From the GTMI Executive Director

This 2015 Annual Report highlights the progress of the Georgia Tech Manufacturing Institute (GTMI). Over the last year we have continued our many collaborations across the Georgia Tech campus, the state, the United States and abroad to fulfill three major goals:

- to leverage the expertise of Georgia Tech researchers, faculty and students
- to accelerate the time it takes to move manufacturing technology from the lab to the marketplace
- to engage our many stakeholders in the process

My colleagues and I welcome all opportunities to share what we are doing. In May, GTMI successfully completed a five-year review of the organization and its programs. Much of what we shared with the committee appears on these pages. I hope you enjoy reading about our accomplishments.

Ben Wang, Executive Director, GTMI

Workforce Development: Preparing Students and Professionals for Manufacturing Innovation

GTMI’s educational programs give students the critical knowledge and hands-on experience necessary to succeed in a highly competitive, multidisciplinary manufacturing environment. We offer the following programs: 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. In 2015, GTMI hosted its second class of Research Experience for Student Veterans in Advanced Manufacturing and Entrepreneurship (REVAMP) students. The program is 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 about the transition of basic discoveries in manufacturing science into innovative commercial products and processes. Pictured at right are the 2015 REVAMP participants.

Manufacturing Scholars Program

The new Manufacturing Scholars Program is designed to provide top Georgia Tech (Tech) undergraduate students with a combination of project- and industry-based experiential learning opportunities in manufacturing. The program will leverage critical partnerships between GTMI, Tech faculty, and sponsoring manufacturing companies to accelerate the development of awareness, interest, skills, and knowledge in manufacturing for Tech undergraduates.
Thought Leadership
GTMI engages stakeholders in broadening the scope and understanding of manufacturing and manufacturing challenges in a number of ways:

AMP 2.0 - Leaders from Tech remain involved in President Obama’s Advanced Manufacturing Partnership (AMP) that focuses on different aspects of manufacturing competitiveness. GTMI continues to support Tech President Dr. G. P. “Bud” Peterson, Tech Executive Vice President of Research Dr. Steve Cross and other faculty with their AMP endeavors.

Industry Partners Symposium - Each year, GTMI hosts a symposium devoted to addressing manufacturing challenges. In November 2015, GTMI welcomed more than 150 stakeholders to hear from Michelle Gloeckler, Walmart executive vice president, who addressed accelerating U.S. manufacturing. The afternoon presentations focused on: manufacturing and economic policy, the Manufacturing Universities Act of 2015, and manufacturing workforce and education. Participants also heard a keynote address on biomedical applications of additive manufacturing given by Professor Scott Hollister from the University of Michigan. Pictured at right are (l to r) Dr. Steve Cross, Georgia Tech executive vice president for research; Michelle Glockler, Walmart executive vice president of Consumables and Health and Wellness and U.S. Manufacturing Lead; and Dr. Ben Wang, GTMI executive director.

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.

Industry Partnerships Fuel GTMI
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. Research projects are defined in association with partner companies and when initiated, ongoing project interaction is maintained between the sponsoring company and GTMI. Our partners provide not only vital financial support, but they also play an active role in GTMI’s strategy to efficiently deliver innovative concepts from the laboratory to 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 2015, GTMI supported more than 65 companies and non-governmental organizations, academic and government organizations.
Making Untreatable Diseases Treatable
Researchers from GTMI, the Parker H. Petit Institute for Bioengineering and Bioscience, and the Wallace H. Coulter Department of Biomedical Engineering are collaborating with industry leaders and government and regulatory agencies to make the incurable curable for everyone in need. Researchers are working to develop leading-edge manufacturing processes to scale up cell manufacturing to make it repeatable, reliable and affordable. The goal is to increase cell production scale by three orders and reduce cost per dose by two orders of magnitude. More than 30 companies and federal agencies like the NIH, FDA, NSF, departments of Defense and Commerce and not-for-profit foundations are collaborating with Tech on a national roadmap.

