



ANNUAL REPORT

FY 2018-19

July 1, 2018 – June 30, 2019



Cybersecurity Education, Research and Outreach Center

College of Engineering

Tennessee Tech University



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Executive Summary

CEROC's FY 19 (July 2018 to June 2019) could be described as the center's "established" year. The center's name contains the pillars of mission, namely education, research, and outreach. With the completion of FY 17 and FY 18 efforts, the center worked on the development of its research infrastructure. The center achieved some substantial milestones which established a solid foundation for future growth. Among those milestones are the following:

- Phase Two of the Cyber Range began with the Infrastructure as Code project supporting all three center pillars
- Expansion of Three Cyber Interest Groups (CTF, Defense, Offense) to include maturing student mentoring and peer learning processes
- Continued to be the only Tennessee university to have both CyberCorps SFS and DoD Cybersecurity Scholar Programs

FY 17 (Education Focus) was the center's Year 0 where much effort was put into the development of our education and outreach pillars. Through these programs, CEROC has developed a recognized brand among key members (state and national level) in the education, government, and industry sectors. Our CyberCorps SFS Bootcamp, the first of its kind in the SFS program's history, has established CEROC as a formative leader in the current program and its future forms.

FY 18 (Outreach Focus) saw the development of center processes for fiscal and program management to better serve our student population and external partners. FY 18 also saw the completion of the center's staffing plan filling key positions for financial management and cyber range management and development.

As listed above, FY 19 (Research Focus) focused on the continued development of infrastructure and processes to support research initiatives. The dynamic nature of the center's work required a dynamic solution. Development of the CEROC Cyber Range focused on frameworks to facilitate the dynamic creation of virtual environments to support all three center pillars. A collaboration between center staff and upper-division/graduate students, PTerraDactSL is a platform built upon the TerraForm and SaltStack open source projects which facilitates the dynamic creation of virtual, experimental environments for cyber competition training, classroom support, K12 outreach programming, and cyber research.

About Tennessee Tech

Tennessee Tech University[1] is located in the city of Cookeville in Putnam County, Tennessee. With a population of 31,004 in Cookeville and 75,931 in the county, the area is regarded as the hub of the Upper Cumberland region, which include the 14-county area surrounding Putnam. The county has earned this designation due to its relative economic strength and concentration of academic and industrial resources. Complete profiles on Putnam County (and surrounding counties) as well as quick facts and summaries of state information can be found at the Tennessee Department of Economic and Community Development[2].



The areas of the Upper Cumberland region that surround Putnam County are mostly rural areas where unemployment and poverty rates are generally higher; CEROC outreach programming has focused on these areas, providing opportunities for students in rural schools to see cybersecurity educational material, encouraging consideration of cybersecurity as a field of study, sparking interest in cybersecurity competitions, and encouraging participation of underrepresented populations in STEM areas. We have replicated some of these programs for use in other venues across the state and at national conferences.

The state's only public technological university, Tennessee Tech University offers more than 200 undergraduate and graduate programs of study to about 10,100 students[3]. According to U.S. News & World Report, Tennessee Tech ranks in the top 150 Best Public National Universities, and Tennessee Tech graduates leave with the least debt of all public universities in Tennessee[1]. Tennessee Tech's College of Engineering receives one of the Best Undergraduate Engineering Programs rankings consistently. Tennessee Tech's Computer Science (CS) program[4] enrollment is increasing at a higher rate than any other departments in the college. There are 516 students in the current semester enrolled in the CS undergraduate and graduate programs. The combined CS student population is composed of 13.57% female students and 86.43% male students. In regards to ethnic background diversity, 15.31% are from underrepresented ethnic backgrounds.

In the computer science curriculum, there are three focus areas of studies: cybersecurity, data science and high-performance computing. The majority of the students (around 44%) are in the cybersecurity concentration and enrollment quadrupled in the four years since it started. We are the only program in Tennessee that offers student specialization in cybersecurity in CS at all three levels of education: bachelor's, master's and doctorate.

Tennessee, as a state, has become nationally recognized as an educational reform and workforce development state with multiple programs supporting the goals set forth by Governor Bill Haslam's administration and continued and expanded under Governor Bill Lee. A complete listing of publications about these efforts can be found at the Tennessee Department of Economic and Community Development website[2]. Education specific to post-secondary education reform and develop programs include:

- Drive to 55 Alliance[5]: drive to get 55% of Tennesseans equipped with a college degree or certificate by 2025
- Tennessee Reconnect[6]: aid adult learners in entering or returning to higher education to gain new skills, advance in the workplace, and completing a degree or credential.
- Tennessee Promise[7]: the first PK-14 program in the nation providing Tennessee high school graduates the opportunity to complete an associate's degree tuition free

Although cybersecurity is not central to Tennessee's Drive to 55 initiatives, it certainly can serve as a catalyst to accelerate cybersecurity efforts in the state. Therefore, this places Tennessee in



a special position to become a national example in using these unique initiatives to extend cybersecurity educational opportunities to both traditional and non-traditional student pipelines. The Middle Tennessee market has established itself as the healthcare management and technology capital in the nation, as well as a manufacturing technologies capital in the southeastern region. Middle Tennessee has an urgent need for the development of a stronger cybersecurity workforce to protect these vital infrastructures.

About CEROC

General

The Cybersecurity Education, Research and Outreach Center (CEROC) at Tennessee Tech University, virtually established in October 2015 and physically established in January 2016, is a Center of Academic Excellence in Cyber Defense Education (CAE-CDE) accredited by the National Security Agency (NSA) and Department of Homeland Security (DHS)[8]. The center was established by the Department of Computer Science and the College of Engineering to integrate university-wide existing activities and initiatives in cybersecurity education, research and outreach, the emphasis of which makes it unique in the state.

Mission

The mission of CEROC is heavily influenced by the federal CAE-CDE program and CyberCorps SFS programs and stands:

To advance and support cybersecurity workforce development following the pillars of education, research, and outreach in producing the next generation of cyber defenders and finding solutions to security and privacy problems in cyberspace.

With the overarching goals of increasing the number of qualified students entering the fields of cybersecurity and contributing to the capacity of the cybersecurity workforce, the activities of the center are centered on the following objectives:

1. To increase public awareness of information assurance and cybersecurity;
2. To supply adequately trained students in cybersecurity workforce pipeline;
3. To enhance students' knowledge, skill, research aptitude, and service-learning motivation through a program that values fair participation in education, research, and outreach
4. To create additional pipelines of qualified cybersecurity professionals in industry and federal agencies from Tennessee (and the region);
5. To increase women and under-represented minority students' participation in cybersecurity;
6. To promote and disseminate cybersecurity educational and research artifacts and experience in the academic community; and
7. To share expertise with partners through collaborative initiatives in cybersecurity workforce development and research.



To achieve these goals and support our mission, CEROC supports students with:

1. Scholarship opportunities to Tennessee Tech students in Computer Science within the Cybersecurity Concentration that allows for the completion of a graduate degree in half the time of a traditional path;
2. Technical and professional development infrastructure and training to supplement formal education and prepare students for challenging careers in cybersecurity in all sectors;
3. Opportunities for field-related work experiences and research guided by mentors from Tennessee Tech, and center partners;
4. Opportunities to participate in professional development events such as competitions and conferences in the field;
5. Opportunities to participate in student communities and professional societies; and
6. Opportunities for active involvement in outreach and service learning at different events organized by Tennessee Tech.

