

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

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ACRONYMS AND DEFINITIONS

Abbreviation	Definition
ABET	Accreditation Board for Engineering and Technology
AIHEC	American Indian Higher Education Consortium
BMCC	Bay Mills Community College
CAD	computer aided design
CCCC	Cankdeska Cikana Community College
FMECA	Failure Modes, Effects & Criticality Analysis
GIS	Global Information System
HLC	Higher Learning Commission
IE	Indian Energy
KCNSC	Kansas City National Security Campus
MSIPP	Minority Serving Institution Partnership Plan
MSU	Montana State University
NDSU	North Dakota State University
NNSA	National Nuclear Security Agency
NTU	Navajo Technical University
PEEC	Pre-Engineering Education Collaboration
R&D	research and development
SIPI	Southwestern Indian Polytechnic Institute
SKC	Salish Kooteani College
SLAM	Simultaneous Localization and Mapping
SMC	Sioux Manufacturing Corporation
SME	subject matter expert
STEM	science, technology, engineering, and mathematics
TCUs	Tribal Colleges and Universities
TEAMED	Tribal Ecology using Advanced Manufacturing, Education, and Drones
TMCC	Turtle Mountain Community College
UNL	University Nebraska Lincoln
UTTC	United Tribes Technical College

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 updates 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 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 (Sandia) 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 (SKC). AIHEC and Sandia, with collaboration from SIPI, established an eight-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 was consistent with current advanced manufacturing design and engineering practices. In addition, Sandia provided technical assistance to each of the TCUs regarding their current advanced manufacturing activities.

Sandia, AIHEC, and the TCUs under this project had a kickoff meeting on the SIPI campus on 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 provides 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 Gencarelle (Smarter Building Systems-Materials Consultant), Stan Atcity (Sandia), and Don Bender (Sandia flywheel expert). First discussed and strongly emphasized by Mr. Bender was approaching a 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 and 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 to review and provide 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 9 with Sandia. Stan Atcity, 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 was 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 was to reach a tensile strength well above the 6 ksi level with a target performance of 12-15 ksi. Nick Gencarelle 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 was 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. 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 was the stress concentration factor at the shaft-to-rotor interface (2x) which was 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. 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 this was a priority action item to involve BMCC students within the project through computer aided design (CAD) work, concept 3D printing of the flywheel, and coordination with present course work taught by Chet Kasper at BMCC as a demonstration project which would be 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.

Flywheel energy storage future development is under re-evaluation due to the question of concrete as a viable material in cost, performance limits, and global market penetration. The concern is based on a theoretical prediction of flywheel stress states that limit the ability of concrete to meet radial and hoop strength criteria. Chris Griffen is completing this analysis which thus far indicates a strong long-term market need for flywheel energy storage technology; however, at this point it does not indicate specific technical demonstration/capability for concrete material applications other than on proven commercial application in Europe.

A conference call was held on August 28, 2018, between Chris Griffen (BMCC), Don Bender (Sandia) and Stan Atcitty (Sandia) to get technical status update. Griffen stated that over a 2.5-month period earlier in the year, he concluded that concrete was not an economic choice for a flywheel rotor material. He further stated that he identified an orthotropic material that would be economic for flywheel rotors. Griffen explained that he decided to cancel work on the concrete rotor, and plans to pursue an orthotropic composite rotor instead.

2.1.2. *Ballistic Panels for Energy Systems*

The first meeting was held on February 13, 2017, and included Chris Griffen (BMCC), Nick Gencarelle (Smarter Building Systems-Materials Consultant), Stan Atcity (Sandia) and William Reinhart (Sandia technical expert in impact/ballistics). William Reinhart provided an 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 shock wave 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 presently has in-house tools 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 Atcity, 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 25 (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 supplied 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 funded this through their grant.

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.

BMCC worked with CCCC and Sioux Manufacturing in early 2018 to provide both computer-aided engineering support and material baseline ballistic panels representing current technology in materials and construction strategies. The team determined future design changes using lower cost basalt and interface layers.

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.

Stan Atcity (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 (two students) and 2017 (three 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.

Stan was an invited speaker at the 5th Annual North Dakota Tribal College Research Symposium at CCCC on April 7, 2017. 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. A tour was also provided by Sioux Manufacturing Corporation (SMC) where Stan met with Jim Anderson (manager) and Jacob Toward (staff member). SMC manufactures composite materials for 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). CCCC provided simulation and modeling services and rapid prototyping coordination to SMC in early 2018. Services included:

- Production panels bench marking, including Ablative, Kevlar, S2, and thermoplastic formulations
- Internal test specifications for the aforementioned panels
- Derivative layers and materials supplied by BMCC
- Aberdeen test requirements

The R&D and technical discussion are on-going between CCCC, Chris Griffin, and SMC.

Stan Atcity (Sandia) provided background on air and water drone development at Turtle Mountain Community College (TMCC) and how it maps to the outreach, education, and R&D activities on October 24, 2017. The TMCC drone R&D is further discussed in this report in Section 2.5. As a result, R&D planning has begun at CCCC with a focus on Eco-Drone development and special emphasis on additive manufacturing. CCCC is in the process of selecting and procuring high-end drones. CCCC will be utilizing the AM 3-D equipment to create various payload equipment such as Global Information System (GIS) monitoring, a camera, infrared camera, barometer, thermometer, hygrometer, and moisture ground reader for the Eco-Drone. Sandia and Kansas City National Security Campus (KCNSC) will provide assistance in professional development and subject matter expertise in modeling, simulation, and mechatronics.

CCCC has been involved in a number of undertakings during this reporting period. The additive manufacturing faculty continued to advance their knowledge in Solid Works utilizing Solid Professor software and related text books and experimenting with 3D prototype printing. The faculty and students began using a new Mark Forge Mark 2 3D printer. This printer has the advantage of faster and more accurate print operations than previous versions.

The AM-101: 3D Modeling for Advanced Manufacturing course, which was first taught in the spring of 2016, was taught for the fourth time in the spring of 2018 with a total of two students. CCCC has completed the New Program Review Report for its proposed certificate program in additive manufacturing, and it has steadily made its way through the approval process. It has passed through the CCCC curriculum committee as well as the school's Board of Regents. It still needs to go through the Higher Learning Commission (HLC) and the Department of Education for final approval.

CCCC hosted a half-day workshop on February 23, 2018, that included hands-on activities to encourage participants to consider non-traditional employment, including 3D engineering in additive manufacturing and other fields of study. Participants learned about 3D printing and scanning. Less than five students from around the area attended the event. CCCC will continue to hold workshops and recruitment at local high schools with technical assistance from Sandia and KCSNC.

