Manufacturing @ Tech
Point of View (POV) Paper

Interdisciplinary Manufacturing Research

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MOTIVATION OF POV PAPER
Georgia Tech (GT) has established seven Interdisciplinary Research Institutes (IRI). Each Institute has the mission to bring together campus-wide interdisciplinary research, strengthen external partnerships and maximize the societal impact aligned within the Institute’s assigned core research area.

This POV paper presents the mission, approach, grand challenges and next steps of Georgia Tech Manufacturing Institute, the GT IRI for the core research area of Manufacturing, Trade and Logistics.

MISSION
The Georgia Tech Manufacturing Institute (GTMI) was established to lead the core research area for Manufacturing, Trade and Logistics.

GTMI Mission
To sustain Georgia Tech’s global leadership in manufacturing innovation and societal impact by:

1. Developing and growing a community of interdisciplinary experts and external partners who are passionate about innovative manufacturing and how manufacturing will enhance the standards of living, innovation and national security;
2. Identifying and pursuing interdisciplinary research and grand manufacturing challenges that provides societal impacts;
3. Encourage and promote across-campus research and knowledge among manufacturing related disciplines that enable viewing manufacturing as a system.
Why is interdisciplinary in GTMI mission?

Dr. Stephen E. Cross, Executive Vice President for Research of Georgia Tech, recently discussed how manufacturing in the U.S. has transformed over the past 250 years via a series of disruptive events.

Reusable parts for muskets were introduced during the American Revolution. New machines to do hazardous tasks were introduced during the Industrial Revolution. Mass production was introduced in the early 1900s. A focus on quality as well as the Six Sigma quality and lean principles and tools were introduced during the last 50 years. More recently, new manufacturing business models, the Internet and globally distributed supply chains have entered and disrupted the manufacturing domain.

Dr. Cross noted that we are now on the verge of the next disruptive event in manufacturing:

“Viewing manufacturing as a system where all past innovations couple with across-culture collaboration, rapidly evolving technology, business practices, market needs, and political realities collide across an entire manufacturing enterprise”

Treating manufacturing as a system requires interdisciplinary research as part of the GTMI strategy.

Why are partners important to GTMI mission?

The President’s Council of Advisors for Science and Technology (PCAST) completed an industry-government-academia study of U.S. manufacturing challenges. This partnership of manufacturing stakeholders documented that the United States must do better in accelerating the translation from discovery to productization. An important finding of the PCAST was that today’s “Discovery – Translation – Product Build (DTB)” innovation chain is not producing the needed results, and it's time span is measured in decades.

Simply stated, today’s “DTB innovation chain” takes too long, is too costly, and the results are too random. Some might argue that these inefficiencies are indicative of a capitalistic market at work. Instead, the authors see that a major cause of the DTB inefficiency is rooted in the conflicting stovepipe cultures of “science push” and “business risk aversion.”

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1 Enterprise Transformation: Manufacturing in a Global Enterprise, Edited by W Kessler, L. McGinnis, and N. Bennett; Published by IOS Press in 2012

2 Report to the President on capturing domestic competitive advantage in advanced manufacturing (2012), The President’s Council of Advisors on Science and Technology.

An effective partnership between the disciplines of science, engineering and business must be incorporated within the GTMI manufacturing as a system strategy.

**Why is societal impact important to GTMI mission?**

There is an abundance of evidence that manufacturing is a critical sector of a nation’s economy. “Making things” is an important way to improve a society’s standard of living\(^4\) and makes a significant societal impact:

- 70% of US exports consist of manufactured goods,
- One manufacturing job produces up to six additional jobs in the general economy,
- 66% of U.S. scientists and engineers are employed in manufacturing,
- 90% of patents are credited to the manufacturing sector.

The inclusion of “societal impact” in the GTMI strategy requires incorporating the full spectrum of required disciplines. Realizing this impact is vital for readiness in the DTB innovation chain.