Diversity Background

CEROC has a rich history of diversity and outreach programming. Dr. Ambareen Siraj, CEROC director, is the founder of the National Women in Cybersecurity[9] (WiCyS) conference and non-profit organization. This is the largest initiative of its type in the nation focusing on workforce development and recruitment of women in the field of cybersecurity.

The Computer Science Department submitted an application to the BRAID (Building, Recruiting, And Inclusion for Diversity) initiative[10] and was designated a BRAID affiliate in 2018. The program, led by the Anita Borg Institute and Harvey Mudd College, provides support to computer science departments to help increase the percentage of women and underrepresented minority students in their undergraduate computing programs. As a result of this application, faculty members from the department have attended a diversity workshop. New diversity language for inclusion in all future proposals has been created as well as the creation of a standing diversity committee have resulted.

Regarding gender analysis in Tennessee Tech's computer science program over the past five years, modest gains have been made partially as a result of local diversity efforts such as participation in the Women in Cybersecurity conference, the establishment of an ACM-W and CyberEagles-W chapters, and direct recruitment. The table below shows a steady increase in female enrollment. Note that Spring 2012 is the last semester prior to many of the new diversity recruitment efforts.

Table 1 - Computer Science Gender Enrollment Analysis (8 year span)

Term	Spring 2012	Spring 2014	Spring 2016	Spring 2018
Female Enrollment	27 / 8.94%	31 / 8.49%	32 / 9.28%	60 / 13.48%
Male Enrollment	275 / 91.06%	334 / 91.51%	313 / 90.72%	385 / 86.52%
Total Enrollment	302	365	345	445

Influences of NSF CyberCorps SFS and DoD Cyber Scholarship Program

Tennessee Tech was awarded the **NSF CyberCorps SFS scholarship grant** in December 2015 (NSF Award 1565562). We were the first university in the State of Tennessee to be awarded the opportunity to manage this prestigious scholarship and remains the largest of such program in the state. The primary focus of the program was to produce candidates with M.S. degrees. With current extensions to the grant, we will produce approximately 32 workforce ready cybersecurity professionals over a span of five years. Twelve of them have graduated already with 10 serving in Federal agencies.

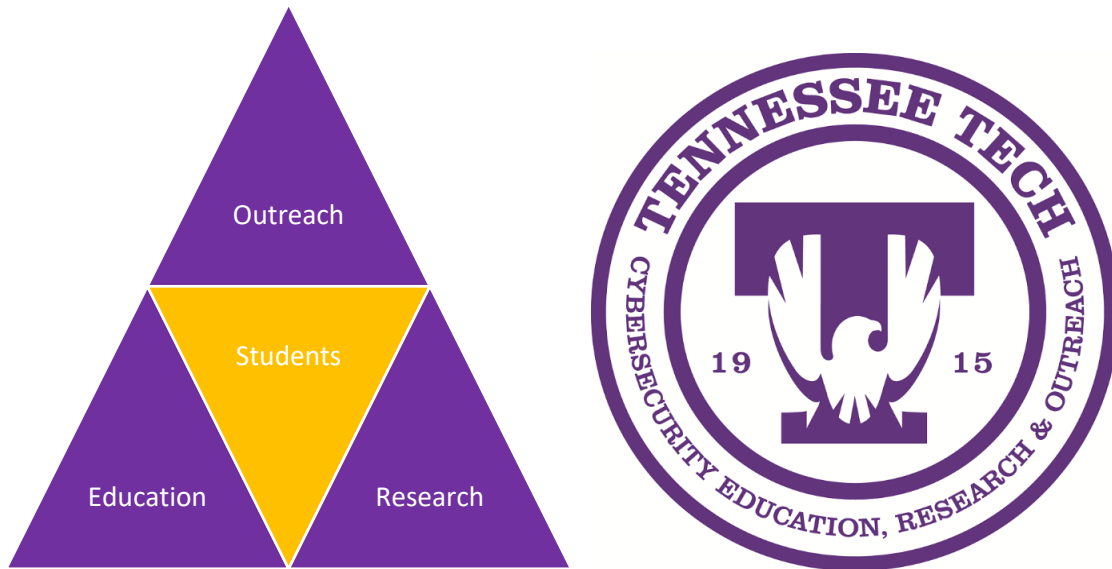
Tennessee Tech is one of 10 universities that participated in the **CyberCorps 2Y Community College Pathways Program** working with three of our four community college partners in the state. Five community college students have joined during their sophomore year at their original school and transferred to Tennessee Tech for two additional years, allowing completion of a B.S. degree in three years.

The impact of the SFS program for our school is indisputably groundbreaking. As a result of the center's CAE designation and the subsequent award of the CyberCorps SFS grant, the State of Tennessee, as part of the FY 2017 state budget process, appropriated "\$500,000 to Tennessee Technological University to match funds provided by the National Science Foundation for cyber security research (year 1 of 4)", a total of \$2,000,000 for the four-year period ending FY 2021. This non-recurring budget allocation was crucial in the establishment of CEROC and is the sole source of its logistical operations. The funds have been allocated each year in alignment with the center's three pillars of operation namely, education (20%), research (40%), and outreach (15%). CEROC has made every effort to maintain administrative overhead at approximately 20%. The funds provide for salaries for center staff, research infrastructure including the cyber range, mini-grants for faculty researchers, support for graduate and research assistants, and support for the many outreach activities that are conducted throughout the year for the community at large.

Tennessee Tech was awarded the **Department of Defense Cyber Scholarship (CySP)** grant in May 2018 (Award H98230-18-1-0315). This puts Tennessee Tech among an elite group of universities in the nation to have both the DoD CySP and CyberCorps SFS programs, not to

mention the only university in the State of Tennessee to have such a distinction. The primary focus of the program is to produce candidates with M.S. degrees, and currently we have three CySP scholars (2 males and 2 female).

CEROC Focus Areas and Goals



Education

Figure 1 - CEROC Focus Areas

Goal E1: To provide quality cybersecurity education – one of the essential skillsets for the 21st century

Objectives:

1. Increase the number of cybersecurity courses in the computer science curriculum based upon peer and industry feedback
2. Increase the number of cyber-related workshops focusing on professional development of educations in K12 and higher education offered by CEROC and its partners

Goal E2: To supply trained students for the cybersecurity workforce pipeline

Objectives:

1. Educate and mentor CyberCorps SFS and DoD CySP students to participate in quality professional development opportunities and internships positioning them to take their place in the federal, cybersecurity workforce
2. Education and mentor CEROC student affiliates to engage in professional development and research projects to development cyber skills which contribute to improved internship opportunities leading to better positioning for cyber careers in the public and private sector



Research

Goal R1: To facilitate and advance research in trending areas in cybersecurity

Objectives:

1. Collaborate with faculty members at Tennessee Tech and other peer / partner higher education institutions to develop proposals for emerging areas in cybersecurity related to high performance computing, big data, smart grid, smart manufacturing, IoT, and critical infrastructure
2. Increase recruitment efforts for M.S. and Ph.D. students especially in the 250-mile radius of campus referred to as Eagle's Reach where perspective students will be offered in-state tuition rates

Goal R2: To share expertise with partners in collaborative initiatives in cybersecurity workforce development and research

Objectives:

1. Expand undergraduate student research programs to reach out to K12 teachers and guidance counselors and to community college transition coaches thereby increasing an interest in the field
2. Develop strategies for workforce development and training exchange within National Guard and Army Reserve units through on-site and online programs

Outreach

Goal O1: To increase public awareness of information assurance and cybersecurity

Objectives:

1. Continue and expand, where possible, programs such as the Cyber STEMmobile and NSA GenCyber to reach more K12 students, teachers, and guidance counselors increasing an interest in the field.
2. Continue and expand media advisory and publication programs directed at the general public through traditional media outlets
3. Expand and improve the social media and traditional media footprint of the center

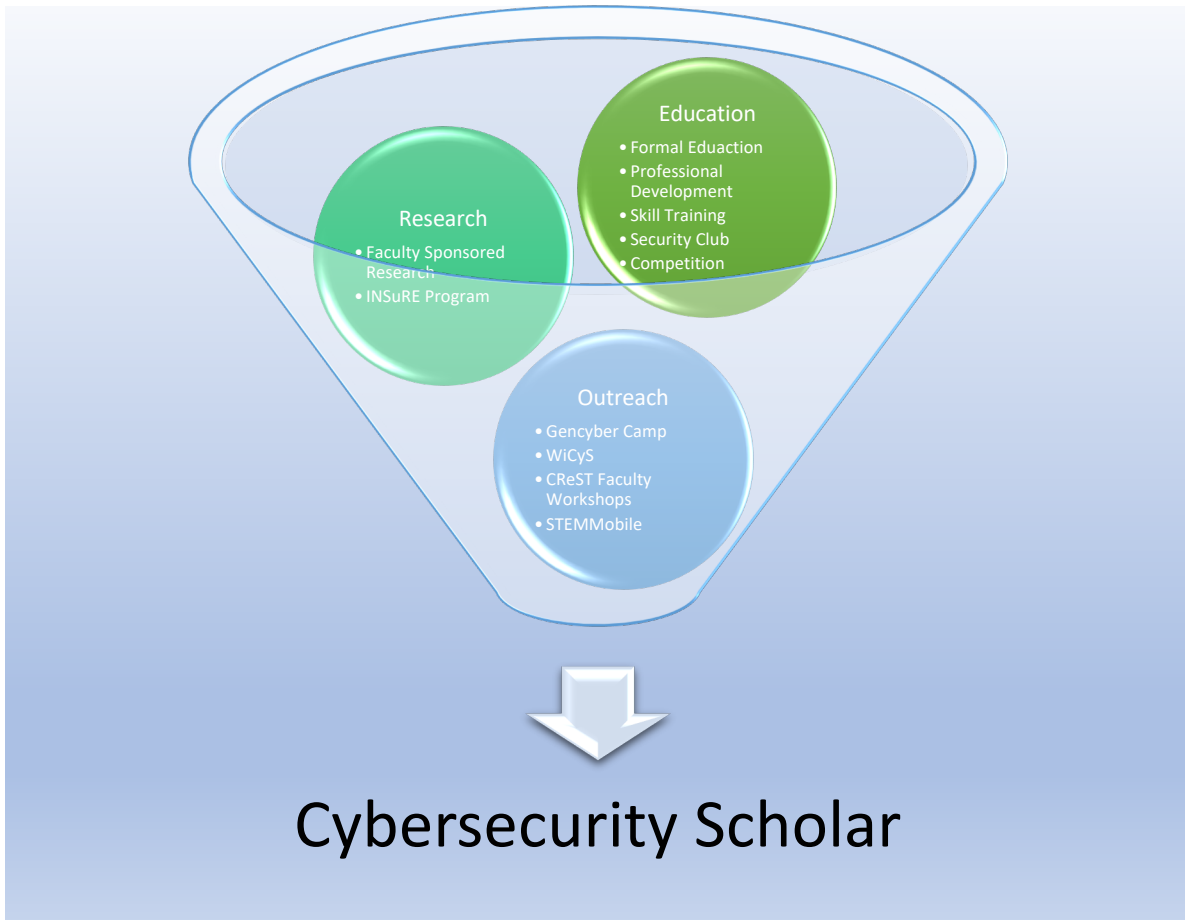
Goal O2: To promote and disseminate cybersecurity educational and research experience in the academic and commercial communities.

Objectives:

1. Continue a presence at major cybersecurity conferences featuring a mix of academia, industry, and Department of Defense presenting current research projects and prospective new projects focusing on critical infrastructure as defined by Presidential Policy Directive 21 [11].
2. Publish training materials via public project distribution points such as GitHub making resource kits available on a variety of computer platforms

Our Students

At CEROC, we facilitate an integrated experience for our cybersecurity students ensuring their participation in research and outreach activities alongside education activities in cybersecurity.



Education

At CEROC, we facilitate an integrated experience for our cybersecurity students ensuring their participation in informal education, research and outreach activities alongside their formal cybersecurity education as part of the CS curriculum. With the mantra of ***continuous learning, crowdsource learning and paying it forward***, our students are constantly challenged to immerse themselves into their educational experiences with the goals of enriching themselves and providing opportunities to enrich their peers and community around them.



FORMAL Education

The Department of Computer Science (CS) at TnTech has an ABET-accredited bachelor's program and offers degrees in multiple concentrations, as well as both MS and Ph.D. degrees. The degree requirements include those of the University, the College (COE), and the Department (CS).

Undergraduate Program in Cyber-Security

TnTech's undergraduate CS curriculum has included a concentration in the field of cybersecurity since Fall 2014. The purpose of this concentration is to provide a career path for TnTech students to obtain a Bachelor's degree in CS with an Information Assurance and Cybersecurity focus. This concentration includes a CS background with security relevant concepts that are applicable to computer and information systems security. There are 15 courses in the undergraduate cybersecurity curriculum that map to 22 knowledge units (KU) as specified in the CAE IA/Cyber Defense academic requirements. The curriculum offers dedicated security courses as well as courses where security topics are integrated:

Dedicated security courses

- **CSC 4570 – IT Security (Fall only):** This required course covers the fundamentals of computer security needed for information technology (IT) professionals. It is an overview of various technical and administrative aspects of information security. It introduces students to assets in a typical IT infrastructure, potential threats to assets, common associated vulnerabilities, asset protection strategies, and responses to security incidents.
- **CSC 4575/5575 - Information Assurance and Cryptography (Spring only):** This required course introduces students to the fundamentals of information assurance and cryptographic techniques along with their application to the prevention, detection, and mitigation of cyber threats.
- **DS 4125/5125 – Computer Forensics and Investigations:** This elective course covers investigation, discovery, and analysis of digital computer evidence. Students work in groups to use computer hardware and forensic software to perform computer forensic investigations and solve sample cases.
- **CSC 4580/5580 Malware Reverse Engineering:** This elective course offers basic concepts of and general techniques used for reverse engineering. Reverse engineering includes basic static and dynamic analysis of malware executables, study of malware behavior, techniques that malware uses to thwart detection and analysis, and hands-on exercises using malware analysis tools and best practices.
- **CSC 5901/6901 Ethical Hacking:** This elective course offers the basic concepts of and general techniques used for pen testing. It includes pre-engagement interactions, intelligence gathering, threat modeling, vulnerability analysis, validation, exploitation, privilege escalation, post-exploitation attacks, and reporting.

Integrated security modules in traditional CS courses

With institutionalization of the Security Knitting Kit Project - SecKnitKit (NSF Award #1140864), five of the upper-division courses (*CSC 4610: Software Engineering I*, *CSC 4620: Software*

Engineering II, CSC 3300: Database Management Systems, CSC 4100/5100: Operating Systems, and CSC 4200/5200: Networks) have been integrating relevant security modules with active learning exercises. In addition, the two-semester capstone sequence (*CSC 4610: Software Engineering I, CSC 4620: Software Engineering II*) is designed to place students in teams to build a real-world application for an industry partner. The Cybersecurity concentration students are assigned to projects with security requirements. Student learn the basics of project management using Agile methodologies as well as technology integration to create viable client solutions.