Jeri Timlin (Sandia), Tom Reichardt (Sandia), Stan Atcity (Sandia), Karl Heafner (CCCC), Heidi Ziegenmeyer (CCCC) held the initial teleconference on August 13, 2018, to discuss biological sensing and sensor technologies and how they integrated with the CCCC drone R&D. Another meeting was held on August 23 with the same group including Sreekala Bajwa (NDSU) and Josh Vance (KCP) to further discuss biological sensing. This meeting resulted in the establishment of roles and responsibilities for all parties.

The Sandia team consisting of Stan, Tom Reichardt, and Jeri Timlin, met with Karl Heafner (CCCC), Heidi Ziegenmeyer (CCCC), Xin (Rex) Sun (NDSU), Mike Parker (CCCC) on November 6, 2018. Rachel Grotzsky (KCNCS) and Amy Moser (KCNCS) joined the meeting via teleconference. The purpose of the meeting was to get updates on the projects and discuss possible biological/environmental science applications areas for the drone-based sensing that have tribal significance. The Sandia team and North Dakota State University (NDSU) team received tours of Heidi Ziegenmeyer's biological laboratory, the indoor greenhouse facility, and several of the advanced manufacturing/engineering classrooms, including 3D printing capabilities. Karl presented a comprehensive update of the CCCC's activities in education, R&D, and outreach. Rex briefed the team on additional projects underway at NDSU that are relevant to agricultural sensing and discussed new majors in precision agriculture and upcoming course he will be teaching on mapping of agricultural data. The team enjoyed a presentation by a CCCC student, Isnala N. Roan Eagle, on his research in breast cancer under the supervision of Dr. Brent Voels. Isnala is a mechanical engineering student who is also interested in biomechanical engineering. Stan gave an overview of the three potential summer intern positions that will be coming available and specifically targeting students from tribal colleges. Information was shared about the student intern program and the application process. KCNSC gave an update about the status of the rover they are working on for CCCC as well as "Industry Day" event planned for spring. Stan gave a motivational and STEM related speech to approximately 150 students at the Four Winds Community High School.

Stan shared a motivational speech entitled, “From the Navajo Nation to a Distinguished National Laboratory”, to over 25 students at the 7th Annual Tribal College Research Symposium held at CCCC on April 2, 2019. The symposium is a showcase for all STEM related research conducted at the Tribal Colleges in North Dakota. It is also meant to inspire students to become researchers in the STEM fields. While at this event, Stan met with Karl Hefner (CCCC) to get updates on the project.

2.2.1. CCCC TEAMED

CCCC has embraced the Tribal Ecology using Advanced Manufacturing, Education, and Drones (TEAMED) concept similar to TMCC. The TEAMED concept is described below.

2.2.1.1. Introduction

Spirit Lake Nation is one of the 567 federally recognized Indian tribes in the United States. There are 7,256 total members enrolled living on the Spirit Lake Reservation, but only 2,069 have a current physical address on file with the Enrollment Office. The Spirit Lake Tribe is made up of people of the Pabakse, Sisseton, and Wahpeton bands. The topography of the Reservation is generally consistent with the Northern Plains region, with both flat terrain and rolling hills, and some wooded areas. The major surface water feature of the Reservation is Devils Lake, which comprises 90,000 acres of area stretched over 200 miles. There are also numerous small lakes on the Reservation, including Twin Lakes, Spring Lake, Free Peoples Lake, Elbow Lake, and Skin and Bone Lake. The Tribe’s traditions, stories, and dependence are built around the region’s multiple lakes, ponds, wetlands, and ecologically diverse landscape that includes a variety of trees, birds, mammals, reptiles, fish, deer, and a buffalo herd.

Drone technology aids in studying this ecological system and provides educational opportunities at CCCC in the areas of advanced manufacturing and STEM. In addition, establishing an advanced manufacturing program to study this technology at CCCC provides opportunities to partner with NDSU, other TCUs, industry, and government.

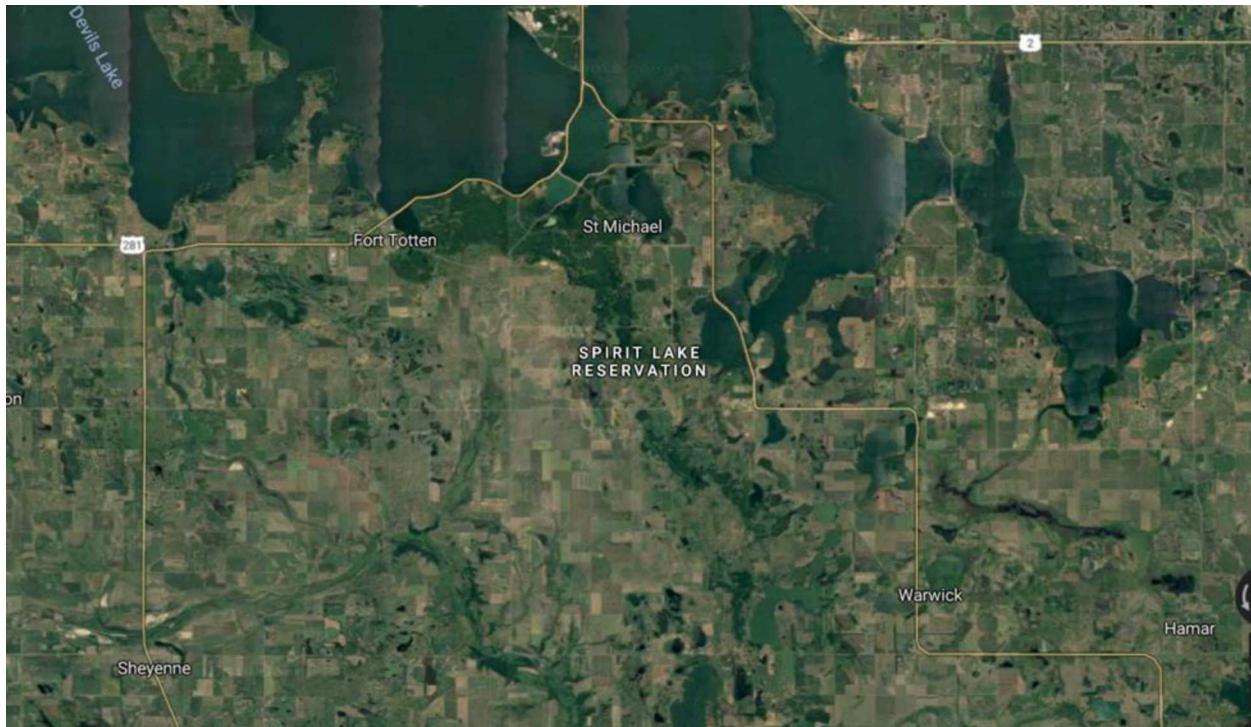


Figure 1. Aerial view of Spirit Lake Nation displaying multiple lakes and diverse landscape, courtesy of Google Maps.