Achieving the outcomes of societal impact demands the availability of capable GTMI means (strategies, technologies, processes, skills, methods and tools, etc.). For GTMI to determine if the existing capabilities across GT are sufficient to achieve such societal impacts, two grand challenges were identified. GT and indeed the Nation must meet these two grand manufacturing challenges to significantly improve manufacturing national outcomes:

1. **Accelerate innovations that seamlessly create and deliver new customer values in the market place.**
2. **Discover here and build here in the U.S.**

**APPROACH TO MEETING GRAND CHALLENGES**

An illustrative view of the proposed future GTMI operating approach provides insights to the enhanced and new capabilities required for mission success — “pursue and achieve grand manufacturing challenges that provide societal impact”

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\(^4\) The Manufacturing Resurgence: What it could mean for the US Economy, Aspen Institute, March 2013
The future GTMI operating approach requires viewing manufacturing as a system that includes the complete DTB innovation chain and requires external partnerships to collaborate and provide their knowledge at each targeted phase – discover, translation and build.

Multidisciplinary readiness (xRL) is measured on a scale of 1 to 10 across the DTB innovation chain. A network of knowledgeable and motivated stakeholders must participate in measuring and prioritizing the process. High performance GTMI-industry-government-academia partnerships are required for mission success.

The GTMI established a set of GT and GTMI internal imperatives for success. Five of the imperatives are discussed in the following:

1. **Study and synchronize interdependencies among technology, manufacturing, business case and ecosystem within the “Discovery – Translation – Product Build” (DTB) innovation chain.**

   Technology or manufacturing readiness alone does not produce desired translational acceleration outcomes without a strong and focused market pull or a compelling business case. Without a robust domestic industrial base, the new product will not meet the “build here” challenge. Solving both grand challenges requires understanding and synchronizing the four acceleration pillars of technology, manufacturing, business case and ecosystem readiness.

   “Readiness” in the GTMI strategy has a socio and technical construct. Socio and technical readiness are evaluated from the perspectives of commitment, sufficiency
and potency (ref 3). Much of what is proposed is transformative and, in such efforts, the socio readiness is often more problematic than the technical readiness.

2. Institutionalize actionable, repeatable processes for accelerating the translation phase.
GTMI conducted an initial evaluation of the current DTB operating processes for each phase in the chain:

- Discovery phase (xRL 1-4) is “robust” in individual discipline research but lacking in scope and research on manufacturing as a system.
- Translation phase (xRL 4-7) is “random, ineffective and costly.” The phase lacks structured collaborations between sciences, engineering and businesses that are focused on impactful manufactured products.
- Product Build phase (xRL 7-10) phase is “good but declining” due to concerns within the manufacturing system, including economic development, national and state policies and regulations, adversity to risk, fact-based business cases, etc.

GTMI argues that the xRL 4-7 portion of the DTB innovation chain is key for establishing and validating GTMI capabilities for pursuing grand challenges.

3. Focus on multi-disciplinary bottlenecks within the DTB innovation chain by exemplar-guided collaboration
Product exemplars are “model” components that embody the “representative” or “at-risk” characteristics of a potential product. By using exemplars, rather than real product designs, companies are more willing to collaborate without disclosing proprietary information or sharing trade secrets. Additionally, in the xRL 4-7 phase, exact product specifications have not been finalized.

Figure 2, a radar chart depicting various readiness levels of a potential product exemplar, illustrates the power of the xRL innovative synchronized measurement methodology. For a specific technology and set of product exemplars, the enterprise stakeholders assess multi-disciplinary readiness in the “as-is” (yellow) state and also establish “to-be” goals (blue) for the next time span, and set capability and investment priorities.

In Figure 2, the technology and manufacturing “as-is” (yellow) readiness levels indicate process quality and supply chain readiness lags. However, business case and ecosystem readiness levels are actually the pacing issues as they slow the translation – the firm’s business cases are totally absent, and the regional ecosystem has not been defined, let alone engaged. The “to-be” (blue) readiness levels are projected by the enterprise stakeholders and are used to build a priority action plan to accelerate maturation toward the business case “tipping point” (xRL = 7).
4. Identify accurate measures and collect and analyze data focused on synchronized readiness and accelerated translation

GTMI proposes an innovative systems approach incorporating a measurement methodology that adopts available readiness level measures for technology and manufacturing, and establishes two additional measures of socio and technical readiness for business case and ecosystem. The resultant integrated readiness methodology, xRL, is foundational for driving acceleration from discovery to build.