Graduate Program in Cybersecurity

Fast-track Program

Through this program, students can take graduate courses for undergraduate credit that can then be applied toward a graduate degree in CS at TnTech. The Fast-track program is designed to enable TnTech CS undergraduates to accumulate up to 12 credit hours of graduate coursework while still pursuing their undergraduate degree and transition to the graduate program smoothly, with accelerated completion. Up to six hours of the graduate coursework, exclusive of directed study, taken during the student's junior/senior year can also be used to satisfy both undergraduate and graduate degree requirements. Fast-track students are mentored by their M.S. advisor for course enrollment and thesis research. If they are able to successfully start their research early and earn a minimum grade of "B" in the graduate courses upon successful admission into the graduate program, they will be able to complete their MS in one additional year.

Master of Science

The Department of Computer Science offers advanced studies leading to a Master of Science (MS) degree in CS with a concentration in Internet-Based Computing. One of the areas of specialization is Information Assurance and Security. In addition to *CSC 5575: Information Assurance and Cryptography*, this specialization includes the following dedicated security courses:

- *CSC 6575 – Internet Security (Spring only)*: This course covers security-related special issues, concerns and trends in the complex environment of the Internet. Topics include (but are not limited to) vulnerabilities, attacks and security mechanisms to the networking protocols, email security, web security, online game security, social networking security, ecommerce security and mobile security.
- *CSC 6800: Advanced Topics in Security*: This course offers students the opportunity to delve deeper into their area of interest. The main objective is to critically evaluate research papers and write one.

M.S. students are also allowed to take Ph.D.-level dedicated security courses such as:

- *CSC 7575: Security Topics in the Smart Grid (Bi-annual)*: This course introduces students to timely topics related to security issues, concerns and trends in the modern power grid.

- *CSC 7210 –Anomaly and Intrusion Detection Systems (Bi-annual)*: This course covers traditional intrusion and anomaly detection systems, as well as current advances in this ever-growing field.
- *ECE 7970 – Selected Topics: Advanced Cryptography Applications in Emerging Wireless Networks (Bi-annual)*: Offered by the Electrical and Computer Engineering department, this course covers advanced topics in the design of security and privacy protocols for the emerging wireless networks.

INFORMAL Education and Professional Development

Hands-on Skill Training

Hands-on active learning is an integral part of education. It has been found that students actively engaging with concepts from course material learn more effectively. For students to effectively contribute in the defense of our nation in cyberspace, it is crucial for them to gain experience in active hands-on offense/defense training. Most of the courses with security content already contain hands-on exercise modules for students to actively engage with course concepts. Additionally, CEROC supports and facilitates the following student skill training interest groups:

- The ***Capture the Flag (CTF) cyber interest group*** that meets to hone interest and gain active learning experiences in CTF style of activities. The group competes in a variety of online CTF competitions such as National Cyber League, Virginia Cyber Summit, picoCTF. An additional goal for this team is to facilitate local competitions and events for K12 CTF teams either at on-campus events or on-site at local schools.
- The ***Defensive cyber interest group*** cultivates interest and supports training in defensive skills. The primary competition for this team is the Collegiate Cyber Defense Competition. Other competitions that they participate in are the DOE CyberForce competition and Hivestorm.
- The ***Offensive cyber interest group*** (largest group among the three) meets to practice and acquire offensive proficiencies. The primary competition for this team is the Collegiate Penetration Testing Completion. Other competitions they participate in are DOE CyberForce, SFSCon etc.

DoD and NSF Funded Cyber (Eagles) Range

With funding from DoD and NSF, CEROC has developed the Cyber (Eagles) Range, which is a virtual infrastructure that supports our education, research and outreach activities. This space is supported by virtualization hardware located in the university's datacenter, which is also physically and logistically air-gapped through the wired and wireless network supported by Information Technology Services (ITS). The range is extensively used in various activities such as: special interest group training, competitions, cyber war games, lab support in courses such as IT Security, Reverse Engineering and Ethical Hacking, K12 lesson plans, outreach activities and research projects.



Cybersecurity Student Club

Tennessee Tech CyberEagles[12] is a student organization with a mission to raise computer and information security consciousness and proficiency of students in using, designing, developing and operating computing technology. The club welcomes student members interested in cybersecurity from departments across the university. Currently there are 100+ members, and membership continues to grow. The club has been recognized as a National Cybersecurity Student Association (NCSA)[13] affiliated club. It is very active and conducts bi-weekly seminars for club members such as invited talks by external speakers from diverse walks of life including research, industry, and government service sectors, virtual CAE NSA Tech talks, training seminars., and regional security conference attendance. The club has been a very positive influence on our students. Aside from the educational benefit of these meetings, CyberEagles is an important part of our internal recruitment strategy to get more Tennessee Tech students to consider the cybersecurity focus area. Senior members of the club are strongly encouraged to take leadership roles to improve their organizational and management skills and provide mentorship to newcomers.

Tennessee Tech also founded the first installation of WiCyS student chapter, CyberEagle-W(omen)[14], which is now among a group of 89 in the nation. The 25+ members in the student organization under hosts a variety of professional development activities monthly to all students who are interested to attend. It includes networking events, technological activities, field trips and guest speaker engagements.

Competition Participation

TnTech students regularly participate in several security competitions including the Annual Southeast Regional Collegiate Cyber Defense Competition (SECCDC), Collegiate Penetration Testing Competition (CPTC), National Cyber League, and different “Capture the Flag” competitions. Our students will continue to participate in these various competitions and improve their skills with experience. Competition teams are a crucial element in the hard skills development of cybersecurity scholars. CEROC has established three standing interest groups out of which competition teams are developed, which are:



- The **capture the flag (CTF) cyber interest group** has approximately 30 members. There is no primary competition for this team as it is newly formed. This group competes in a variety of online CTF competitions such as National Cyber League. An additional goal for this team is to facilitate local competitions and events for K12 CTF teams either at on-campus events or on-site at local schools. The student report from this group can be found in Appendix A.
- The **defensive cyber interest group** has approximately 50 members. The primary competition for this team is the Collegiate Cyber Defense Competition. Our team competes in the SECCDC event held at Kennesaw State University. This team has been in existence since 2013. The student report from this group can be found in Appendix B.
- The **offensive cyber interest group** has approximately 70 members. The primary competition for this team is the Collegiate Penetration Testing Completion. Our team competes in the CPTC event held at the Rochester Institute of Technology. The team has been in existence since 2016. The student report from this group can be found in Appendix C.

Service Learning with Cyber Reviews

CEROC has collaborated with the Tennessee 3-Star Industrial Assessment Center (IAC) at Tennessee Tech to provide cybersecurity risk assessments for small to mid-sized manufacturing companies in the State of Tennessee. As part of a joint effort funded through a grant with the Department of Energy, CEROC and the 3-Star IAC deploy student assessment teams led by CEROC’s assistant director to conduct cyber reviews for local and regional manufacturing companies and small businesses. The reviews involve an on-site evaluation component providing students the opportunity to exercise their team and client development skills. Once data collection activities (via survey and personal interview) are complete, the students begin processing the collected data and evaluating it against a scoring rubric based upon the NIST



Cybersecurity Framework and other NIST SP documents. A final report is delivered by the student team with recommendations for improvement of their security posture. CEROC has also piloted a program of K-12 school district reviews with county districts. This program focuses on the unique challenges associated with school districts.