2.2.1.2. Environmental Science

The state of the ecological system at the Spirit Lake Nation is critical to the future of the tribal people who call it home. 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.

2.2.1.3. Drone Technology and Advanced Manufacturing

A multifaceted and sustainable educational program at CCCC 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 CCCC, 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 CCCC’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.

2.2.1.4. CCCC Advanced Manufacturing Program Plan

CCCC is currently funded by the NNSA's 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.

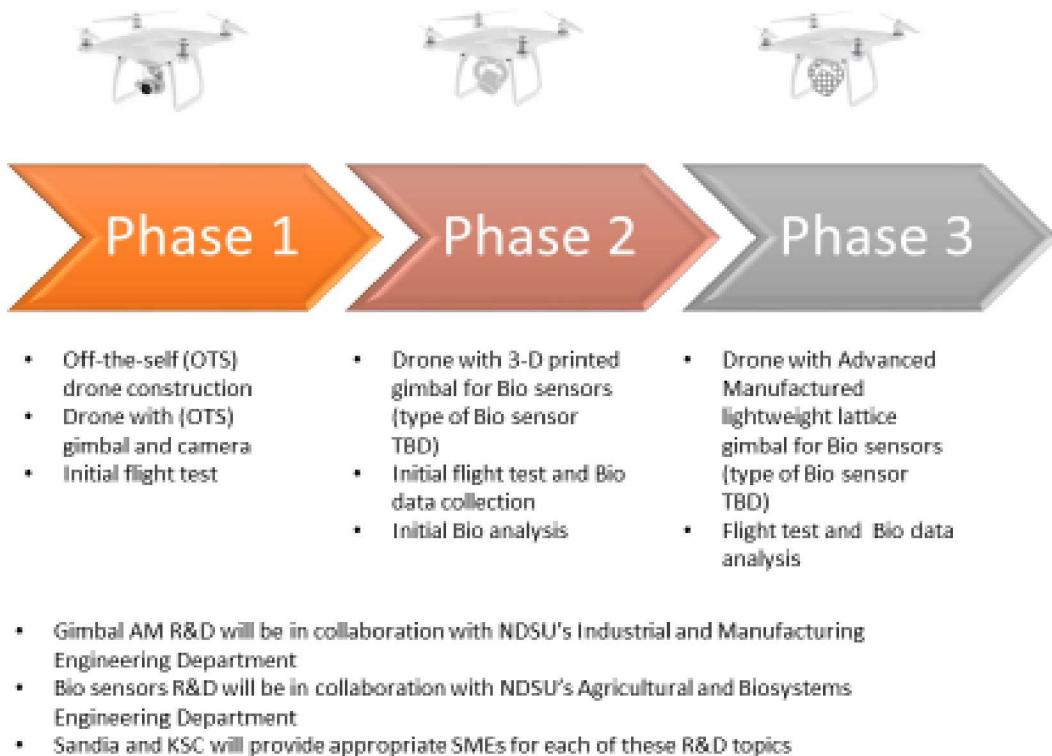


Figure 2. Key Drone Advanced Manufacturing phases at CCCC

The following captures the overall vision of the advanced manufacturing program at CCCC.

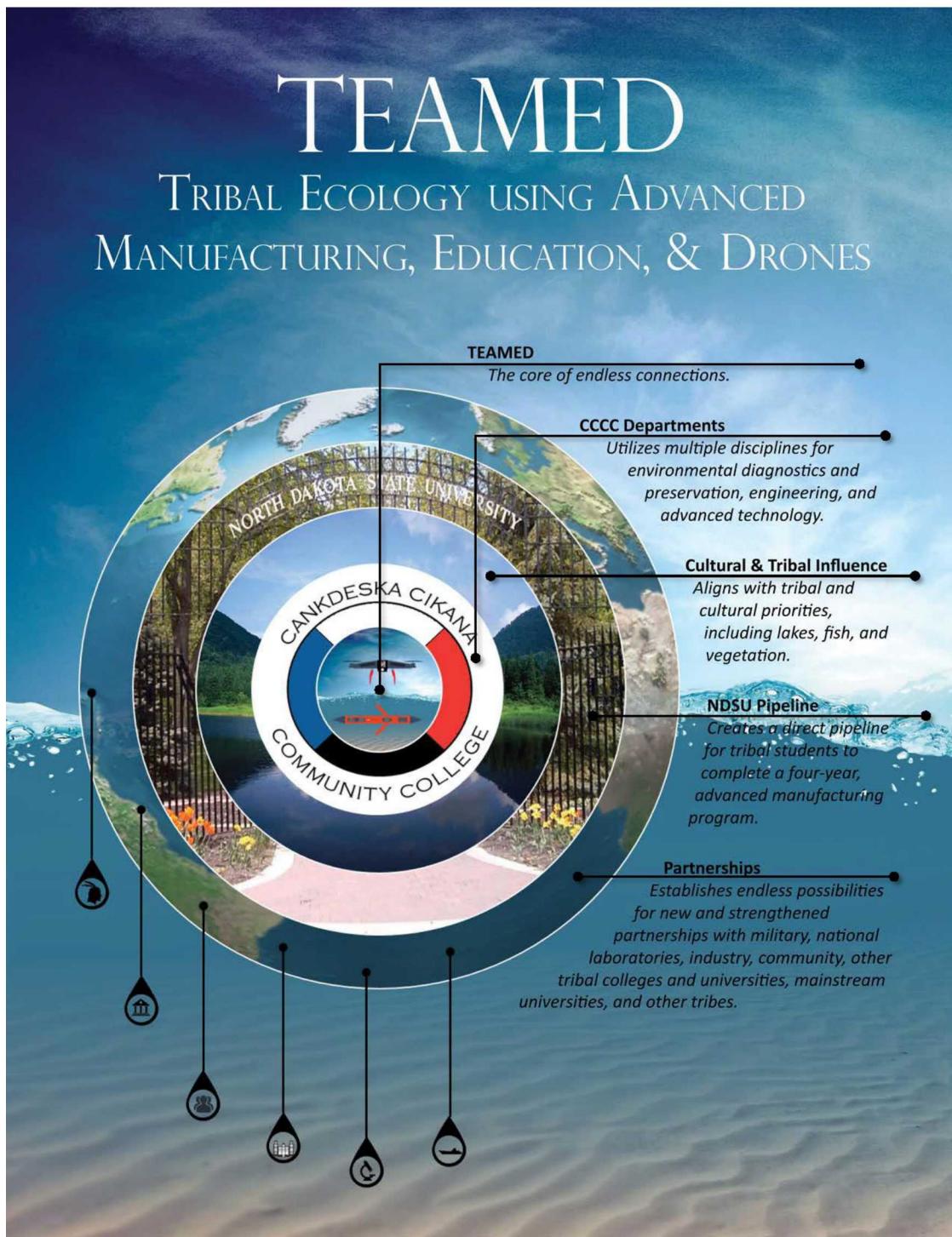


Figure 3. CCCC's advanced manufacturing program concept.