Consortium for Accelerated Innovation and Insertion of Advanced Composites (CAIIAC)
GTMI led an industry consortium (CAIIAC) to create the first national composites joining and repair (CJAR) technology roadmap (sponsored by a NIST AMTech Program). This research is critical in cutting costs on the repair and maintenance of aircraft and other products made from composites. The total cost over the lifetime of an airframe for all Airbus A350 and Boeing 787 composite aircraft delivered by 2021 is estimated to be in the range of $34.1 billion. To meet this demand, GTMI is developing innovative technologies in computational modeling and big data, digital CJAR, smart monitoring/prognostics, and non-destructive evaluation. GTMI is in partnership with more than 40 companies and government agencies including Airbus, Boeing, Chrysler, Delta, Oak Ridge National Laboratory and others to solve the CJAR challenge.

3D Printed Heart Valves With Sensors Prove Useful for Surgeons
There is a new tool for surgeons to use before operating on a patient’s heart valve that can improve the success rate of inserting a stent in a damaged valve. 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. The diagram at right shows how the printed valve helped surgeons select and insert a stent for this patient that doesn’t leak, which can happen when surgeons have to use the “best guess” method. Using the printed valve gives surgeons a complete model that mimics the actual heart valve and better information from which to make decisions.

Model-Based Systems Engineering (MBSE)
As modern factories grow in both complexity and financial investment, a critical factor for success is “smart manufacturing operations management,” i.e., the ability to respond in real-time to contingencies on the factory floor. A major hurdle to realizing this ability is integrating shop floor systems, like SCADA and MES, with artificial intelligence and operations research. With funding from the National Institutes of Science and Technology (NIST), researchers in GTMI’s Model-Based Systems Engineering Center are developing a “smart manufacturing operations management controller” architecture, which is reusable, provides a platform for implementing a variety of control strategies, and enables “plug and play” decision support modules for control. This novel approach to smart manufacturing operations management enables automation of routine operations management/control decisions, freeing shop floor managers to focus on higher level issues, and avoiding costly delays and non-productive time on bottleneck resources.
Experimenting with the Future of Mobility

The automotive industry is facing new opportunities and challenges with the advent of autonomous vehicles, increased connectivity, and customer expectations of increased and easier mobility throughout the world. As part of Ford’s Smart Mobility plan, researchers at Georgia Tech are conducting experiments to help take Ford to the next level in the areas of connectivity, mobility, autonomous vehicles, the customer experience and big data. In the Remote Repositioning experiment, researchers outfitted a golf cart with technology that allows it to be driven remotely via a streaming 4G LTE cellular phone connection using a remote control set-up similar to a video arcade system. This technology could be used, for example, to relocate a car from where a driver left it to where a car needs to be for the next driver or customer. The technology could also lead to a more affordable and widely available valet parking service. In the Parking Spotter experiment, existing sonar and radar technology already available on Ford vehicles was used to collect data and map parking information on the go. Vehicles act as roving probes and can map out open parking spots. This information is then uploaded to a cloud-based location, which other drivers looking for parking can access. Parking Spotter has the potential to reduce parking anxiety and increase parking efficiency, especially in dense urban areas.

Manufacturing of Additively Generated Interlaced Composites (MAGIC)

Conventional manufacturing techniques are unable to meet the anticipated design requirements of the high performance composites industry, particularly for aerospace and automotive applications. This is due to limitations in conventional manufacturing processes. These limitations make it difficult to create a load-customized composite by manipulating fabric geometry, fiber orientation, and matrix/fiber materials within a composite structure. To address the problem, GTMI is developing a novel compositing process and building a prototype printer system capable of forming 2D and 3D woven continuous fiber reinforced composite structures with locally customized strength and stiffness properties. Our technology enables engineering the fabric structure of the composite to maximize reinforcement along the load path and minimize weight elsewhere. This process allows for the production of composite structures that are lighter but still the same strength. Reduction of a composite’s mass without sacrificing its load carrying capacity will reduce fuel consumption and increase payload for air/spaceframes. In the past year, we have constructed a proof of concept and filed a non-provisional patent covering this technology. Work is currently progressing on a lab-scale prototype.

