Center for Advanced Manufacturing

1.0 Name of the proposed center
Center for Advanced Manufacturing

2.0 Background
Manufacturing is fundamentally important to the national security and economic strength of the United States and is an integral part of innovation, development, and growth in many industrial sectors that include aerospace, transportation, infrastructure, energy, medical devices, and consumer products. The country's globally competitive manufacturing sector translates inventions, research, discoveries, and new ideas into better or novel products and processes, resulting in economic growth. The largest manufacturing industries produce motor vehicles, ships, agricultural and construction machinery, semiconductors, and pharmaceuticals. However, the competitive status of U. S. manufacturing is increasingly challenged by the state-of-the-art technologies being developed by nations such as Japan, Germany, Korea, Taiwan, and China all of whom have varying degrees of sponsored program collaboration between research universities, national governments and private industries.

Advanced manufacturing utilizes innovative technology to improve products or processes and usually requires fewer but higher-skilled workers than traditional manufacturing. It is useful to conceptualize manufacturing in the context of materials, processes and logistics.

In its broadest sense, advanced manufacturing represents the confluence of new materials based on their atomic composition, elucidating their properties and performance at the nano-level, and the development of processes and equipment that leverage these enhanced properties in the bulk form to achieve production efficiencies, quality and improved product performance. Material science focusses on the development of new and improved materials for the next generation of engineering applications. It explores the fundamentals of biomaterials, nanomaterials, ceramics, metals, polymers, powders, electronic materials and composites, emphasizing the relationships between atomic structure and microstructure as well as the properties, processing and performance of the bulk material.

Materials are the building blocks of every physical product. Traditional materials such as metals, plastics, and ceramics are giving way to advanced materials such as nanocomposite, biological, and smart materials. The Materials Genome Initiative is a key component of the Federal advanced manufacturing investment portfolio. Federal agencies such as the Departments of Energy and Defense, along with NSF, NIST, and private industry are seeking ways to develop advanced materials for a variety of applications such as lighter vehicles, safer medical devices, or higher density batteries. needed to make vehicles much lighter or dramatically increase the energy density of batteries.

The traditional manufacturing processes that relied heavily on material removal are being replaced by advanced methods that are based on additive manufacturing, nanoscale processing such as chemical vapor deposition, molecular beam and atomic layer epitaxy, nanoimprint lithography and self-assembly. These processes have common underlying features of extreme customization, rapid production lead times and uncompromising quality.

The logistics and enterprise level management of manufacturing continues to push the state of the art through the use of flexible automation and robotics on factory floor to large scale optimization of the supply chain enabled through the Internet of Things (IoT). The promise of wide scale enterprise management is to integrate customer needs with design, materials characterization, procurement, manufacturing processes, quality control, and distribution without manual intervention. This raises additional demands on data security and integrity in manufacturing. Additionally, society will continue to place demands on manufacturing industry to minimize energy usage and carbon footprint.

This strategic plan for advanced manufacturing research, development and education over the next five years articulates a commitment from the University to advance its existing research culture and

agenda to a higher level in line with the A&T Preeminence 2023 goals. The successful implementation of this strategic plan will require the engagement of a large cross section of the university including faculty, staff and students belonging to all academic colleges, and administrators and staff from most of the administrative divisions

3.1 Need for Center

Advanced manufacturing research and education is a growing interest area at North Carolina A&T and will continue to grow in terms of external funding opportunities and student employment openings. In order to respond meaningfully to the opportunities, there is a need to have a strong unified approach that builds on the collective strengths of many faculty in several academic departments across the campus. To date most of the work in this area has been performed in a few academic departments without a single coordinated strategy at the university level. Materials science is an area of focus in the chemistry, chemical engineering, bioengineering, mechanical engineering, and nanoengineering departments. The applied engineering technology, industrial and systems engineering, mechanical engineering and nanoengineering departments are interested in manufacturing processes. Furthermore, the logistics and enterprise planning to support manufacturing is of interest in the marketing transportation and supply chain, and the industrial and systems engineering departments. Establishing a center will provide the structure and resources to enhance N. C. A&T's positioning and reputation in advanced manufacturing thereby leading to greater opportunities for faculty and students.

3.2 Scope

The Center will advance all aspects of scholarly manufacturing research, education and outreach through collaboration across the university's academic units; partnerships with educational and research institutions and private industry; education and engagement of undergraduate and graduate students; workforce training, development of intellectual property and technology transfer; research dissemination; testing and evaluation; consultation; and awareness and outreach to the general community and public media.

While the Center's scope will eventually broaden and grow over time, it will begin with research and education through five thrust areas, each with its own thrust leader: materials characterization and testing, multi-functional materials, manufacturing processes, manufacturing logistics, and public policy.