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 January 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 regarding tensile testing, fatigue testing, density testing, computed tomography (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 (EAB) 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 the Accreditation Board for Engineering and Technology (ABET) accreditation; and support promotion and development of education programs and facilities. Stan has been serving in that capacity since spring of 2015. The ABET accreditation team had a formal visit to NTU on November 1-3, 2017. No significant deficiencies were noted in their exit report; thus, the NTU received an official notice on August 28, 2018, that their Electrical and Industrial Engineering programs will be ABET accredited retroactively from October 1, 2015, until September 30, 2024. NTU is the first TCU to obtain such a significant milestone. This will significantly expand the students' opportunities and marketability as they enter the workplace. Stan has been conducting NTU on-site EAB meetings twice a year during the spring and fall semesters. A majority of the EAB meeting focus is on sustaining the ABET accreditation and continued improvements.

NTU visited and toured Sandia's additive manufacturing and testing methodologies laboratories on October 17, 2017. Adam Cook (Sandia) met with Scott Halliday (NTU) to discuss alternative ways to view additive manufacturing, the possibilities of adopting 5-axis computer numerical control machines, and the principles held within as they apply to additive manufacturing to existing objects. The visit also included demonstrations of the compression testing of polymers by John Schroder (Sandia). Sandia's polymer testing is focused on flexible polymers, which is different than the rigid polymers utilized at NTU. The demonstration was helpful for NTU, and it helped explain some of the software language used in machines at NTU, which allowed them to move towards research in 3D printed lattice structures. The visit provided a deeper understanding of the architecture of the lattice structure and simulation in 3D printed materials. Scott also met with Bradley Jared (Sandia) to discuss metal advanced manufacturing technologies. Information on building miniature tensile specimen and methodologies were helpful for NTU. Because of the visit to Sandia, NTU is now able to move forward with lattice structure compression testing and evaluation.

NTU hosted the Annual TCU Advanced Manufacturing meeting in Crownpoint, New Mexico, on September 13 through September 14, 2018. Sandia provided a status update regarding the technical assistance input throughout FY18. Jerilyn Timlin, a technical staff in the Bioenergy & Defense Technology Department, prepared and presented an overview entitled, "Remote Sensing of Algal Growth in Waterways" on September 14, 2018. This lecture was provided to TCU faculty members to gain a better understanding of optical sensors and optical spectroscopy for drone-based detection of algal blooms as a case-study due to its relevance to their respective Advanced Manufacturing

Drone R&D, namely regarding activities at TMCC, CCCC, and SKC. The presentation was very useful and it was well received.

Karen McDaniel's, manager of the Tester Development & Use Control Design at Sandia, visited Scott Halliday, Monsuru Ramoni, and students on April 3, 2019, to discuss pathways from NTU to Sandia in the area CAD. Sandia has a significant need in this area and is in the process of hiring CAD technologists. Gaps were identified in NTU's curriculum and are currently being addressed by the NTU faculty members. This discussion is on going.

Sandia provided a support letter for NTU for the NNSA MSIPP proposal entitled, "Sustainable Workforce through Advanced Manufacturing (SWAM)" on February 15, 2019. This project was not funded. If funded, Sandia would have provided 3D modeling and additive manufacturing abilities specifically directed towards energy deposition.

Sandia provided a support letter for the continuation proposal lead by NTU focused on advanced materials and advanced manufacturing. This two-year proposal was selected and Sandia will be providing subject matter experts (SMEs) and identifying specific technologies for tribal and community-scale projects.

2.4. Salish Kootenai 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 after more than two years in orbit. A teleconference meeting took place on December 12, 2016, between Thomas Trickel (SKC), Stan Atcitty (Sandia), and Charles Carter (Sandia SME 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 and physics laboratory, networking lab, hardware implementation laboratory, and computer class room. An 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 engineering lab sequence of three courses and an Internet of Things information technologies course were offered 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 and 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. Stan Atcitty (Sandia), Amy Moser (KSNSC), and Kevin Baughn (KCNSC) made a visit to SKC on September 12, 2017. The focus of the visit was to discuss SKC's Advanced Manufacturing goals and objectives and to look for additional ways for both Sandia and KCNSC to contribute to SKC's goals and objectives.

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 includes electrical circuit board R&D. Sandia provided the state-of-the-art tools and techniques and technical guidance on rapid prototyping. Technical discussions continued in the FY18 school year.

2.4.5. *Biological Science R&D*

Jeri Timlin and Tom Reichardt, both in the Sandia's biological science department, have been providing technical assistance for biological monitoring utilizing underwater drones. In particular, there were several discussions to date focused on the application of using underwater drones to monitor and detect Zebra/Quagga Mussels due to their invasive nature in waterways. There are two possible methods to use the drone to detect these: image-based and optical spectroscopy-based. It was recommended to use the image-based approach because it is simpler and the Quagga mussels have a distinctive colorings and markings on their surfaces. The optical spectroscopy-based method will be considered at a latter time as the drone monitoring systems mature. An overall outline of experiments to collect the data necessary to demonstrate proof-of-concepts for detection was provided. Discussions on this topic are on-going.

2.4.6. *SKC TEAMED*

SKC has embraced the TEAMED concept as a path forward and is described below. This is very similar to the TEAMED concept at TMCC but the initial focus is on underwater drone-based biological monitoring.

2.4.6.1. *Introduction*

The Flathead Indian Reservation is home to three of the 567 federally recognized Indian tribes in the United States: the Bitterroot Salish, Upper Pend d'Oreille, and the Kootenai. There are 7,753 total members enrolled with about 5,000 living on or near the Flathead Reservation. The topography of the Reservation is generally consistent with the Pacific Northwest region, made up of valleys and mountains. The major surface water feature of the Reservation is Flathead Lake—the largest, by surface area, fresh water lake west of the Mississippi—which comprises 191.5 square miles stretched over an area of 30 by 16 miles. For its size and type, Flathead Lake is one of the cleanest lakes in the populated world. The Flathead River, which flows out of Flathead Lake, is the largest tributary of the Clark Fork River constituting over half of its flow. There are also other numerous small lakes and rivers on the Reservation. The Tribes' traditions, stories, and dependence are built around the region's multiple lakes, ponds, wetlands, and ecologically diverse landscape that includes a variety of trees, birds, mammals, reptiles, fish, deer, and a bison herd.

