leveraging our network, we provide manufacturing expertise, networking opportunities and access to core facilities and students. This strong partnership is a key component to helping companies accelerate innovation from the lab to the marketplace.

GTMI and Technical Colleges in Georgia Are Preparing Students for the 21st Century Advanced Manufacturing Workforce

Critical to the U.S. manufacturing renaissance is a skilled workforce. GTMI has a robust partnership with the Technical College System of Georgia (TCSG) and the Georgia Department of Economic Development (GDEcE). Programs already in place provide opportunities for two-year TCSG students to work with Georgia Tech undergraduate and graduate students, and post-doctoral fellows. Georgia Tech faculty and staff supervise all student teams as they work on real-world challenges. This model directly and effectively addresses the workforce challenges facing Georgia and the US.

Pictured at left, TCSG student Chris Gilmore works with GTMI staff and faculty in the GTMI Service Center.

Georgia Tech-Boeing 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 St. Louis, Missouri. The partnership with Georgia Tech 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 participation in the program is drawn from several academic units in the College of Engineering, including Aerospace Engineering, Materials Science and Engineering, Mechanical Engineering, Industrial and Systems Engineering, and the College of Computing/IRIM. In prior years, the program also supported faculty participants from Civil Engineering, Electrical and Computer Engineering, GTRI, and GTMI. The overarching goal of the program is to collaborate with Boeing on the research and development of next generation manufacturing technologies (both hardware and software), which will feed into the factory of the future for aerospace manufacturing. Another significant aspect of the program is education and training of students through research aimed at solving technical challenges pertinent to the aerospace industry. The program fosters close and frequent interactions between Georgia Tech faculty and students and Boeing engineers and researchers. Finally, the program strives to transition innovations stemming from the faculty-driven research projects to Boeing.