Material Characterization, and Testing: Material characterization and testing is the process of measuring and determining physical, chemical, mechanical and microstructural properties of materials. This process leads to the higher level of understanding needed to resolve important issues, such as causes of failure and process-related problems, and allows the manufacturer to make critical manufacturing decisions. Materials and devices are becoming increasingly complex. The methods and techniques used to study and characterize them, in turn, need to be progressively sophisticated. The Center will use a variety of instruments to characterize and test materials including, transmission electron microscopes (TEM), scanning electron microscopes (SEM), and electron probe micro-analyzers (EPMA), three-dimensional atom probes (3DAP). The Center will establish national reputation in performing standardized analytical methods as well as specialized application-specific advanced techniques such as failure analysis, product development, identification of unknown substances and contaminants, de-formulation and reverse engineering, and comparative analyses of materials.

Multi-Functional Materials: Regardless of the application, whether rail, automotive, aerospace, or military, etc., reducing structural weight and increasing impact loading are primary factors in optimizing performance and reducing operating costs. Lighter, stronger, and multi-functional materials including metal alloys (aluminum/magnesium/titanium), composites, and hybrid materials are all under investigation. Emphasis will include nano/microstructural characterization and its relationship to mechanical properties of specific materials systems. The Center will focus on achieving core critical knowledge to develop "advanced material by design" approaches to address

various application requirements. In addition, the Center will extend basic research findings to applications related to the advanced manufacturability of new materials and their combinations.

Manufacturing processes: The Center will conduct research and offer innovative solutions to problems in both military and commercial sector. Most engineering structures, components, medical devices and consumer goods increasingly require more complex heterogeneous materials joints. Materials joining makes a substantial contribution to the U.S. economy, being a critical enabling technology for at least one-third of its gross domestic product and influencing the backbone of its defense, infrastructure, and economic well-being. Therefore, the Center will lead the transformation of joining processes for heterogeneous materials through a comprehensive approach using fundamental science, process innovation, innovative design, simulation and predictive modeling. The Center will also continue ongoing research in additive manufacturing, nanomanufacturing and biomanufacturing.

Manufacturing logistics: The long-term direction of the equipment manufacturing industry is in the midst of being shaped by cutting-edge industry trends including; Industrial Internet of Things, data analytics, smart manufacturing, automation, robotics, augmented reality, artificial intelligence, and cyber-physical systems. The Center will lead an integrated approach to the optimization of the entire manufacturing supply with the objectives of cost and lead time reduction, quality improvement and environmental sustainability.

Public policy: Advanced manufacturing is being seen as an important way for enhancing high paying job growth in the USA as well improving its global competitiveness. While technical approaches will continue to focus on improving the efficiency, precision and sustainability of the manufacturing and distribution processes, policy discussions have ranged from the short term focus on jobs and employment to the impact of automation and new materials on the environment and societies in general. Experts in social, political, economic, and business disciplines will be needed to address a wide range of important questions in this regard, for example, the environmental impact of faster product obsolescence, the tradeoffs between higher productivity and loss of jobs, and the ethics of on-demand production of biologic materials.

The thrust areas will be advanced through interdisciplinary teams of faculty, staff and students that will result in the development of advanced manufacturing resources for the larger university community, provide research and innovation in advanced manufacturing, and offer education and outreach in advanced manufacturing.

Resource Development: The Center will lead the creation of a facility to support research, development, and testing of advanced materials, manufacturing, and logistics. The materials research laboratories will be capable of discovery, small-scale processing and characterization of new materials, while the manufacturing facility will have large doors and a high bay for entrance and exit of large material, equipment, and potentially test articles including, for example, airframe and automobile components. It will also include equipment appropriate to the scale-up manufacturing development, processing and testing of a variety of materials including metals, composites, ceramics, and coatings originating from either internal research or external sources.

Research and Innovation: The Center will unify the university's current research capability in materials characterization, multi-functional materials, modern manufacturing processes, and logistics and supply chain to create an environment for faculty and students to explore cross-cutting applications in materials development and advanced manufacturing. The Center will collaborate with academic department to engage graduate students and post-doctoral scholars in advanced research, sponsor seminars and workshops.

Education and outreach: The Center will provide expertise, training, and support for faculty, students and professionals to enhance their skills in materials and manufacturing. The Center will offer workshops on materials characterization, multi-functional materials, modern manufacturing processes, and logistics and supply chain as keys to advancing the manufacturing industry. In addition, the

Center will establish a forum for intellectual discussions and research on the social, economic, and cultural factors associated with manufacturing. The Center will increase public awareness of the role of manufacturing and will engage the general community in discussions affecting public policy, laws and regulations related to environment, energy and water use, international trade, and other issues manufacturing issues.