Drone technology aids in studying this ecological system and provides educational opportunities at SKC in the areas of advanced manufacturing, science, technology, engineering, and math. In addition, establishing an advanced manufacturing program to study this technology at SKC provides opportunities to partner with Montana State University (MSU), other TCUs, industry, and government.

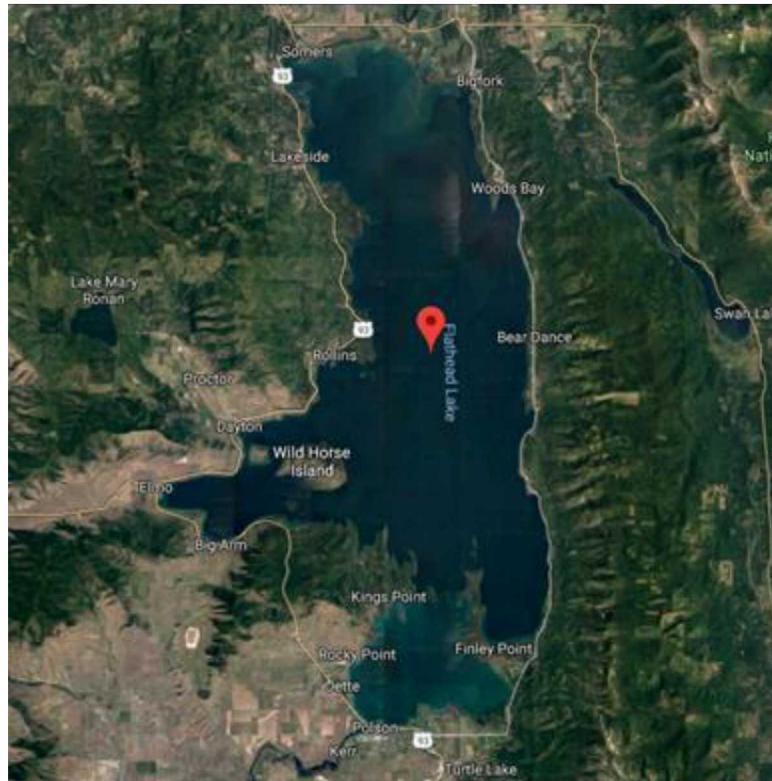


Figure 4. Aerial view of Flathead Lake, courtesy of Google Maps.

2.4.6.2. Environmental Science

The state of the ecological system on the Flathead reservation is critical to the future of the tribal people who call it home. 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.

2.4.6.3. Drone Technology and Advanced Manufacturing

A multifaceted and sustainable educational program at SKC can be implemented using existing programs, including wildlife and fisheries management, hydrology, mathematics, life science, social science, geography, pre-engineering, and digital fabrication. In addition to supporting existing programs at SKC, this plan anticipates collaboration with MSU's engineering programs. It is envisioned that SKC's engineering and digital fabrication programs will be a feeder school for MSU. This will also provide an opportunity to engage with national laboratories, other TCUs, other mainstream universities, military, industry, and other Tribal entities.

2.4.6.4. SKC Advanced Manufacturing Program Plan

SKC is currently funded by the NNSA's 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.

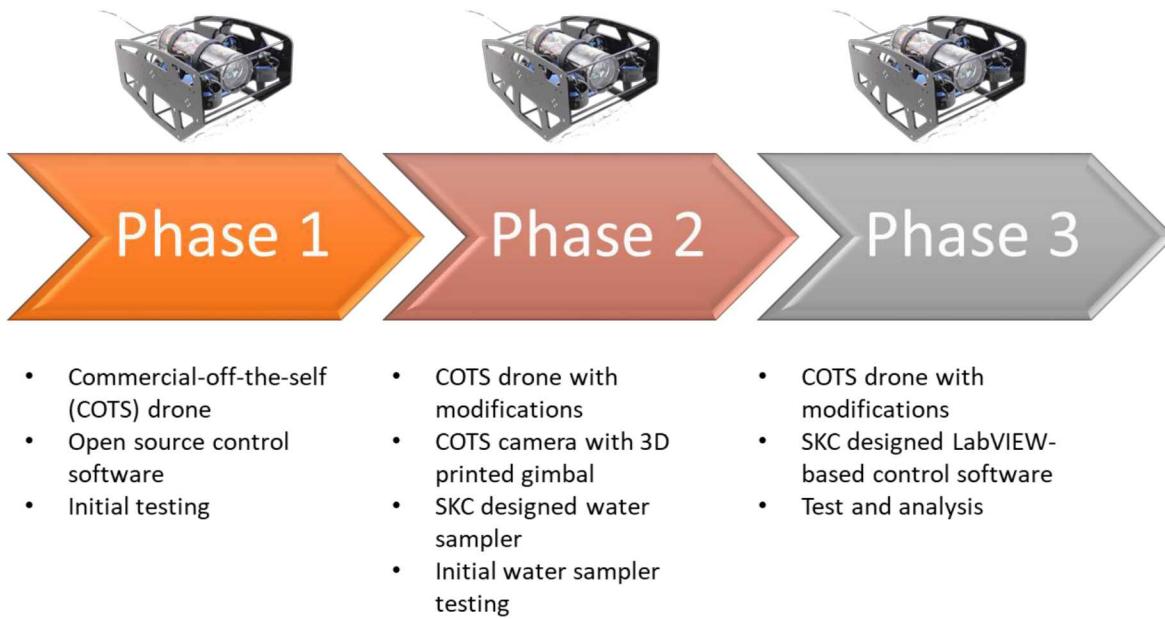


Figure 5. Key Drone Advanced Manufacturing phases at SKC.

The following captures the overall vision of the advanced manufacturing program at SKC.

