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Tribal Colleges and Universities/ American Indian Higher Education Consortium Advanced Manufacturing Technical Assistance Project

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Prepared by
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1 Introduction

The National Nuclear Security Agency (NNSA) created a Minority Serving Institution Partnership Plan (MSIPP) to 1) align investments in a university capacity and workforce development with the NNSA mission to develop the needed skills and talent for NNSA's enduring technical workforce at the laboratories and production plants and 2) to enhance research and education at under-represented colleges and universities. Out of this effort, MSIPP launched a new program in early FY17 focused on Tribal Colleges and Universities (TCUs). The following report summarizes the project focus and status update during this reporting period.

2 Tribal Colleges and Universities/American Indian Higher Education Consortium Advanced Manufacturing Project

The overall goal of this project is to establish a network of TCUs with essential advanced manufacturing (AM) facilities, associated training and education programs, and private sector and federal agency partnerships to both prepare an American Indian advanced manufacturing workforce and create economic and employment opportunities within Tribal communities through design, manufacturing, and marketing of high quality products. Some examples of high quality products involve next generation grid components such as mechanical energy storage, cabling for distribution of energy, and electrochemical energy storage enclosures. Sandia National Laboratories is tasked to provide technical advising, planning, and academic program development support for the TCU/American Indian Higher Education Consortium (AIHEC) Advanced Manufacturing Project. The TCUs include Bay Mills Community College (BMCC), Cankdeska Cikana Community College (CCCC), Navajo Technical University (NTU), Southwestern Indian Polytechnic Institute (SIPI), and Salish Kooteani College (SKI). AIHEC and Sandia, with collaboration from SIPI, established an 8-week summer institute on the SIPI campus during the summer of 2017. Seventeen students from the TCUs took part in the summer program. The goal of the program is to bring advanced manufacturing science, technology, engineering, and mathematics (STEM) awareness and opportunities for the American Indian students. Prior to the summer institute, Sandia provided reviews on curriculum plans at the each of the TCUs to ensure the content is consistent with current advanced manufacturing design and engineering practice. In addition, Sandia provided technical assistance to each of the TCUs in regards to their current advanced manufacturing activities.

Sandia, AIHEC, and the TCUs under this project had a kickoff meeting on the SIPI campus October 21, 2016. The purpose of the meeting was to discuss the goals of the advanced manufacturing project, advanced manufacturing research and development (R&D) project ideas, and the summer institute. Each of the TCUs proposed various advanced manufacturing R&D ideas, and Sandia provided feedback and recommendations for each idea. In addition, the first TCU Advanced Manufacturing Technology Summer Institute hosted by SIPI in Albuquerque, New Mexico with collaboration with NTU, AIHEC, TCU's and Sandia took place from June 26 through August 18, 2017. The following sections will provide updates on the TCU R&D, education, and summer institute.

2.1 Bay Mills Community College

BMCC is a two-year tribal college chartered by the federally recognized Bay Mills Indian Community of Michigan. The school is located in Brimley, Michigan. Based on the October 2016 kick-off meeting, BMCC will be focusing on three advanced manufacturing related R&D projects: 1) advanced material for flywheel energy storage systems, 2) ballistic panels for energy systems, and 3) reinforced/lightweight materials for energy systems.

2.1.1 Advanced Material for Flywheel Energy Storage Systems

The first meeting took place on January 10, 2017 between Chris Griffen (BMCC), Jeff Parker (BMCC Technical Liaison), Nick Gencerelle (Smarter Building Systems-Materials Consultant), Stan Atcitty (Sandia), and Don Bender (Sandia flywheel expert). First discussed and strongly emphasized by Mr.

Bender was approaching flywheel energy storage design from a systems level comprised of the flywheel rotor, low friction bearings, rotor spin-up drive, energy converter and with higher spin speeds a containment structure. Several basic design and operational considerations were addressed with respect to rotor shape and response parameters (e.g. tangential velocity, maximum stress safety factor, etc.). BMCC reviewed some of the material technologies being considered based on very preliminary comparative evaluations. Subsequent to the meeting, BMCC submitted to Sandia a proposed development scope and associated questions for Sandia review and recommendations.

Mr. Bender provided comprehensive feedback to BMCC with respect to methods of flywheel rotor manufacturing, flywheel testing, and advanced materials for next generation flywheels. Also provided to BMCC were three documents: 1) Recommended practices for safe design and operation of flywheels, 2) Flywheel engineering principles, and 3) Predictive rotor stress calculation tool. This information will be very useful in development going forward.