CyberCorps SFS New Scholar Bootcamp

Since 2016, TnTech has organized the annual Cybersecurity Scholar Bootcamp (funded through an extension of our original SFS grant) every summer. This first of its kind camp provides cybersecurity scholars from across the country an opportunity to attend a day and a half workshop covering a wide variety of essential soft skills for their future academic and professional careers. Topics covered during the camp include: financial planning, communications, diversity awareness, resume development, and research ethics and methodologies. The TnTech cohort have an additional half day of training conducted in the Volpe Library to become further acquainted with University research resources. CEROC also includes TnTech students participating in the Department of Defense Cyber Scholarship program in this bootcamp given such a camp does not currently exist for the DoD program.

Soft Skills Development

CEROC student affiliates are included in most of our outreach events, which requires them to practice and exercise their soft skills for audiences in K12, higher education, and industry. A sample of the activities in which a Cybersecurity Scholar would be involved include:

- Presenting current research projects and training works at conferences and workshops
- Instructing a group of students on a CEROC-developed exercise
- Assisting in the development of cybersecurity exercises through creation, proofing, or implementation review activities
- Participating/presenting in diversity events

Cybersecurity Ambassador Program

We encourage our scholars to participate in locally hosted events as project presenters, counselors, panel participants, and guest facilitators. This requires them to practice and exercise their soft skills for audiences in K12, higher education, and industry. These social settings are a key part of our holistic approach to scholar development. The students effectively serve as ambassadors of our program to the external community.

Professional Organization Membership

All scholars (Cybersecurity and SFS) are required to join and participate in professional organizations internal and external to TnTech. The center facilitates these memberships to the extent possible. CEROC, via the work of one of our SFS scholars, has affiliated our CyberEagles student cybersecurity club with the National Cybersecurity Student Association[13] and CyberEagles-W student cybersecurity club with the National Women in CyberSecurity Organization[15]. We also require that all scholars apply for membership with InfraGard[16].



Other organizations introduced to the students include Middle Tennessee ISACA[17] and the Middle Tennessee ISSA Chapter[18]. We also encourage and support our students to volunteer at regional cybersecurity events such as InfoSec and attend peer-training meetings such as BSides Nashville[19].

TnTech Student Success Center (optional service provided by the College of Engineering)

The College of Engineering (CoE)-based Clay N. Hixson Student Success Center (SSC) at TnTech focuses on initiatives and programs that develop and provide resources to help students achieve their goals of becoming engineers and computer scientists. The center provides support to our scholarship program with the following existing SSC resources that will be specially tailored for potential and new scholars:

- Access to tutors to help with challenging hands-on Cybersecurity concentration courses including programming, IT security, assembly language, operating system, etc. The SSC currently employs and trains engineering students to work as tutors in the Center.
- Access to the Student Ambassador Program where senior students are recruited to mentor new students. The Ambassador Program provides leadership and professional development opportunities for high-achieving students.
- Access to sponsored programs, such as participating in regional conferences and competitions.

TnTech Library Programs (optional service provided by the University)

The TnTech Library also offers tutoring services as well as a program called Class+[20] which includes regularly-scheduled peer-assisted study sessions and informal review sessions where students learn how to integrate course content and study skills while working together toward common goals. Internal studies have shown that students who attend similar programs earn on average one-half to one full letter grade higher than their classmates who choose not to attend. We believe that access to programs that offer academic assistance with historically difficult courses in the cybersecurity concentration increases retention in the program.

TnTech TLSAMP Alliance (optional service provided by the University)

For retention of women and underrepresented minority students in the program, the Tennessee Louis Stokes Alliance for Minority Participation (TLSAMP) program[21] and its resources are leveraged. The students in the CySP program are encouraged to participate in weekly and monthly activities such as informal meetings/dinners with the CoE Director of Diversity, study groups, club activities of local chapters of NSBE and WiCyS.

Support for Military Veterans (optional service provided by the University)

TnTech has been consecutively ranked as a “Military Friendly School” (G.I. Jobs Magazine and Victory Media), honored as a “Best College” for veterans (Military Advanced Education), ranked as a top ten university in the South for veterans (U.S. News and World Report), and was the first university in the State of Tennessee to be publicly recognized as a VETS Campus (Tennessee Higher Education Commission)[22]. The Office of Military and Veterans Affairs has dedicated



staff assigned to the direct service of our military veterans providing a range of transition support services. Most recently, the OMVA opened a Veterans' Lounge on campus providing access to technology, personal and career support information, and other support systems. The OMVA operates under the direction of Mary Benedict, M. Div.

Placement Plan

CySP and SFS Scholars regularly participate in career fair events until successful internship/final employment opportunities are contracted. We have students participate in the SFS virtual job fair in the Fall of each year and take students to the annual SFS Job Fair in Washington DC. We also include the CAE Virtual Career Fair as one of the regular events assuring scholars have ample opportunities to engage with potential employers. Additionally, scholars have an opportunity to participate at the WiCyS job fair held as part of the annual conference[23]. A review of job application efforts is conducted at each, bi-weekly meeting of the CySP and SFS Scholars. Students struggling with their job search are further counseled by CEROC staff using other employer contact avenues.

Research

Research Engagement

With healthy Ph.D. production and financial commitment to research, in 2019 Tennessee Tech bolstered its position in the Carnegie Classification and moved up as a R2 university — a doctoral university with high research activity[24]. This is indicative of Tennessee Tech's increased performance in research/scholarship doctoral degrees and research expenditures.

In Computer Science, there are thirteen faculty who are active in security-related research and are working with students in cybersecurity-related research projects as mentors. Research areas in security include (but not limited to): cyber physical systems security, internet of things (IoT) security, vehicular ad-hoc network security, network and 5G security, DarkNet, healthcare security, web application security, and machine learning assisted security. Students have multiple opportunities to conduct research under the guidance of CS faculty mentors through sponsored projects, courses in curriculum, thesis and project requirements.

DOE Oak Ridge National Laboratory Collaboration

Our faculty and graduate students have been conducting research with the scientists and engineers at ORNL in various Department of Energy funded research projects. They have been working on the following funded research Projects: 1) Detection and Analysis of Malware in Critical Infrastructure, 2) Black Box: Highly Secure Environment for Health Data Computation, 3) From can't to CAN: Attack Prevention & In-situ Detection of Advanced Attacks on Controller Area Networks, and 4) Intrusion Detection Using Multimodal Machine Learning. Apart from these, there are several unfunded projects that our faculty and students are working on with ORNL. Many of our graduate and undergraduate students work in cybersecurity area research projects as interns in summer or regular semester at ORNL. ORNL scientists teaches cybersecurity-related classes at Tennessee Tech and supervise Ph.D. and Master's students. Tennessee Tech's



Computer Science department has a special Ph.D. program for ORNL employees who do not have Ph.D. Our faculty also travel to ORNL to teach classes.

NSA INSuRE Project Participation

We also participate in the INSuRE (Information Security Research and Education) project [25] which has been supported by NSA since 2012 for current and potential CAE-R institutions since 2012. The project cultivates research acumen, skills and experience for undergraduate and graduate students through a research network of 19 universities, multiple agencies and national labs. Students engage in interdisciplinary, distributed teams to address information security problems of national interest. Our students have been participating in INSuRE projects since 2018.