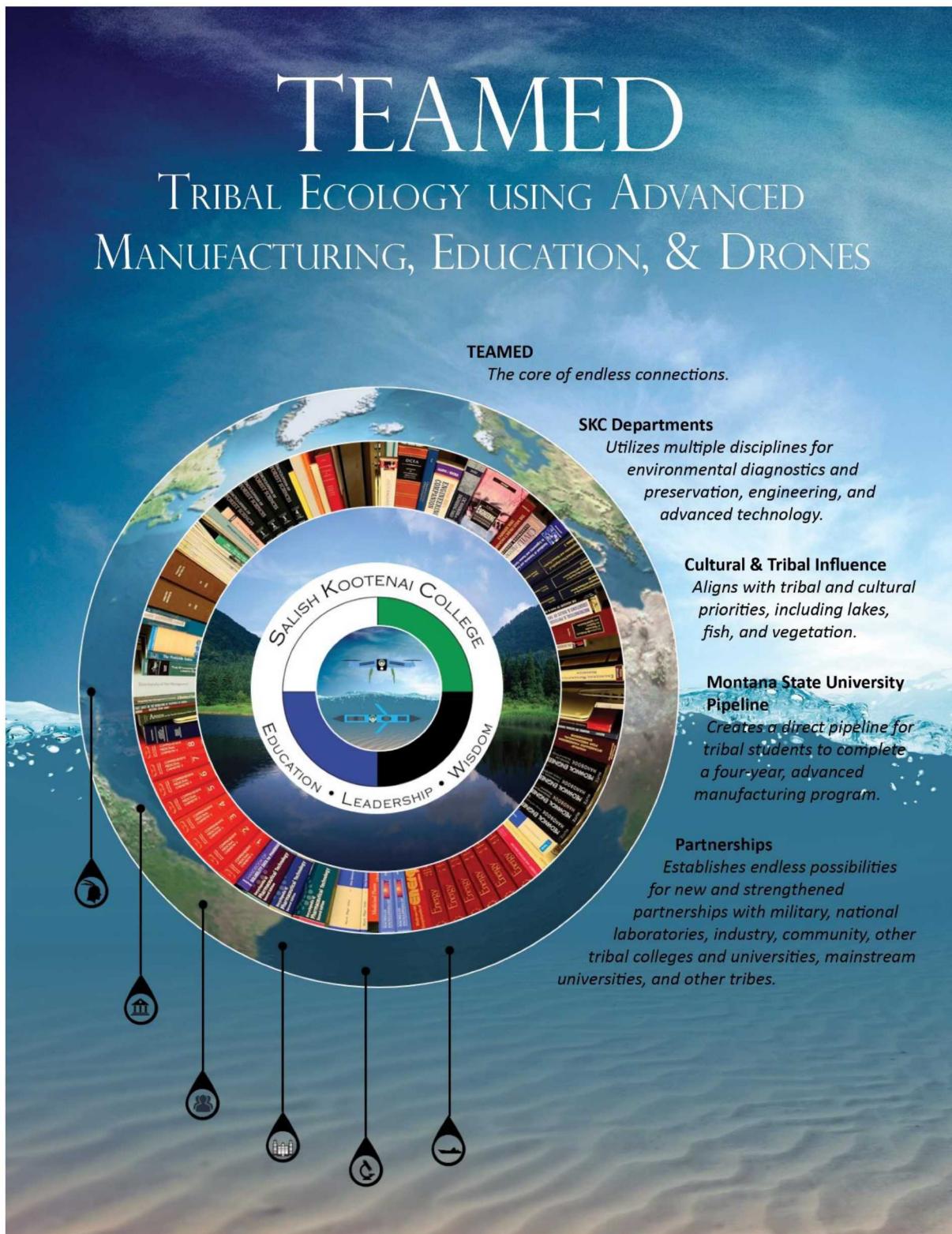


Figure 6. SKC's advanced manufacturing program concept.

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 Atcity (Sandia) conducted a site visit to TMCC on April 6, 2017, to learn more about the educational programs, meet current students, and see the advanced manufacturing R&D. TMCC is in 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 Atcity 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 Atcity 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 NDSU other TCUs, industry, and government.

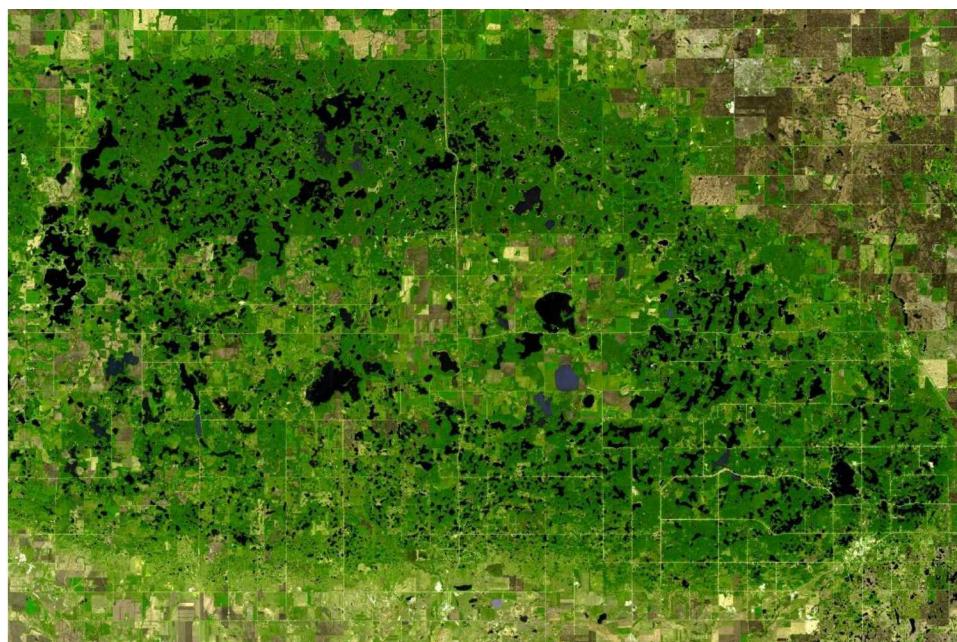


Figure 7. Aerial view of Turtle Mountain displaying multiple lakes and diverse landscape, courtesy of NASA's Earth Observatory.

2.5.1.2. Environmental Science

The state of the ecological system at Turtle Mountain is critical to the future of the Ojibwa Tribe. 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.

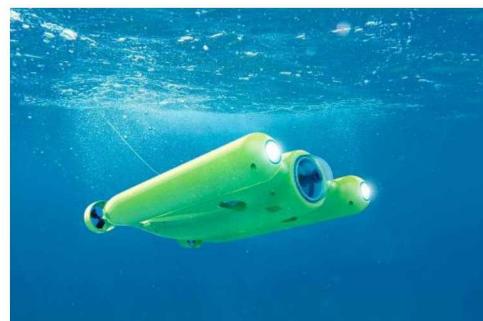


Figure 8. Example drones for aerial and marine explorations.