GTMI Gives a Boost to Georgia Tech Student/Alumni Led Atlanta Startups in 2015

As a result of financial support provided by the Georgia Center of Innovation for Manufacturing, a program under the Georgia Department of Economic Development, GTMI was able to provide technical and resource assistance to local startups run by Georgia Tech undergraduate students and recent alumni. The following is one of several examples:

Collaboration with ARMR Systems: First Wearable Hemorrhage Control System

ARMR Systems, led by two recent graduates of Georgia Tech, collaborated with GTMI on a medical device prototype known as the Arterial Compression Tool (ACT). The ACT is integrated into a soldier’s uniform and weapon and designed to quickly and reliably stop a junctional hemorrhage. A junctional hemorrhage, bleeding from the areas at the junction of the trunk and its appendages, is a difficult problem in trauma and is the leading cause of death of U.S. soldiers overseas. Regular tourniquets don’t work for these types of wounds because they cannot give the right kind of pressure around the extremity of the wound. GTMI provided design advice for functionality and manufacturability, and used 3D printing and machining services to fabricate several prototypes. The project funding also enabled in-vivo testing of the prototypes in cadavers provided by Georgia Tech’s T3 Labs. The cadaver testing was successful and showed marked performance improvement over the traditional tourniquet. The preliminary data set and video evidence has sparked the interest of investors and military branches across the country.
Additive Manufacturing

GTMI is a leader in research and commercialization of innovative and advanced additive manufacturing technologies including:

- **LAMP technology** - disrupts the precision metal casting industry through reductions in manufacturing costs of over 60 percent and lead time of over 90 percent.

- **SLE technology** - disrupts the MRO industry by restoring previously non-repairable components at less than 50 percent of the cost of replacement parts while dramatically reducing inventory and down-time.

Atlanta-based DDM Systems is commercializing both under exclusive license from Georgia Tech. Leading OEMs and industrial companies are evaluating the technologies with an aim towards use in production. *Pictured above is Suman Das, who leads the Direct Digital Manufacturing Lab.*

Factory Information Systems: First GTMI Internet of Things for Manufacturing (IoTfM) Workshop Held

The Internet of Things is big business and could mean trillions in saved or new revenue for manufacturers. With a desire to ramp up collaboration efforts for IoTfM, GTMI hosted its first workshop on the topic in November 2015. More than 100 participants from companies like AGCO, Accenture, Amazon Web Services, AMT, Cimetrix, Cisco, Dassault Systems, GE Power and Water, IBM, Metalforming, Microsoft, SAP, Steelcase, Verizon and Wipro attended. A letter of intent was submitted to the National Science Foundation (NSF) after the workshop to submit an NSF Industry and University Cooperative Research Program (I/UCRC) proposal on the topic of IoTfM in 2016.

Tribology: Instrumentation for the Electrothermomechanical Testing of Materials Under Cyclic Loading

GTMI acquired a $400K Defense University Research Instrumentation Program (DURIP) grant that will enable 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.

Seed Grants Accelerate Research

2015 marked the first year that GTMI awarded Cross Discipline Manufacturing Innovation (CDMI) Seed Grants. The program is designed to assist in launching research projects. The awards were for six-month projects. This year’s recipients were: 1) Christopher Saldana, GTMI; Angela Lin, Parker H. Petit Institute for Bioengineering and Bioscience (IBB); Robert Guldberg, IBB: “Hybrid Micro/Nano Direct-Write Texturing for Biomedical Implant Devices;” and 2) Alexey Tarasov, Institute for Electronics and Nanotechnology (IEN); Eric Vogel, IEN; Kan Wang, GTMI: “Aerosol-jet printed biological functionalization for flexible label-free nanoelectronic sensors.”

*Pictured: From left - Ryan Liu, graduate student; Chris Saldana, assistant professor of manufacturing; Angela Lin, graduate student; Eric Vogel, deputy director, IEN; Billyde Brown, GTMI research associate; and Kan Wang, post doctoral researcher.*
Facilities Improvements and Lab Augmentation

GTMI staff worked with the Tech facilities department on improvements and upgrades to the Callaway Manufacturing Research Building. The following are major projects and augmentations of labs.