A second technical review meeting was held on August 9th with Sandia. Stan Atcitty, Chris Griffen, Al Kuslikis, Nick Gencarelle, and Don Bender participated on the conference call. The meeting was intended as a status update of present progress as well as concurrence in next steps going into the second year of the grant. First presented was the proposed flywheel energy storage material matrix for evaluation of physical properties of various concrete and reinforcement formulations. The matrix is comprised of three levels in base concretes and four levels of Basalt reinforcement to assess tensile and flex properties using plaque mold samples. The goal is reaching tensile strength well above the 6 ksi level with a target performance of 12-15 ksi. Nick Gencarelle has delivered all materials to BMCC/Great Lakes Composite Institute. Don Bender indicated since these materials have not been used before in his work, the materials being tested would offer potential for new technology in flywheel applications. This evaluation is targeted for completion by the end of September.

The sub-scale design configuration for spin testing was then covered and several recommendations were made by Don Bender. He has also supplied a rotor dimensional concept to start with. A disc system was recommended since most drum based rotors utilized hoop strength characteristics common in carbon fiber layup structures. It was re-emphasized that tangential surface velocity is the primary design metric in both predictive and hardware testing to understand the tensile material performance/safety factors. The second design consideration is the stress concentration factor at the shaft to rotor interface (2x) which is addressed by increased thickness (2-3x target) at the interface hub. The third design consideration was in shaft diameter to manage the rotor dynamics. Bearing placement was discussed in reducing dynamic response sensitivity via nodal mode placement as well. Mr. Bender also indicated the moment of inertia in the Z axis (polar moment) of the rotor required at least a 2X separation from the in-plane and symmetric X and Y spin axes for the moment of inertia to prevent coupling behavior.

Chris Griffen brought up specific rotor dynamic instabilities which could be predicted and designed for using a finite element normal modes analysis with frequency optimization. The model would have to extract eigenvalue/eigenvector base modal parameters to simulate and optimize for gyroscopic moments including precession/whirl, critical speed limit, and internal bending/torsional resonances. With the bearings as geometric boundary constraints, that modal alignment and potentially maximum spin speeds below these critical frequencies should be optimized. The model would also predict stress states within the shaft for sizing as well as rotor/hub interface stresses not exceeding tensile strengths achieved through

matrix formulation evaluations. This should be the guiding design tool for mold construction and subsequent dynamic tests.

Also discussed was the importance and key objective within the grant to actively engage students in the technical R&D. Chris Griffen indicated that this is a priority action item to involve BMCC students within the project through CAD work, concept 3D printing of the flywheel, and coordination with present course work taught by Chet Kasper at BMCC as a demonstration project is forth coming. Additionally, the student involvement will include collaborative work with an outside design and analysis group to be selected with rotor dynamics experience in optimizing the flywheel energy storage for sub-scale modeling and testing.

2.1.2 Ballistic Panels for Energy Systems

The first meeting was held on February 13, 2017 and included Chris Griffen (BMCC), Nick Gencerelle (Smarter Building Systems-Materials Consultant), Stan Atcitty (Sandia) and William Reinhart (Sandia technical expert in impact/ballistics). William Reinhart provided introduction with respect to his experience/background in this field and the scope of work in impact simulation and testing conducted at Sandia. BMCC described prior development efforts at the college in impact material evaluations and associated multilayer construction testing using various thermoplastic fiber and thermoplastic resin alternatives for exclusively projectile ballistics applications.

Three needs were identified by BMCC in conducting further development. The first was in gaining a higher level of knowledge in both planar compressional shockwave as well as ballistic impact phenomena through historic reference data. The second area was incorporation of impact simulation methods for predictive response and design optimization either through Finite Element or Finite Difference based solvers to support hardware testing. The college has in-house tools presently to support this. The third need was how to approach the material and construction modeling and test evaluations with greater engineering basis primarily in material characterization.

Sandia gave response and action items to these needs with the following: 1) Sandia provided technical reference impact case studies and research papers for BMCC review through William Reinhart; 2) BMCC presented to Sandia a baseline impact prediction finite element method (solid works) for review and recommendations by Sandia on key modeling/analysis parameters (e.g. element type, material data input, loading/boundary conditions, interface effect, etc.); 3) BMCC selected key materials that required defining the equations of state and elastic and plastic characterization with Sandia support as a primary material selection criteria.

A second meeting occurred on August 29, 2017 between Stan Atcitty, Chris Griffen, William Reinhart, and Nick Gencarelle to update new developments on the impact and ballistic technical work and define next steps entering into the second year of the grant.

Chris Griffen gave an overview of a pre- meeting held with BMCC, CCCC, and Sioux Manufacturing on August 25th (Dr. Griffen, Jacob Toward, Jim Anderson, Michael Parker, and Karl Haefner) to outline the support required by CCCC and Sioux Manufacturing towards development of impact and ballistic material. Sioux Manufacturing will be supplying production ballistic panel sets at various layering and thickness levels, material types (Aramid, S2, Ablative, and conventional glass) along with impact test data

(internal and from Aberdeen labs) for benchmarking future development. CCCC will be funding this through their grant with a purchase order targeted for issue in late September.