TnTech Research and Creative Inquiry Day

Research and Creative Inquiry Day[26] is an annual event designed to promote student research and creative inquiry and provide a venue for presenting that work. This event is open to undergraduate and graduate students from all departments who want to display their research and creative projects. SFS and Cybersecurity Scholars are encouraged to present their current work at this event. The event is open to the public and advertised within the Upper Cumberland business community.

Outreach

CEROC conducts multiple outreach projects for the K-12, higher education, and industry sectors. Our outreach programming especially provides opportunities for students in rural schools to be aware of cybersecurity careers and prospects, encouraging consideration of cybersecurity as a field of study, sparking interest in cybersecurity education and competitions, and encouraging participation of under-represented populations in STEM areas. Along with other Tennessee Tech students, SFS and Cybersecurity Scholars actively participates in various outreach activities hosted by CEROC, which includes but not limited to the following:

- Women in CyberSecurity conference
- Faculty development workshops (onsite and offsite)
- Computer Security Awareness and Training Workshop for TNTech and Staff
- GenCyber Summer Camp
- FAB Fridays at the Tennessee Tech STEM Center (elementary and middle school)
- Cybersecurity Awareness Workshops informing students about topics within cybersecurity and opportunities to study in the field at Tennessee Tech
- Cybersecurity Risk Assessments and Workshops informing small to mid-sized businesses on techniques to improve risk mitigation postures
- GenCyber on Wheels deployments to area schools.



NSA and NSF Funded GenCyber Program

Tennessee Tech has been awarded funds from NSA and NSF to conduct GenCyber camps since 2016. CEROC organizes a one-week camp focused on cybersecurity hands-on exercises with and without use of technology. CEROC camps have focused on high school students (rising 9th grade – rising 12th grade). Over the last four years, we have directly interacted with 510 students (155 in the state, and 355 students in four other states through GenCyber Day WiCyS events). Additionally, we have directly interacted with 12 teachers and 13 school counselors in the Middle and East Tennessee regions. These specific contacts have indirectly influenced thousands of students over the past three years.

NSF Funded WiCyS Project

The Women in Cybersecurity (WiCyS) project was launched in 2013 with support of a National Science Foundation grant (Award# 1303441). The annual conference brings together women (students/faculty/researchers/professionals) in cybersecurity from academia, research and industry for sharing of knowledge/experience, networking and mentoring. Every year Tennessee Tech brings around 20-30 students to volunteer and actively participate at the annual WiCyS conference.

It should be noted that all these outreach events are presented as options to our scholars to earn service-learning time. It is ultimately their decision to select the ones in which they want to participate, as they are not required to participate in all of them.

Our Team



Dr. Ambareen Siraj, Professor of Computer Science at Tennessee Tech, teaches security courses at both the undergraduate and graduate level. She has focused her research on the vast areas surrounding cybersecurity, including security in cyber-physical systems, Internet of Things, situation assessment in network security, security education and workforce development.

As the founding director of Tennessee Tech’s Cybersecurity Education, Research and Outreach Center (CEROC), Dr. Siraj is the leader on several National Science Foundation and National Security Agency grants involving cybersecurity, and is the founder of the national Women in CyberSecurity conference, an initiative to recruit, retain and advance women in the cybersecurity industry.

Dr. Siraj’s effort to educate students and enhance the cybersecurity field of study goes beyond classes, research and outreach projects, workshops and conferences. She has authored or co-authored more than 40 journal and conference articles while taking an active part in promoting cybersecurity training throughout the nation.



Mr. Eric Brown serves as the assistant director for CEROC managing daily operations of the center. He holds a B.S. and M.S. in computer science from Tennessee Tech. He served 20 years in the Computer Science Department at Tennessee Tech as an information and instructional technology specialist and adjunct instructor teaching portions of the information technology curriculum. He also has extensive experience in K12 education administration through his work on the Putnam County School Board and Tennessee Department of Education.



Ms. Lana Richardson serves as the financial associate for CEROC managing financial operations of the center and many of its grant programs. She has extensive experience in institutional proposal development and pricing from her years with Verizon. She has also worked in front office operations at Putnam County Schools.



Mr. Joseph Cross serves as the cybersecurity technologist for CEROC responsible for development and maintenance of the center's cyber range and supporting technologies. He holds a B.S. in computer science from Tennessee Tech. Prior to joining CEROC, Mr. Cross worked in enterprise IT management within the healthcare sector.

A complete list of CEROC faculty and staff associates can be found on our website at <https://www.tntech.edu/ceroc/people>.

Our Facilities

Administrative Spaces

As of August 2018, CEROC has four administrative spaces assigned to the center that includes office space for the director, assistant director, financial associate, and cybersecurity technologist.

Cyber (Eagles) Range

The CEROC Cyber (Eagles) Range is a laboratory space consisting of six, four-person team workstations. This space is supported by virtualization hardware located in the university's datacenter.



Aside from the virtual air-gapping provided by the virtualization software, the room is also physically and logistically air-gapped through the wired and wireless network supported by Information Technology Services (ITS). Design was based on an immersive, collaborative concept, and the stand-up stations provide a 49-inch display allowing students to plug in their own laptops (or center-owned equipment) to collaboratively work within the group. The room has a collection of portable whiteboards which can be configured to facilitate the needs of working teams at any given time. Aside from the team workstations, the room also has a regular four-person conference table in the center of the room to facilitate small group conferences where only whiteboards may be needed. The space has been designed to support multiple use cases including:

- Cybersecurity course support active learning
- Competition team training
- Workshop training
- R&D (using actual hardware or virtualized hardware)

[Student Research and Development Lab](#)

The primary goal for this space is to provide researching students a quiet place to work in between classes and meetings. The Student Research and Development Lab is an area providing 20 workstation areas for students participating in the CyberCorps SFS, Cybersecurity Scholar, or CEROC-funded research programs. Each workstation provides a work surface with two hard-wired network connections, university wireless connections, and a storage cabinet. The area also provides a general office work counter and a high-performance B/W copier. A large message board display provides rotating information slides about upcoming deadlines and events. Similar to the Cyber (Eagles) Range, the area has multiple, rolling whiteboards to create ad-hoc collaboration spaces for students working on common projects. The area is built upon an open concept model with half-wall workstations encouraging collaboration with peers.

CEROC also has a six-student laboratory space dedicated to graduate assistants pursuing doctoral degrees. This space provides facilities for focused research time. Like the 20-student lab, this area provides quality access to wired and wireless networks along with ample storage.

[Multi-Center Video Conference Room](#)

The SIP-enabled conference room can natively host Skype and Zoom conferences. Aside from group meetings, this video-capable room can support remote training.