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's 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 acquisition
- Establish preliminary 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 institute in Albuquerque, NM
- Develop preliminary design of the underwater drone
- Seek internship opportunities 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 institute in Albuquerque, NM
- Prototype testing of the underwater drone
- Seek internship opportunities for the advanced manufacturing students

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



Figure 9. 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. Stan Atcitty (Sandia) and TMCC had an additional meeting October 23-24, 2017, at TMCC. Sandia provided additional background on the TEAMED concept to the TMCC president, Dr. Jim Davis, and the academic dean and head of Career Technology Education, Sheila Trottier. The meeting was productive, and both Dr. Davis and Ms. Trottier thought that the concept would be advantageous for TMCC to embark on such activities on campus. Discussions with faculty and administration is on-going. Sandia also toured the potential additive manufacturing lab within the TMCC main campus. This lab is large enough to conduct both lectures and additive manufacturing lab experiments and activities. The additive manufacturing lab was approved by the school administration.

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. TMCC also bought an underwater drone and a Phantom Pro 4 drone to help accelerate curriculum, STEM outreach, and R&D activities.

A Sandia team consisting of Stan, Jeri Timlin, and Tom Reichardt met the new lead, Austin Allard, on November 5, 2018, at TMCC, to learn about his background, expertise, and role in the project. Austin provide a tour of his lab space. Stan shared the project history, over-arching goals, and current progress with Austin. Austin has his Ph.D. from Texas A&M in civil engineering and is a member of the Turtle Mountain Ojibwa Nation. The Sandia team and TMCC team also met with Xin (Rex) Sun, a new Assistant Professor at NDSU's Agricultural and Biosystems Engineering Department, on November 6, 2018, to learn about his background, expertise, and the courses he is developing in precision agriculture. He took over Dr. Sreekala Bajwa's projects after her departure in January 2019. Additionally, Dr. Sun briefed the team on other projects underway at NDSU that were relevant to agricultural sensing and whose outcomes could be leveraged for this project (e.g. Farm-BEETs has kits that tribal college students could be trained to use for monitoring soil moisture and plant health, and a recent USDA grant). Two TMCC professors, Debbie Hunter (Biology) and Stacy Blue (Environmental Science), discussed their interest areas with the Sandia team (population diversity, natural resources, leeches, and birch). From this, variety and health of the birch trees, emerged as a strong potential application area with tribal significance. Stan gave an overview of the three potential summer internship positions that will be coming available and specifically targeting for students from tribal colleges. Information was shared about the student intern program and the application process.

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 five-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, New Mexico, during the summer of 2017.

2.6. *United Tribes Technical College*

Stan visited the United Tribes Technical College (UTTC) on Sepember 12-13, 2019. He made a motivational speech on his background and what it means to be a native professional during the Environmental Science and Research seminar class. There were 12 environmental science and research students, one pre-engineering student, and 10 faculty/staff who attended. He did a similar speech during the Introduction to Engineering with CAD class. There were nine pre-engineering students, one environmental science and research student and two faculty members who attended the meeting. Both presentations were well received and students had multiple questions. Stan met with multiple students and some of whom may be good candidates for the upcoming Sandia summer internship.

2.7. 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. 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 developed by the teams.



Figure 10. Group photo TCU Advanced Manufacturing Summer Institute students, faculty, and mentors (courtesy of SIPI).

2.7.1. *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

2.7.2. *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 lists 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 Atcity, 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 for 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.

2.8. 2018-19 TCU Advanced Manufacturing Technology Summer Institute

AIHEC in partnership with the University of Nebraska Lincoln's (UNLs) department of Mechanical and Material Engineering hosted the 2nd and 3rd annual Advanced Manufacturing Summer Institute from June 18 through August 8, 2018, and June 19 through Aug 02, 2019, on the UNL campus. Fourteen students from six TCUs (College of Menominee Nation, CCCC, Northwest Indian College, Haskell Indian National University, Nebraska Indian Community College, and NTU) attended the Institute during the 2018 program. Sixteen students from eight TCUs (Sitting Bull College, Cankdeska Cikana Community College, Nueta Hidatsa Sahnish College, Salish Kootenai College, United Tribes Technical College, College of Menominee Nation, Navajo Tech University, and Institute of American Indian Arts) attended the Institute during the 2019 program. During both summers, they were provided hands-on experimental learning opportunities on designing, building and testing aerial drones using 3D design, 3D printing, and metrological analysis tools using UNL's engineering facilities. During the Institute, the students heard presentations from industry leaders, UNL and TCU faculty, and national laboratory SMEs. Sandia had several conversations with Iman Esfahani, one of UNL's team leaders who contributed to the Summer Institute planning. The main objective of these conversations was focused on providing the appropriate SME best suited for the summer program. Three SMEs were provided and they are summarized below. In addition, Stan Atcity (Sandia) provided a presentation focused on his experience as a Native engineer at a national laboratory. The students were very engaged and asked multiple questions that helped them craft their own education pursuits. Stan has provided mentorship to the students during both of his visit to UNL.

2.8.1. Soft Skills

The soft skills lecture focused on *The Power of Introverts* was provided on July 19, 2018, and June 11, 2019, by Marie Capitan, a Diversity Workforce Specialist whose is a member of the Navajo Tribe. The lectures focused on interpersonal and communication skills, detecting unconscious bias, insights on how most people experience difference, the impacts of introversion and extroversion in the workplace, and how to practice courageous conversations utilizing eight leadership skills. The students were engaged through a combination of short video clips and structured dialogue that reinforced key learning objectives. Some of the student's comments from 2019 were, "I will be aware of toxic situations and I will know to express myself respectfully", and "I will learn to unpack and unhook stresses and deal with situations head-on".

2.8.2. Mechatronics

There were two lectures were given by Stephen Buerger, a technical staff in the Robotics & Counter Robotics Department, on July 19, 2018, in the area of Mechatronics. The morning lecture titled, "Mechatronics System Elements" provided definitions of mechatronics, an overview of the types of elements that compose typical mechatronic systems (including sensors, effectors, intelligent processing, and interface elements), and an overview of specific examples of each type of system elements. The afternoon lecture entitled, "Mechatronics Architectures and Examples" detailed specific examples that make up a number of different types of modern mechatronic systems, with particular emphasis on modern robotic system development by Sandia's robotics group. Stephen provided two similar lectures on June 18, 2019, but with a more interactive approach.

2.8.3. Additive Manufacturing

Two lectures were provided by Shawn Whetten, a technical staff in the Coating & Additive Manufacturing Department, on July 18, 2018. The first lecture included an overview of additive manufacturing and brief description of additive manufacturing processes and design principals. The second lecture included an overview of additive manufacturing programs at Sandia. The purpose was to show the students the science and engineering involved in advanced manufacturing in real world scenarios such as nano scale and 3D printing utilized at Sandia. No additive manufacturing lectures were provided by Sandia during the 2019 program.