Nick Gencarelle and Chris Griffen briefly described the materials and constructions being considered for ballistic and impact performance benefits over existing solutions; however, they have not defined a test matrix plan at this time. During the prior conference call earlier in the year, several applications for concrete flywheel containment, battery protection, electrochemical applications, and general electronic enclosures were identified as possible development areas. At this time, no specific application focus was recommended until material level development is completed.

In addition to the R&D discussion above, it was also emphasized the equally important objective to involve students in technical development. A pilot program through the 3D modeling courses being offered this fall at BMCC will commence and be applied to this project. There will also be an increased amount of engagement with Chet Kasper at BMCC who teaches this course. BMCC students involved in the 3D build of multilayer structures as well as finite element analysis will realize the power in virtual tools. Additionally, they will have the opportunity to understand how testing and simulations are interrelated.

2.2 Cankdeska Cikana Community College

CCCC is a tribal college in Fort Totten, North Dakota on the Spirit Lake Reservation. CCCC will work collaboratively with Sioux Manufacturing and BMCC on advanced manufacturing of various energy systems. CCCC is in the early stages of defining advanced manufacturing related R&D. Sandia plans to work closely with BMCC and CCCC to determine the R&D focus area related to advanced manufacturing. A preliminary meeting and discussion took place during the October 2016 kick-off meeting. Technical discussions are on-going.

Stan Atcitty (Sandia) visited CCCC on April 6 and 7, 2017 to gather additional information on the school's advanced manufacturing R&D efforts along with educational curriculum development and outreach. CCCC offered AM-101: 3D Modeling for Advanced Manufacturing for the fall of 2016 (2 students) and 2017 (3 students). Four CCCC students attended the TCU Advanced Manufacturing Summer Institute in Albuquerque, New Mexico. A tour of the advanced manufacturing classroom and lab was provided by CCCC. The advanced manufacturing lab includes 3D printers including 2-Makerbot 2X Replicators, Z18 Markerbot, Project 360 Power base materials, and HDI-3X white light scanner.

A tour was also provided by Sioux Manufacturing Corporation where Stan met with Jim Anderson (manager) and Jacob Toward (staff member). Sioux Manufacturing Corporation manufacturers composite materials for armed armors. It also offers ablative tile components, spall liners, woven materials, and other miscellaneous materials. This company is located in Fort Totten, North Dakota, approximately one mile from CCCC. Its proximity affords unparalleled research and internship opportunities. Internship and R&D discussions are on-going. CCCC is also working with BMCC's Chris Griffin and Sioux Manufacturing on ballistic and impact materials supply (i.e. Kevlar for ballistic and impact testing). The R&D and technical discussion are on-going between CCCC, Chris Griffin, and Sioux Manufacturing.

Stan was an invited speaker at the 5th Annual North Dakota Tribal College Research Symposium at CCCC. Stan provided insights in engineering principles, design process, and STEM opportunities to over

40 students who attended the conference. The students were also given an opportunity to present their respective research conducted at their institutions during the afternoon poster session.

2.3 Navajo Technical University

NTU is a tribally controlled postsecondary career and technical institution in Crownpoint, New Mexico. Two smaller campuses are located in Chinle, Arizona and Teec Nos Pos, Arizona. The NTU campuses are located on the Navajo Reservation. NTU activity is focused on the exploration of additive manufacturing techniques. The first teleconference took place on Jan 16, 2017 between Scott Halliday (NTU), Stan Atcitty (Sandia), and Bradley Jared (Sandia additive manufacturing subject matter expert). Sandia provided technical feedback on additive manufacturing of metal part machining and processing, certification of 3D metal printed parts, and inspection methodologies and techniques including equipment operation and optical metrology. Technical discussions are on-going in regards to tensile testing, fatigue testing, density testing, CT scanning, radiography, heat treatment, and hot isostatic pressing. NTU will benefit significantly if experience is gained in these areas, especially for additive manufacturing.

Stan Atcitty is currently a Chair of the Engineering Advisory Board for NTU. The Engineering Advisory Board's purpose is to catalyze interactions between students, faculty, and the larger engineering community; provide input on academic issues, especially those related to ABET accreditation; and support promotion and development of education programs and facilities. Stan has been serving at the capacity since spring of 2015. The ABET accreditation preparation and dialog are on-going. Once accredited, NTU will be the first TCU to obtain such an accreditation.