FY 19 CEROC Highlights

Among the notable highlights during FY 19:

- Dr. Ambareen Siraj was recognized by the Cyber Defense Magazine as the Editors Choice 2019 for her work in the Women in Cybersecurity Organization
- Dr. Ambareen Siraj continues to serve on a committee which will help form CyberCorps SFS version 2
- Dr. Ambareen Siraj was promoted to full professor within the Department of Computer Science
- Dr. Ambareen Siraj participated as an invited guest in the “Post-Secondary and Workforce Discussion” at the 2019 Arkansas State Governor’s Summit on CS Education held June 10, 2019 in Little Rock, AR.
- Dr. Ambareen Siraj participated as an invited panelist (“Integrating Security Across the Curriculum”) and speaker (“Encouraging Diversity in Cybersecurity”) at the 2019 NSF Cyber Education Workshop held April 15-16, 2019 in Santa Fe, NM.
- Dr. Ambareen Siraj participated as an invited presenter (“The Response – Equipping the Next Generation”) at the 2019 ABET Symposium held April 10-13, 2019 in Dallas, TX.
- Dr. Ambareen Siraj was awarded the Tennessee Tech Wings Up Research Award for 2019.
- Dr. Ambareen Siraj was awarded the CDM 2019 InfoSec Awards for Editor’s Choice – Women in Cybersecurity.
- Dr. Ambareen Siraj served as an invited participant in the NIST-sponsored New America Foundation meeting on The State of the Cybersecurity Gender Gap in November 2018.
- Dr. Ambareen Siraj participated as an invited speaker (“60 Minutes in Exploring Cybersecurity: Introduction with Career Landscape”) as part of the Distinguished Lecture Series at the University of Colorado Springs on October 25, 2018.
- Mr. Eric Brown served on the IT Pathway Committee, part of the Highlands Initiative for 2018-19.
- Mr. Eric Brown earned ICAgile Certified Professional and DevOps Foundation certifications in August 2018 and November 2018, respectively.
- CEROC conducted annual events including the Cyber Discovery Day, National CyberCorps SFS Bootcamp, and GenCyber Cybersecurity Summer Camp.
- CEROC provided support for Internet of Things research under the direction of Dr. Terry Gao. The center also provides mini-grants to five other researchers in diverse areas of cybersecurity.
- CEROC was awarded the DoD Cybersecurity Scholarship Program for a second year. The award places TnTech in another first in Tennessee to achieve category having both the CyberCorps SFS and DoD Cybersecurity Scholarship Program grants.
- The cybersecurity focus area of the CS program continues represents the largest subgroup of all CS students. The CS program is now the second largest program in the



College of Engineering largely driven by the exponential growth of the cybersecurity focus area.

- CEROC students have participated in more competitions this year than in all prior years combine continuing to place in the upper 20% in their respective groups.
- CyberEagles created three (3) cybersecurity interest groups supporting a focus on capture the flag, defensive, and offensive works respectively. These groups established a peer mentoring model which has produced positive results in competition capacity and performance.

Grants
Proposals

FUNDING AGENCY	TITLE	PIs	PIs Department	PROPOSAL NUMBER	Project Period	Total Funding	Indirect Cost
National Science Foundation	CAREER: Control-Aware Resiliency Analysis and Hardening for Cyber-Physical Systems	Rahman	CS		41/1/19-12/31/23	\$549,492	\$162,526
Oak Ridge National Laboratory	Black Box: Highly Secure Environment for Health Data Computation	Ghafoor, Rogers	CS		8/1/18-7/31/21	\$112,508	\$11,604
National Science Foundation and National Security Agency	2019 GenCyber Student Camp at Tennessee Tech University	Siraj	CS	1718M0790	5/1/19-4/30/20	\$138,475	\$32,634
National Science Foundation	III: Small: Collaborative Research: Mining Patterns and Anomalies from Dynamic Networks	Eberle	CS	1718M0796	6/1/19-5/31/22	\$221,692	\$65,571
National Science Foundation	Collaborative: CyberTraining: Pilot: Semi-Automatic Assessment of parallel programs in training of Students and Faculty	Ghafoor, Haynes	CS, Political Science		8/1/19-7/31/21	\$82,000	\$24,254
						\$1,104,167	\$296,589

Activations

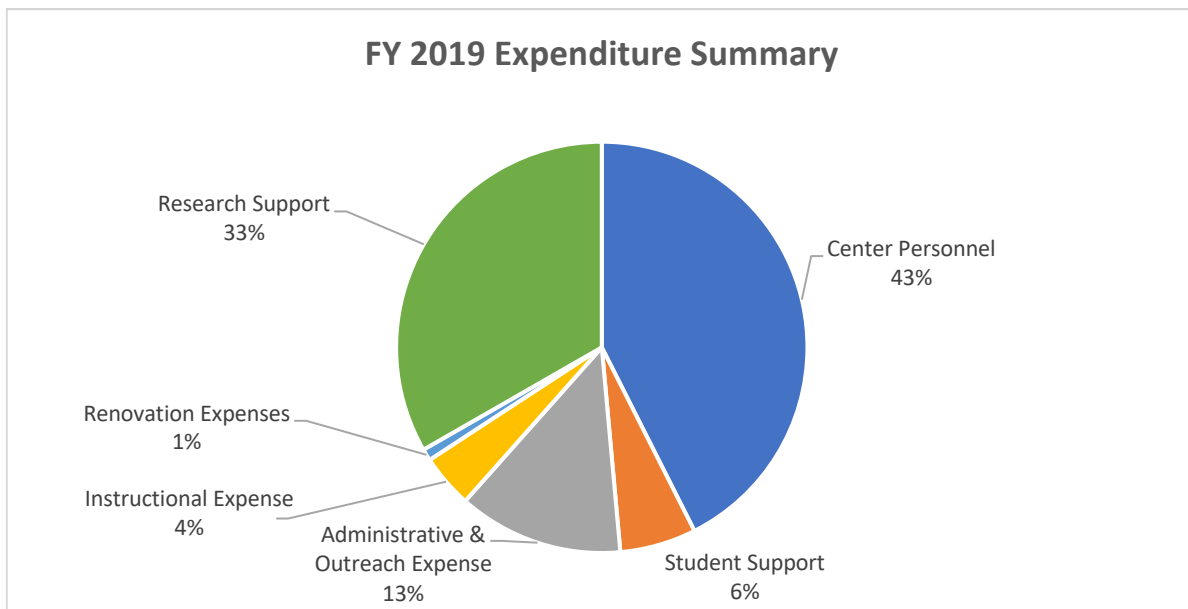
FUNDING AGENCY	TITLE	PIs	SENIOR PERSONNEL	PIs Department	PROPOSAL NUMBER	Period of Activation	Project Period	Total Funding	Indirect Cost
National Science Foundation	Supplement to Tennessee Cybercorps: A Hybrid Program in Cybersecurity-Community College Inclusion <i>Yr. 2 of 3</i>	Siraj, Rahman, Talbert	Haynes/Eberle	CS	192 (16-17)	8/1/18-7/31/19	1/1/16-12/31/20	\$52,693	\$1,387
National Science Foundation	Supplement to Tennessee Cybercorps: A Hybrid Program in Cybersecurity-Community College Inclusion <i>Yr. 3 of 3</i>	Siraj, Rahman, Talbert	Haynes/Eberle	CS	216 (15-16)	8/18/18-8/17/19	1/1/16-12/31/20	\$55,270	\$3,616
National Science Foundation	Supplement to Tennessee Cybercorps: A Hybrid Program in Cybersecurity-Community College Inclusion-2018-2021 <i>Yr. 1 of 3</i>	Siraj, Rahman, Talbert		CS		8/1/18-7/31/19	1/1/16-12/31/20	\$56,213	\$10,500
National Science Foundation	Tennessee Cybercorps: A Hybrid Program in Cybersecurity <i>Yr. 3 of 5</i>	Siraj, Rahman, Talbert	A. Haynes (A&S), Eberle	CS	216 (15-16)	1/1/18-5/31/19	1/1/16-12/31/20	\$1,005,445	\$47,186
DoD Cybersecurity Scholarship Program	DoD Cybersecurity Scholarship Program	Siraj, E. Brown		CS		8/1/18-8/1/19	8/1/18-8/1/19	\$261,284	\$27,235
National Science Foundation	Cyber Training CDL IPDC Summer Institute for Integrating Parallel and Distributed Computing...	Ghafoor, Rogers, Brown	Haynes	CS	119201617	9/1/18-8/31/19	9/1/17-8/31/20	\$177,377	\$29,985
ORNL	Detection and Analysis of Malware in Critical Infrastructure	Ghafoor, Rogers, Brown		CS	52 (17-18)	10/1/18-9/30/19	10/4/17-9/30/19	\$24,738	\$2,551
Oak Ridge National Laboratory	Detection and Analysis of Malware in Critical Infrastructure	Ghafoor	Rogers	CS	52 (17-18)	10/1/18-9/30/19	10/4/17-9/30/19	\$18,239	\$1,881
National Science Foundation	Tennessee Cybercorps: A Hybrid Program in Cybersecurity <i>Yr. 4 of 5</i>	Siraj, Talbert	Haynes, Eberle	CS	216 (15-16)	1/1/19-12/31/19	1/1/16-12/31/20	\$917,561	\$48,114
								\$2,568,820	\$172,455