3.3 Mission

The Center will be the academic and research nexus for material characterization and multi-functional materials development, advanced manufacturing processes and manufacturing logistics. The purpose of the Center is to investigate comprehensive and integrated approaches to material development and characterization, prototype manufacturing, and enterprise level logistical support for advanced manufacturing operations. The center will provide a unique framework for partnerships between academia, government and industry on research programs of various sizes and applications. Advances in education and research in this field will provide students and faculty with opportunities to participate in interdisciplinary programs, and to prepare for careers in the rapidly changing field of advanced manufacturing to serve industry and government needs across the Piedmont Triad region, the state of North Carolina and the United States. These efforts will support the growing manufacturing industry in the region as well as federal efforts across a variety of agencies that will use these new processes for special products. From a regional economic development standpoint, the Center's faculty and facilities represent a vital addition to the Triad's initiatives in enhancing the manufacturing base

3.4 Objectives

The objectives of the Center are to

a. Conduct fundamental research into multifunctional material development, characterization, and testing to support advanced manufacturing
b. Develop innovative manufacturing processes and logistical support technologies to support the needs of government and industry
c. Provide education and training in materials and manufacturing
d. Advise deans and provost on faculty competencies in faculty hiring and professional development leading to the creation of an interdisciplinary community of advanced manufacturing experts
e. Serve as a workforce development pipeline for students with a background in advanced manufacturing
f. Support the creation of new manufacturing business and high skill jobs in the region and state

4.0 Relationship to University Mission

The Center is fully aligned with the university's strategic plan (Preeminence 2023).

4.1 Preeminence 2023 Goal 1: Excellence in Teaching, Research and Student Success

The Center will enhance the faculty's ability to conduct cutting edge research and to offer advanced courses that integrate advances in materials characterization, testing and development with advanced manufacturing processes as well as enterprise level logistical support for manufacturing industry. Advances in education and research in this field will provide students and faculty with opportunities to create interdisciplinary programs, prepare for careers in a burgeoning field, and innovate in interdisciplinary applications in the manufacturing industry.

4.2 Preeminence 2023 GOAL 2: Intellectual Climate

The Center will provide a focal point for materials and manufacturing related research, education and training on the campus. As part of its operations, the Center will conduct workshops, seminars, conferences, and invited lectures to educate both the scientific and technical community and the population at large. In doing so, the Center will attract more faculty and students to the important field of advanced manufacturing, help the university recruit more students and research scientists, and create an environment for faculty and students to explore cross-cutting applications. All these activities will enhance the intellectual climate on campus.

4.3 Preeminence 2023 GOAL 3: Public Service and Community Engagement

The Center will serve as a point of expertise on materials and manufacturing in general and nanoscale manufacturing in particular. The Center will also support the growing manufacturing industry in the state and Piedmont Triad region as well as federal efforts across a variety of agencies that need innovations in materials and manufacturing to support their missions.

4.4 Preeminence 2023 GOAL 4: Stewardship, Operational Effectiveness and Efficiencies

The Center will initially use the resources of the existing facilities including the Engineering Research Center for Biomaterials, the Integrated Nano & Bio Manufacturing Laboratory, JSNN, and the 3D printing laboratory that is currently being established at the Yanceyville building. In the future, the entire operation should be housed in one location at the South Gateway University Research Park.

5.0 Differentiation from similar centers within N.C. A&T and/or UNC system

The Center will be closely related to the Engineering Research Center for Biomaterials, the Integrated Nano & Bio Manufacturing Laboratory, JSNN, and the 3D printing laboratory and will provide a long term institutional structure for manufacturing research and outreach to last beyond the lifespans of several federally funded centers and labs. The JSNN has an extensive suite of laboratories for advanced microscopy, materials testing, micro and nanofabrication, and clean room facilities, The NSF ERC for Revolutionizing Metallic Biomaterials has been focused on material research of metallic biomaterials and coatings and thin film manufacturing using pulsed laser deposition and magnetron sputtering. The Integrated Nano & Bio Manufacturing Laboratory performs research in the areas of hybrid nanomanufacturing, additive fabrication (3D printing), and bio-functional coating. The proposed Center will bring all the expertise from multiple colleges under one umbrella and provide leadership in advancing a unified approach to manufacturing research and development for the university.