2.4 Salish Kooteani College

SKC is a tribal college based in Pablo, Montana which serves the Bitterroot Salish, Kootenai, and Pend d'Oreilles tribes. The SKC campus is on the Flathead Reservation. SKC will focus on four advanced manufacturing related R&D projects: 1) BisonSat II CubeSat Satellite build, testing, and possible deployment, 2) test and measurement in the advanced manufacturing environment, including characterization of advanced manufactured materials, 3) rapid prototyping laboratory development, and 4) STEM community outreach.

2.4.1 BisonSat II Miniature Satellite Deployment

BisonSat is a satellite with an earth science mission to demonstrate the acquisition of 100-meter or better resolution visible light imagery of the earth using passive magnetic stabilization. Some of the images will be of the Flathead Indian Reservation to be used primarily for engaging tribal college students and tribal communities in NASA's mission. BisonSat is the first CubeSat designed, built, tested, and operated by tribal college students. The satellite was launched on October 8, 2015. Unfortunately, the BisonSat is not responding to transmission with less than one year in orbit. A teleconference meeting took place on December 12, 2016 between Thomas Trickel (SKC), Stan Atcitty (Sandia), and Charles Carter (Sandia subject matter expert in complex reliability analysis). Sandia provided technical information on Failure Modes, Effects, & Criticality Analysis (FMECA) process. This is a formal process that looks at each component of the system and addresses how it could fail and what the effects would be.

2.4.2 Sandia Site Visit, SKC Education, and Outreach

Stan Atcitty made a site visit to SKC on May 10, 2017 to gather additional information on BisonSat II R&D, testing and measurement capabilities, advanced manufacturing curriculum, and outreach. Tours consisted of SKC ground station for the satellite, clean box for satellite build, engineering & physics laboratory, networking lab, hardware implementation laboratory, and computer class room. Introduction to Solid Works class was provided by SKC in the spring of 2016 which consisted of six students. Nothing was offered in the 2017 school year due to staffing issues. An information technologies course is planned for the 2018 school year. Starting in 2016, SKC provided open lab opportunities on Fridays which offered access to 3D printers, microcontrollers, and sensors as an outreach opportunity for the community including mid school and high school students.

Stan was invited to speak to the Polson High School pre-calculus and calculus students during his visit to SKC. Each class room consisted of 15 high school seniors. Stan provided background in engineering, STEM, and professional life. The students were very inquisitive and had multiple questions.

Stan also spoke during the Two Eagle River School assembly, an alternative school of the confederate Salish & Kootenai Tribes of the Flathead Reservation. Over 40 students were in attendance. Stan provided background on what it means to be an American Indian engineering professional, STEM education and opportunities that are available to them as they continue their educational endeavors. Again, the students were very inquisitive and discussions were informative.

2.4.3 Characterization of Advanced Manufactured Materials

Discussions at SKC identified a need in the TCU Advanced Manufacturing Network for computer controlled mechatronics-based testing of advanced manufactured materials. Sandia will be providing technical feedback and support for this activity.

2.4.4 Rapid Prototyping Laboratory Development

SKC's rapid prototyping laboratory will include electrical circuit board R&D. Sandia will be providing the state-of-the-art tools and techniques and technical guidance on rapid prototyping. Technical discussions will continue in FY18 school year.

2.5 Turtle Mountain Community College

TMCC is a tribal college located in Belcourt, North Dakota. TMCC was founded by the Turtle Mountain Band of Ojibwa in 1972. There are over 25,000 enrolled members, 34 percent of whom live on or near the Tribe's 86,989 acres. Stan Atcitty (Sandia) conducted a site visit to TMCC on April 06, 2017 to learn more about the educational programs, meet current students, and advanced manufacturing R&D. TMCC is on the early stages of advanced manufacturing curriculum development and R&D scoping. Since R&D is a critical platform to develop curriculums and outreach, Stan Atcitty and Ann Vallie (TMCC) focused much of their efforts discussing potential R&D opportunities and vision to make the best use of the available STEM related programs at the school. The following provides the vision developed by Stan Atcitty and status at the writing of this report.

2.5.1 Tribal Ecology Using Advanced Manufacturing, Education, and Drones (TEAMED)

2.5.1.1 TEAMED Introduction

The Tribe's traditions, stories, and dependence are built around the region's multiple lakes, ponds, wetlands, and ecologically diverse landscape that includes birch trees, many birds, mammals, reptiles, fish, and deer. Drone technology aids in studying this ecological system and provides educational opportunities at TMCC in the areas of advanced manufacturing, science, technology, engineering, and math. In addition, establishing an advanced manufacturing program to study this technology at TMCC provides opportunities to partner with North Dakota State University (NDSU) other TCU's, industry, and government.