Technology readiness levels (TRL) and Manufacturing Readiness Levels (MRL) are well established and adopted directly in the xRL measurement methodology. The purpose of business case readiness levels, or BcRL, is to accelerate the movement of discovery to the product build phase by systematically engaging the business community in understanding technology and manufacturing readiness for a potential product. BcRL also involves working with the business stakeholders to understand the business case framework and readiness. In evaluating the strengths of market pull, the approach focuses directly on the “business case” for the application target. To achieve “build here,” the xRL approach focuses on the regional ecosystem readiness since geographical proximity is important for creating an environment of collaboration and acceleration. The regional ecosystem readiness level, or EcRL, assessment spans all three phases of discovery, translation and productization. EcRL readiness levels identify and engage regional firms, capabilities, skills, training, etc. that can be leveraged and synchronized to accelerate and build toward meeting the grand challenges.
5. **Collaborate and socialize within all stakeholder groups within the manufacturing enterprise required to achieve the grand manufacturing challenges**

The GTMI pursuit of manufacturing grand challenges requires viewing manufacturing as a system and the participation of a number of external-to-GT entities and partners. The needed external partners depends on the intents of the GTMI efforts—some intents are internal to GT in building interdisciplinary capabilities, but any intent pursuing acceleration beyond the discovery phase of the DTB innovation chain requires external knowledge and capabilities. In general, the solution enterprise for pursuit of the GTMI grand challenges includes:

- **Policy & Regulation Makers (National, State and Local):** Set policies to enable the proposed integrated domestic industrial base readiness to achieve significant reduction in time-to-market with measurable impacts on economics, society and national security.

- **Industrial and Government Customers:** Develop accurate interdisciplinary metrics to enable accelerated translation from discovery to productization. Create a fact-based market pull by participating in creating business case frameworks and collaborating in defining multi-disciplinary measures of readiness.

- **Think Tanks (and other ecosystem contributors):** Actionable strategies and processes recommendations to Policy Makers for innovations in collaborations across universities, industry and government, and identify roles and responsibilities within the processes. An example is the recent Georgia Tech innovation of establishing a distributed network connected “Manufacturing College” within the GT University structure to leverage manufacturing-related capabilities across the GT campus. This innovation required Georgia Tech to establish the position of a Chief Manufacturing Officer to lead the embedded “Manufacturing College”.

- **Project Participants:** Participants will depend upon the specific project being pursued. For Projects aligned with the grand challenges, partnerships will be established and roles & responsibilities of each partner documented and agreed upon.

- **GTMI:** Access the GT distributed, networked “Manufacturing centers of excellence” to inventory the full range of multi-disciplinary research (science, engineering, business, policies, workforce development, economic development, manufacturing extension services, etc.). Establish and inventory technology readiness levels for selected topics. Align GTMI strategies and capabilities with the GTMI mission.
**NEXT STEPS**

- Begin deploying the proposed GTMI operating capabilities
  - External Advisory Board will review strategies.
  - Continue “building” the University-embedded, distributed and networked “Manufacturing centers of excellence” to create an inventory of the across-campus manufacturing-related research interests.
- Continue efforts on GTMI Industrial Partner Program (IPP) in preparation for discussions with IPP members about sponsoring projects aligned with the GTMI operating strategy and grand challenges.
- Pursue external funding and participation within AMP 2.0. Consider the GTMI in the topics of sustainability of AMP and policy/economic development opportunities.
- Consider direct engagement with the DOE and AF related to GTMI approach to sustainability and interdisciplinary socio-technical readiness as opportunities. Specifically, pursue a 6-12 month effort related validation and awareness of the GTMI operating approach:
  - Identify stakeholder groups that represent the four solution enterprise entities.
  - Visit each stakeholder to discuss and improve the clarity of the POV paper's grand challenges, proposed operating approach, technology and exemplar relationships, and stakeholder/entities roles and responsibilities.
  - Facilitate a stakeholder working session to design a collaborative beta-test of the operating approach that will be applied to a topic (technology and exemplars) of common high interest. The working session will identify actionable next steps to evaluate the innovative strategy.