2.9. Kansas City National Security Campus

In the latter part of 2017, the NNSA MSIPP added the 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 2017. The interactions were focused on scoping out collaboration ideas between KCNSC, Sandia, and the TCUs. As a result, during 2018 and 2019 Sandia worked 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 and staff, and provide summer internship opportunities. Detailed discussions between Sandia and KCNSC are ongoing.

3. SANDIA NATIONAL LABORATORIES SUMMER INTERNSHIPS

Sandia hired its first ever MSIP summer intern, Gordon North Piegan. He is a member of the Blackfeet Tribe in Montana and is an electrical and computer engineering undergraduate who transferred from SKC. As of the summer of 2018, he has completed his first year at MSU. While in Sandia's Robotics & Counter Robotics R&D Department, Gordon tested various perception and decision tools related to robotics. He researched and developed Simultaneous Localization and Mapping (SLAM) systems to ensure optimal software performance. The following is what he said about his experience at Sandia.

“My overall experience at Sandia National Laboratories was once in a lifetime. I would describe it as one of the most challenging yet rewarding endeavors I have been a part of. The idea that from the very start that I contributed to projects that have the potential to change the world was truly inspiring. However, it was not only the work that was rewarding, but the people I could meet. Sandia had one of the most diverse workforces I have ever been a part of. The Native American community made me feel right at home and other minorities here allowed me to truly see the world from a new perspective.”

Sandia almost hired a second intern from NDSU into Sandia's Coating & Additive Manufacturing Department. The student was a civil engineering who transferred from TMCC. While Sandia was at the final stages of the hiring process, the student decided not to take the offer.

Sandia opened five summer internship positions for the summer of 2019 in the Robotics, Additive Manufacturing, Bioscience, and Use Control departments. Three MSIP students were hired. Gordon was very interested in coming back this past summer but, due to illness, he wasn't able to come. Isnala Nanjin Roan Eagle, a member of the Oglala Sioux Tribe, and Roy Rafael, a member of the Navajo Tribe, were both hired in the Robotics & Counter Robotics R&D Department.

Isnala focused on micro optical sensor development for detecting shear forces of insoles. These next generation insoles will be used to detect body kinetics. In addition, he has worked on tactile-sensing gloves development utilizing SolidWorks, 3D printers, and silicone injection process. Here is what he had to say about his experience. “My internship with Sandia National Laboratories was a very positive and enrichening experience. I met a lot of very talented and bright people. Some of those people I am proud to say that I have become good friends with. My internship was very fulfilling. I met a lot of fantastic, intelligent individuals, gained professional experience, began the foundation of my “independent researcher” skills, and walked away with a better understanding to where I want to take my career in the future.” Isnala received his Associate of Science degree from CCCC and he is currently in his junior year at NDSU and majoring in mechanical engineering.

Roy focused his research on computer vision and deep neural networks using Nvidia's Jetson Xavier development tool kit. He integrated the Xavier and ROS (Robot Operating System) for use with robotic systems. This included writing a technical manual for setting up Jetson Xavier. He was also involved in helping a mobile robotic platform called the Gemini Scout get up and running. This involved generating an electrical schematic for the overall system, matching components needed for the battery system that will allow the robot to operate for a specific period of time, and wiring the hardware subcomponents of the Gemini Scout. Here is what Roy had to say. “I had a very good time at Sandia National Laboratories and honestly enjoyed the projects I was given, not only were they very relevant to what I had already learned but also to what I want to do in the future. It wasn't only about the subjects that I knew either, it was also about learning new subjects like computer vision and deep neural networks. One last great thing about SNL was that I was able to learn from both the post docs and supervisors both of which mentored me and can mentor me in the future”.

Roy has been accepted to Arizona State University's masters program in electrical engineering with concentration in digital signal processing.

The third student, Brett Alberts, a member of the Sisseton Wahpeton Sioux, was hired in the Tester Development & Use Control Design department. Brett embraced an opportunity to take a class on Creo, a CAD tool. With this, he was able to develop 3D model various tester parts and equipment. Here is what he had to say about the summer internship. "This internship has been my best internship so far in my educational career! Sandia really opened my eyes to the daily work life of different engineers and expanded my horizons for potential workplaces after college. The employees at Sandia are always more than willing to help and guide the interns with any troubles they may be having, which is extremely comforting for first-time interns. The networking opportunism I walked away with from this internship is priceless and I hope that one day I will be able to return to Sandia as a full-time Intern and work my way to Employee!" Brett, received his A.S. degree in pre-engineering at United Tribe Technical College and his now pursuing his B.S. in electrical engineering at University of North Dakota.

In addition to mentoring American Indian students, Stan had the privilege to work with a Historically Black College & University (HBCU) and MSIP student, Wesley Matingou. He is currently a fourth-year undergrad biomedical engineering student at Rensselaer Polytechnic Institute. He works alongside Isnala in the Robotics department. Here is what he had to say. "While at Sandia, I was welcomed with open arms and embraced by mentors like Stan who provided invaluable insights that will help me as I prepare for my career as a minority in engineering. I am forever grateful to him and Sandia for the transformative experience I had."



Figure 11. HBCU MSIP summer intern, Wesley Matingou

In addition to various technical projects at Sandia, the MSIP students were introduced to four DOE Indian Energy (IE) summer interns. Callie Singer, Navajo Tribe and civil engineering undergrad at Columbia University, Sherralyn Sneeker, Navajo Tribe and environmental science student from Dartmouth College, Veronique Arguello, Acoma Tribe and environmental planning and design undergrad student at University of New Mexico and Sarah LaVallie, Turtle Mountain Band of Chippewa Tribe and mechanical engineering student at NDSU. Part of the IE summer intern program involved trips to local American Indian reservations including Navajo Nation, Acoma Pueblo, Laguna Pueblo, Mescalero Apache, and Picuris Pueblo. Since parts of the R&D portion of the MSIP program involved tribal focus, the MSIP were given an option to attend these trips. All three

MSIP students were able to make some of the trips. Wesley was able to make one trip. This was an enriching experience for all students.



Figure 12. Sarah LaVallie, Callie Singer, Sherralyn Sneezer, Brett Alberts, Veronique Arguello, Isnala Nanjin Roan Eagle, and Roy Rafael (from left to right)

3.1. 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 UNL 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 addition, 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.

Sandia hired its first MSIPP American Indian summer intern during the summer of 2018 and the student's overall experience was very good; but due to his illness, he was able to return to Sandia. Sandia hired three summer MSIP students for the summer of 2019. A significant increase from last summer.

NTU is now an ABET Accredited institution which allows the National Labs and Industry to directly hire summer students and full-time personnel.

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