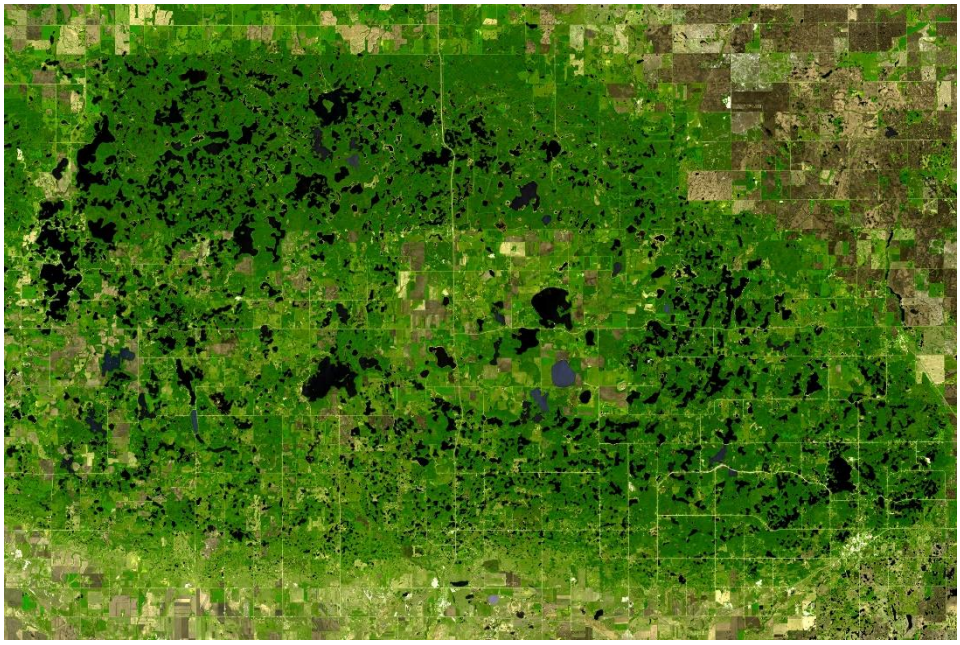

Figure 1. Aerial view of Turtle Mountain displaying multiple lakes and diverse landscape, courtesy of NASA's Earth Observatory.

2.5.1.2 Environmental Science

The state of the ecological system at Turtle Mountain is critical to the future of the Ojibwa Tribe. The study of this system is known as environmental science. Merriam-Webster defines environment as the complex of physical, chemical, and biotic factors (such as climate, soil, and living things) that act upon an organism or an ecological community and ultimately determine its form and survival. Scientists have been studying the environment for decades with a focus on analysis and preservation. Environmental scientists have taken advantage of technology advances, such as drones, that use advanced sensors for various assessments of air and soil quality, water conditions and contaminates, vegetation, and fish health for environmental impact studies due to human impact on the natural environment.

2.5.1.3 Drone Technology and Advanced Manufacturing

Drone technology is becoming ubiquitous around the world. It's used in aerial photography, search and rescue, security, surveying and mapping, science and research, and a host of other applications in energy, military, and industry. A drone aircraft is an unmanned aerial vehicle that operates autonomously or via remote control. Drones can also be deployed underwater for marine exploration via a mini submarine vehicle. Some examples of drones for aerial and marine explorations are shown below.

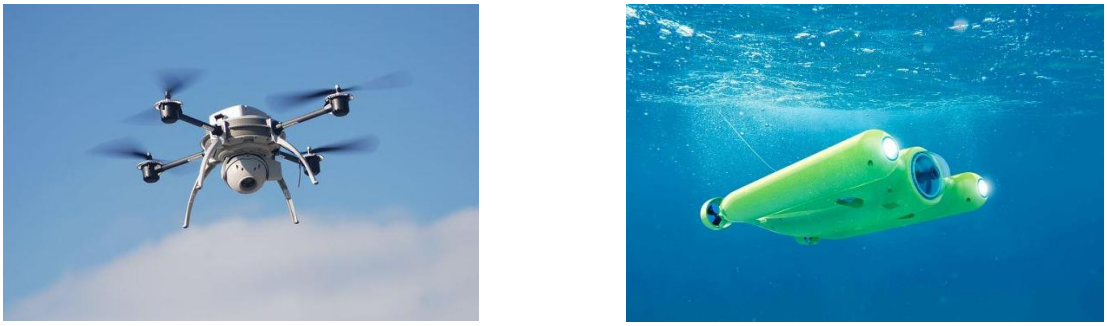

Figure 2. Example drones for aerial and marine explorations.