- Third floor lighting was improved to increase the efficiency of the lighting in the hallways
- New HVAC computerized control system for more effective and faster response
- Construction of new steps in front of the building to address safety issues
- Augmentation of the Additive Manufacturing Lab at GTMI

Financials
*(Funding for January through December 2015)*

- New Industry Funds = 64.29% of budget
- New Federal Funds = 15.08% of budget
- Fiscal Year 16 State Funds = 20.63% 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
- **David Garrison** - Vice President, Engineering, Quality and Planning, Delta
- **Bill Kessler** - Chief Executive Officer, Palisades Enterprises, LLC
- **Theresa Kotanchek**, EAB Chair - Chief Executive Officer, Evolved Analytics, LLC
- **Rob Maskell** - Chief Scientist, Cytec Engineered Materials
- **Michael McGrath** - Consultant and Technical Advisor, McGrath Analytics, LLC
- **John D. Russell** - Technical Director, Manufacturing and Industrial Technologies Division, Air Force Research Laboratory
- **Peter Sigmon** - Vice President Innovation, Shaw Industries, Inc.
- **Charles Wessner** - Faculty, Georgetown University

GTMI Internal Advisory Board (IAB)

All members are Georgia Tech faculty

- **Chris Downing** - Associate Vice President, Enterprise Innovation Institute
- **Richard Fujimoto** - Regents' Professor and Chair, School of Computational Science and Engineering
- **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
- **Chris Paredis** - Professor, Mechanical Engineering
- **Krishnendu Roy** - Carol Ann and David D. Flanagan Professor, Director of the Center for Immunoengineering
- **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

The GTMI Service Center is an advanced manufacturing facility that partners with the academic and business community to assist in the design and development of prototypes. Pictured are Jasmine Burton, an alumnae of Georgia Tech, and Ben Coffman, manager of the service center. Burton turned to GTMI for assistance with building a prototype for her “Wish for Wash” initiative to provide sanitary toilets to underserved populations worldwide.
Collaboration Makes the Research World Go ‘Round

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 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. 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.

Partnerships That Help Companies Grow and Products Find a Market

GTMI partners with the Enterprise Innovation Institute, including the Advanced Technology Development Center, Minority Business Development Agency, Georgia Manufacturing Extension Partnership, and Venture Lab to help companies grow and prosper. We provide manufacturing expertise, networking opportunities and access to core facilities and students. This strong partnership is a key component to accelerate the commercialization of new technologies and processes into the marketplace.

Collaboration with Technical Colleges in Georgia Aims to Better Prepare Technical College Graduates for the 21st Century Advanced Manufacturing Workforce

Georgia manufacturers are having difficulty hiring enough employees with the appropriate skills to be successful in highly technical jobs. A partnership between GTMI and the Technical College System of Georgia (TCSG) was created in the fall of 2012 to improve the preparation of Georgia’s manufacturing workforce. A Manufacturing Competitiveness Committee (MCC) was formed to identify partnership opportunities that: 1) improve the competitiveness of Georgia manufacturers by enhancing the skill set and knowledge of the manufacturing workforce; and 2) identify pathways for enrollment of talented TCSG students into Georgia Tech engineering and other STEM-related programs. Through the work of the MCC a pilot program was developed for West Georgia Technical College (WGTC) students to intern at GTMI in advanced manufacturing research and technology transfer projects. The paid internship pilot program was funded at the level of $20K in July of 2013 by the Georgia Center of Innovation for Manufacturing. Its primary goal is to enhance the education of WGTC students by immersing them in complex, open-ended manufacturing research and technology transfer projects that require creativity, advanced problem-solving, critical thinking, and communication skills. Two interns have participated in the program to date, and each has been heavily engaged in a project in which they perform design work, manual and CNC machining, assembly, and other manufacturing operations to create mission-critical prototypes for Tech startup companies. The program is leading the way in developing opportunities for technical college students to be exposed to higher-level training and knowledge and is creating a new channel from which manufacturers will be able to hire highly-skilled workers. GTMI has submitted a proposal to train an additional 18 TCSG interns over the next three years and is currently awaiting a funding decision.