A review of the universities in the UNC System indicates that three offer degrees in materials science, mechanical engineering or manufacturing. One has a B.S. in Engineering with a concentration in manufacturing, one has a B.S. in Mechanical Engineering with a materials characterization lab for energy, and one has faculty research in biomanufacturing. Only NC State has synergistic capabilities with a PhD in Materials Science and Engineering, and facilities that include; Nanofabrication facility, Molecular Education, Technology and Research Innovation Center (METRIC), and Center for Additive Manufacturing and Logistics. The proposed Center at N.C. A&T will develop partnerships with NC State in effectively using equipment and expertise and in joint funding proposals.

6.0 Relationship with academic programs

Research and education in materials and manufacturing combines chemistry, physics, biology, mathematics, technology, mechanical, chemical, electrical, industrial, civil and nanoengineering. With its initial emphasis on materials science, nanoscale and additive fabrication and supporting logistics to create cross-cutting applications in advanced manufacturing, the Center will naturally be more closely aligned with the following academic programs.

- Applied Engineering Technology
- Chemistry
- Electrical and Computer Engineering
- Industrial and Systems Engineering
- Marketing Transportation and Supply Chain
- Mechanical Engineering
- Nanoengineering
- Physics

The Center will continue to enhance its relationship with these programs as it builds new partnerships with a larger cross section of academic programs. The Center will identify current courses in cybersecurity and will continue to assist academic departments by advising them of new

developments and course enhancements and in further strengthening their portfolio of course offerings. A partial listing of manufacturing related courses in provided below; this list will be continually updated by the Center and promoted on its website.

- MEEN 361: Modern Engineering Materials
- MEEN 363: Manufacturing Processes
- MEEN 650: Mechanical Properties and Structure of Solids
- MEEN 680: Applied Statistics in Mechanical Design
- MEEN 813: Composite Structures

7. Structure and Organization

The Center will be led by a Center Director who will report to the Senior Vice Provost for Academic Affairs. The Center Director shall have a tenured faculty appointment in one of the academic departments but will receive half-time release time to conduct the work of the Center. The Center Director is responsible for all management and operations functions, and for the success of the Center. The Center Director will work closely with the Deans and Chairs of all colleges and departments to form a leadership team, as well as to identify all funded research and faculty with relevance to the Center's mission. The Center Director will recruit and hire additional research staff and post-doctoral fellows to carry out the Center's mission. The Center Director is responsible for developing and fostering strong relationships with university and industry partners. The Center Director will also meet regularly with the Faculty Advisory Committee, and meet once a year with the Steering Committee and the External Advisory Board for guidance and counsel.

The Center Director will be assisted by a Laboratory Manager and a graduate student administrative assistant.

The Steering Committee will consist of the Provost, Senior Vice Provost, Vice Chancellor for Research and Economic Development, and all the Deans of colleges that have affiliated faculty members. The committee will facilitate the work of the Director by helping with collaborations among academic units, development of courses and degree programs, and formation of interdisciplinary research teams. The Steering Committee also conducts periodic assessment of the effectiveness of the Center in meeting identified needs and program goals.

The External Advisory Board will consist of representatives of funding agencies, government and civic bodies, and industry representatives. The External Advisory Board advises the Center Director on strategic directions and priorities and assists in identifying resources required to address priority research, outreach and teaching needs. The Board assists in identifying resources and funding opportunities for Center activities.

Appendix 1: Faculty Listing

Faculty

The following list includes all faculty who either have active research programs, have been nominated by their respective Dean, or have expressed an interest in developing research programs in cybersecurity. Their academic background, current research strengths, and future funding opportunities should guide future faculty hiring plans.

Science and Technology

1. Dr. Aixi Zhou
2. Dr. Yi Cai
3. Dr. Andrea Ofori
4. Dr. Mufeed Basti
5. Dr. Zerihun Assefa

Engineering

6. Dr. Sameer Hamoush
7. Dr. Taher Abu-Lebdeh
8. Dr. Dukka KC
9. Dr. Marwan Bikdash
10. Dr. Abdullah Eroglu
11. Dr. Ali Karimoddini
12. Dr. Chris Doss
13. Dr. Zhijan "Cliff" Xi
14. Dr. Hyung Nam Kim
15. Dr. Salil Desai
16. Dr. Steve Oneyear
17. Dr. Younho Seong
18. Dr. Zichao Li
19. Dr. Dhananjay Kumar
20. Dr. Jag Sankar
21. Dr. John Kizito
22. Dr. Mannur Sundaresan
23. Dr. Sun Yi

Business and Economics

24. Dr. Laquanda Johnson
25. Dr. Mary Lind
26. Dr. Roger Gagnon
27. Dr. Shona Morgan

Nanoengineering

28. Dr. Ajit Kelkar
29. Dr. Jeffery Alston
30. Dr. Lifeng Zhang
31. Dr. Ram Mohan
32. Dr. Shanti lyer
33. Dr. Shyam Aravamudhan