The drone technology typically consists of multiple components, including an advanced manufactured, lightweight outer shell or housing; motors and propellers for propulsion; communication capabilities; sensors; batteries; guidance; and control systems. For this reason, drones provide an excellent platform for developing educational curriculums surrounding advanced manufacturing STEM education. Drones also provide Tribal resource awareness and appreciation by gathering data for environmental impact studies.

A multifaceted and sustainable educational program at TMCC can be implemented using existing programs, including environmental science, mathematics, life science, social science, geography, wildlife management, pre-engineering, machine technology, and welding. In addition to developing a program at TMCC, this plan anticipates collaboration with NDSU's Agricultural and Biosystems Engineering Program where aerial drones, sensors, communications, and data analysis are being developed to solve problems that involve living systems. It is envisioned that TMCC's Advanced Manufacturing Program will be a feeder school for NDSU. This will also provide an opportunity to engage with National laboratories, other TCUs, other mainstream universities, military, industry, and other Tribal entities.

2.5.1.4 TMCC Advanced Manufacturing Program Plan

TMCC is currently funded by the NNSA MSIPP. The mission of this three-year program is to enhance research and education at TCUs in the area of advanced manufacturing and to develop the needed skills and talent for NNSA's enduring technical workforce at the National Laboratories and production plants. The overall goal is to establish a network of TCUs with essential advanced manufacturing facilities, associated training and education programs, and private sector and federal agency partnerships to both prepare an American Indian advanced manufacturing workforce and create economic and employment

opportunities within Tribal communities through design, manufacturing, and marketing of high quality products.

An example of key objectives for a three-year program was provided to TMCC and is as follows.

Year 1 Objectives

- Scoping of key advanced manufacturing hardware and software equipment followed by aquistion
- Establish premliminary advanced manufacturing curriculum with guidance from NDSU
- Advanced manufacturing training for instructors
- Obtain preliminary drone design
- Send students to the advanced manufacturing summer institute in Albuquerque, NM

Year 2 Objectives

- First advanced manufacturing class with incorporated 3D design and manufacture
- Send students to the 2nd year advanced manufacturing summer insitttue in Albuquerque, NM
- Develop preliminary design of the underwater drone
- Seek internship opportunties for the advanced manufacturing students

Year 3 Objectives

- 2nd year of advanced manufacturing class with incorporated 3D design and manufacture
- Send students to the 3rd year advanced manufacturing summer institue in Albuquerque, NM
- Prototype testing of the underwater drone
- Seek internship opportunties for the advanced manufacturing studentss

The following page captures the overall vision the advanced manufacturing program at TMCC.

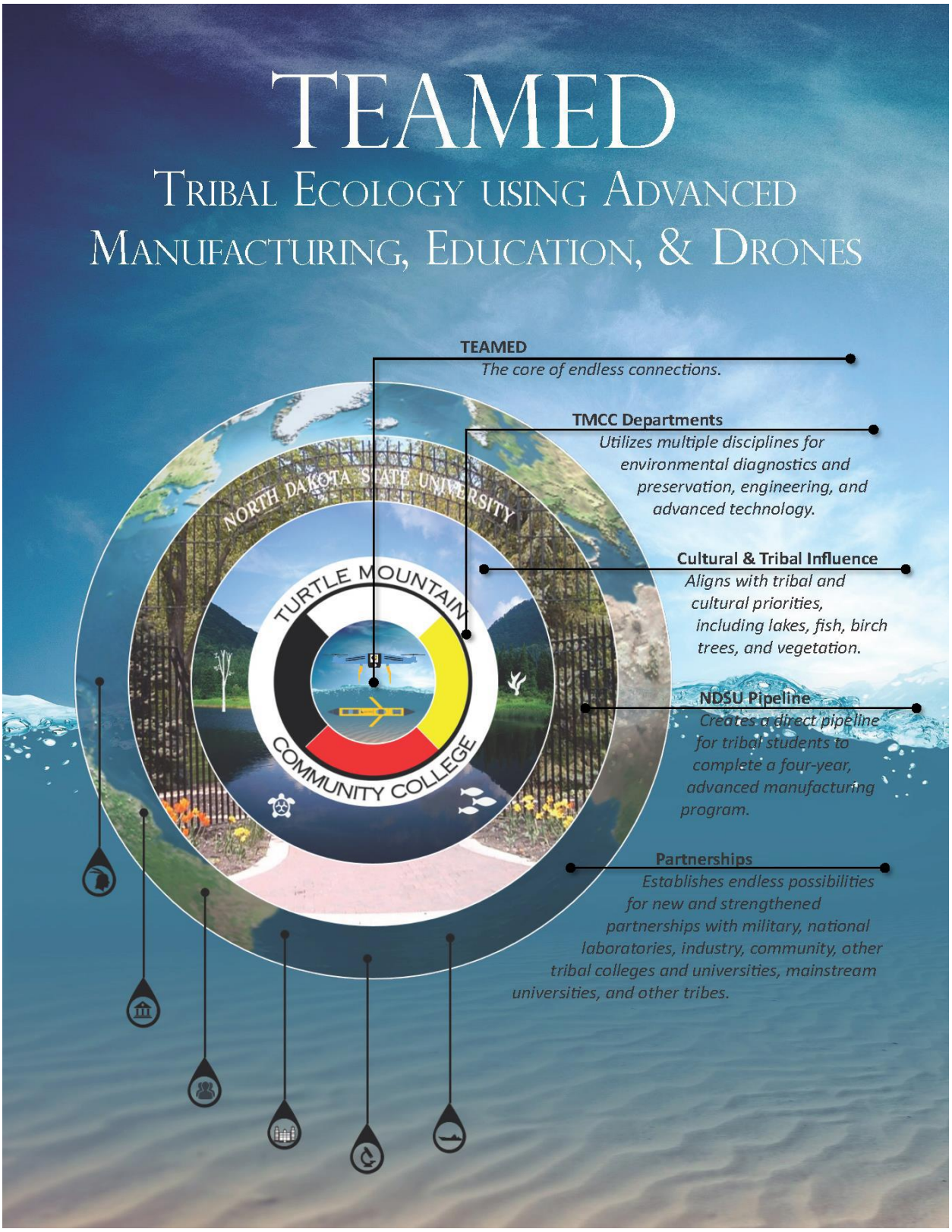

Figure 3. TMCC's advanced manufacturing program concept.

2.5.1.5 TEAMED Status

TMCC presented the TEAMED concept to the school's administration on May 11, 2017. The school administration included the TMCC President, Dr. Jim Davis; Dean of Academics, Dr. Terri Martin-Parisien; and Career Technical Education Director, Sheila Trottier. The TEAMED R&D at TMCC opportunities is still under consideration at the writing of this report.

TMCC also met with NDSU on April 28, 2017 to discuss logistics of implementing such a plan to include curriculum development around the TEAMED concept and R&D assistance. NDSU has a significant program in the unmanned aerial vehicles, commonly known as drones. Research opportunities include areas such as airframe design, flight controls, propulsion systems, power management, and sensor payloads for examples. TMCC has been in close contact with Dr. Sreekala Bajwa, professor and department chair; Dr. John Nowatski, agricultural machines specialist; and Dr. Alimohammad Shirzadifar, a post-doctoral appointee in the Department of Agricultural and Biosystems Engineering department at NDSU. NDSU is eager to work with TMCC and communication is on-going.

TMCC offered the advanced manufacturing class AM101: 3D Modeling in the spring of 2017. It is anticipated that the same class will be offered in the fall semester of 2017. TMCC also bought an underwater drone and a Phantom Pro 4 drone to help accelerate curriculum, STEM outreach, and R&D activities.

2.5.2 Pre-Engineering Education Collaboration (PEEC)

The Pre-Engineering Education Collaboration (PEEC) consists of the four tribal colleges in North Dakota (TMCC, CCCC, Nueta Hidatsa Sahnish Community College, and Sitting Bull College) along with NDSU. TMCC was awarded a 5-year grant from National Science Foundation to start pre-engineering programs at TMCC with the options of students transferring to NDSU at a Junior status in the engineering curriculum of their choice. Since the program has started, eleven students transferred to NDSU. Of the eleven, two have graduated with their B.S. in Civil Engineering and they are currently in graduate school. There are currently eight students enrolled in the program at TMCC. TMCC has utilized this platform for student outreach and as a result, four students attended the TCU Advanced Manufacturing Summer Institute in Albuquerque, NM this past summer.

2.6 2017 TCU Advanced Manufacturing Technology Summer Institute

SIPI and NTU co-hosted the first Advanced Manufacturing Technology Summer Institute at the SIPI campus located in Albuquerque, New Mexico from June 26 through August 18, 2017. The purpose of the institute was to bring together five TCUs under the advanced manufacturing consortium to learn advanced manufacturing techniques and put these unique skills to practical use by building an educational rover and autonomous quadcopter. Five courses were offered during the institute:

- Metrology – study of measurement
- Advanced CADD – 3D modeling for 3D printing
- Mechatronics – integration of electronic control systems and mechanical systems

- Computer Science – introduction to computational science geared for entry level students not familiar with computing experience

The summer institute also included several field trips to surrounding industries in Albuquerque, including Sandia National Laboratories. Seventeen students from TMCC, CCCC, NTU, and SKC attended the institute. There were weekly project status updates provided by the students via PowerPoint presentations by each group. Sandia provided technical feedback on each project. On August 17, 2017, the students made their final presentation delineating the outcomes, technical challenges, and lessons learned. Part of the final presentation involved the demonstration of the autonomous rover and quadcopter.

Figure 4. Group photo TCU Advanced Manufacturing Summer Institute students, faculty, and mentors (courtesy of SIPI).

2.6.1 Sandia Summer Institute Tour

Sandia hosted the summer institute students on July 21, 2017. Tours, presentations, and demonstrations were provided by the Robotics and Additive Manufacturing programs at Sandia. The Robotics tour focused on:

- Unique mobility
- Advanced controls, perception, and autonomy
- Unmanned aerial systems
- High consequence automation
- Remotely operated weapons systems
- Cybernetics and advanced prosthetics
- Robotic vehicle range and mobile manipulation

The Additive Manufacturing tour focused on:

- Hybrid additive and subtractive manufacturing using multiple techniques (direct write, ink jet, aerosol jet, and metal) and materials
- Metal power bed additive manufacturing
- Additive and subtractive laser engineered net shaping additive manufacturing of metals

2.6.2 Sandia Mentoring and R&D Technical Assistance

The summer institute consisted of five teams and each team had two projects focused on the development of autonomous quadcopter and rovers. The following list the Sandia mentors.

1. Steve Buerger, Mechanical Engineer, Robotics and Control Robotics Department
2. Anirban Mazumdar, Postdoc Appointee, Robotic and Controls Robotics Department
3. Anup Parikh, Postdoc Appointee, Robotic and Controls Robotics Department
4. Stan Atcitty, Electrical Engineer, Energy Storage Technologies & Systems Department
5. Sandra Begay, Mechanical Engineer, Device & Energy Technology Department
6. Julius Yellowhair, Optical Engineer, Concentrating Solar Technology Department

The mentoring team provided technical support in various areas including component design, manufacturing and assembly methods, and integration. Specifically, the Sandia mentors assisted the design and engineering teams with engineering targeted solutions for specific reliability problems with the rover and quadcopter designs. The mentors also helped with concepts for dealing with assembly challenges, addressing challenges with integrating the quadcopter flight controller with its electronic speed controllers, and software and firmware issues. With the manufacturing teams, the Sandia mentors used a more advisory approach, helping to facilitate and redirect creative ideas from the teams to improve the likelihood of success. The mentors also communicated the best tools and methods to use for particular aspects of the part production and assembly process.

The Sandia mentoring team also helped develop the rubric used to scoring the project outcomes and the performance of the manufacturing teams. The mentors provided judging and scoring of the teams' performance on the day of the final presentations. Scoring focused on a number of criteria including demonstrated teamwork, time management, creative thinking and problem solving, and presentation and communication skills. Technical performance of the quadcopter, demonstrated in the flight tests, was also evaluated.

Finally, the Sandia mentoring team focused explicitly on embodying good examples of ethics, diligence, and engineering performance and worked to forge relationships with the summer institute students. The team recognized that their attentive presence alone, representing a world-class research laboratory as well as their own successful engineering records, could help to validate the importance of the work being performed by the summer institute students. The mentoring team made sure to listen carefully to the

students and respond as honestly and positively as possible. The mentors made an effort to engage the students in discussions about their plans, futures, and communities, and provide advice about potential career choices and avenues of study. While hopefully enhancing the experience of the summer institute students, the mentoring team also benefitted significantly from the opportunity to work with enthusiastic young minds from diverse backgrounds.

2.7 Kansas City National Security Campus

In the latter part of FY17, the NNSA Minority Serving Institute program has added the Kansas City National Security Campus (KCNSC) Operation to support the TCU/AIHEC advanced manufacturing consortium by applying lessons learned from their previous Institute experience in R&D, education, and outreach. Sandia started working with KCNSC in the fourth quarter of FY17. The interactions were focused on scoping out collaboration ideas between KCNSC, Sandia, and the TCU's. As a result, during FY18 and FY19 Sandia will work closely with KCNSC to coordinate student intern positions, provide opportunities for student exposure to both Labs, promote opportunities for TCU students to gain exposure to other advanced manufacturing opportunities at Sandia, support professional development for TCU faculty & staff, and provide summer internship opportunities. Detailed discussions between Sandia and KCNSC are ongoing.

3 Conclusion

The TCU Advanced Manufacturing Summer Institute was very successful. The students gained multiple Advanced Manufacturing techniques and put their skills to work by building an educational rover and drone. In addition, the students gained new friends and established networking relationships with the SIPI staff and students and Sandia technical advisors. The Sandia technical team found it gratifying and were more than willing to provide technical guidance and mentoring.

In additional, significant gains were made in R&D activities at all TCUs in addition to curriculum and outreach development. Discussions with each of the respective TCUs is on-going.