FY 19 Expenditures

FY 19 represented the second year in which the center received funding from the state. These non-reoccurring funds are included as a line item in the THEC budget. As specified in the FY 2019 state budget documents, “\$500,000 to Tennessee Technological University to match funds provided by the National Science Foundation for cyber security research (year 2 of 4)”. As noted, these funds are allocated to match the CyberCorps SFS grant. As mentioned earlier in the report, there was an increased focus on developing the research pillar of the center. As summary of expenditures follows.

FY 2019 Expenditure Summary

Area	Amount
Center Personnel	\$ 168,528.68
Hourly Student Support	\$ 23,752.78
Administrative & Outreach Expense	\$ 51,502.96
Instructional Expense	\$ 16,715.47
Renovation Expenses	\$ 3,662.29
Research Support	\$ 131,821.77
	\$ 395,983.95



FY 19 Publications

1. **Vitaly Ford**, Daniel Taylor, **Ambareen Siraj**, "AMIsim: Application-layer Advanced Metering Infrastructure Simulation Framework for Secure Communication Protocol Performance Evaluation", Proceedings: 11th USENIX Workshop on Cyber Security Experimentation and Test (CSET '18) held in Baltimore, MD, August, 2018.
2. Enahoro Oriero and **Mohammad Ashiqur Rahman** Privacy Preserving Fine-Grained Data Distribution Aggregation for Smart Grid AMI Networks, the 37th International Conference for Military Communications (MILCOM), Los Angeles, USA, October 2018.
3. **A H M Jakaria** and **Mohammad Ashiqur Rahman**, Formal Analysis of k-Resiliency for Collaborative UAVs, The 42nd IEEE Computer Society International Conference on Computers, Software, and Applications (COMPSAC), Tokyo, Japan, July 2018 (acceptance rate~ 24%).
4. **MGM Mehedi Hasan**, **Amarjit Datta**, **Mohammad A. Rahman**, and Hossain Shahriar, Chained of Things: A Secure and Dependable Design of Autonomous Vehicle Services, 13th IEEE International Workshop on Security, Trust, and Privacy for Software Applications (STPSA) in conjunction with the 42th IEEE COMPSAC, Tokyo, Japan, July 2018.
5. Mohammed, Hawzhin, **Syed Rafay Hasan**, and **Mohammad Ashiqur Rahman**. "Load Control and Privacy-Preserving Scheme for Data Collection in AMI Networks." arXiv preprint arXiv:1807.11565 (2018).
6. **Jakaria, A. H. M.**, Md Mosharaf Hossain, and **Mohammad Ashiqur Rahman**. "Smart Weather Forecasting Using Machine Learning: A Case Study in Tennessee." (2018).
7. Oriero, Enahoro, and **Mohammad Ashiqur Rahman**. "Privacy Preserving Fine-Grained Data Distribution Aggregation for Smart Grid AMI Networks." MILCOM 2018-2018 IEEE Military Communications Conference (MILCOM). IEEE, 2018.
8. **Hasan, Syed Rafay**, Charles A. Kamhoua, Kevin A. Kwiat, and Laurent Njilla. "A Novel Framework to Introduce Hardware Trojan Monitors using Model Checking Based Counterexamples: Inspired by Game Theory." In 2018 IEEE 61st International Midwest Symposium on Circuits and Systems (MWSCAS), pp. 853-856. IEEE, 2018.
9. Mohammed, Hawzhin, Jimmy Howell, **Syed Rafay Hasan**, **Nan Guo**, Faiq Khalid, and Omar Elkeelany. "Hardware Trojan Based Security Issues in Home Area Network: A Testbed Setup." In 2018 IEEE 61st International Midwest Symposium on Circuits and Systems (MWSCAS), pp. 972-975. IEEE, 2018.
10. Oriero, Enahoro, and **Syed Rafay Hasan**. "All Digital Low Power Aging Sensor for Counterfeit Detection in Integrated Circuits." In 2018 IEEE 61st International Midwest Symposium on Circuits and Systems (MWSCAS), pp. 33-36. IEEE, 2018.

11. Baza, Mohamed, Mahmoud Nabil, Nouredine Lasla, Kemal Fidan, **Mohamed Mahmoud**, and Mohamed Abdallah. "Blockchain-based Firmware Update Scheme Tailored for Autonomous Vehicles." *arXiv preprint arXiv:1811.05905*(2018).
12. Alsharif, Ahmad, Mahmoud Nabil, Samet Tonyali, Hawzhin Mohammed, **Mohamed Mahmoud**, and Kemal Akkaya. "EPIC: Efficient Privacy-Preserving Scheme with E2E Data Integrity and Authenticity for AMI Networks." *IEEE Internet of Things Journal* (2018).
13. Alsharif, Ahmad, Mahmoud Nabil, **Mohamed Mahmoud**, and Mohamed Abdallah. "EPDA: Efficient and Privacy-Preserving Data Collection and Access Control Scheme for Multi-Recipient AMI Networks." *IEEE Access* (2019).
14. **David W. Brown, Sheikh K. Ghafoor**, and Stephen Canfield. 2018. Instruction of introductory programming course using multiple contexts. In *Proceedings of the 23rd Annual ACM Conference on Innovation and Technology in Computer Science Education (ITICSE 2018)*. ACM, New York, NY, USA, 147-152. DOI: <https://doi.org/10.1145/3197091.3197105>
15. **Hossain, Md Mosharaf**, Thomas M. Hines, **Sheikh K. Ghafoor**, Ryan J. Marshall, **Muzakhir S. Amanzholov**, and Ramakrishnan Kannan. "Performance Issues of SYRK Implementations in Shared Memory Environments for Edge Cases." In *2018 21st International Conference of Computer and Information Technology (ICCI)*, pp. 1-7. IEEE, 2018.
16. **Islam, Sheikh Rabiul, Sheikh Khaled Ghafoor**, and **William Eberle**. "Mining Illegal Insider Trading of Stocks: A Proactive Approach." In *2018 IEEE International Conference on Big Data (Big Data)*, pp. 1397-1406. IEEE, 2018.
17. Baza, Mohamed, Mahmoud Nabil, Muhammad Ismail, **Mohamed Mahmoud**, Erchin Serpedin, and **Mohammad Rahman**. "Blockchain-based privacy-preserving charging coordination mechanism for energy storage units." *arXiv preprint arXiv:1811.02001* (2018).
18. M. Nabil, A. Alsharif, A. Sherif, **M. Mahmoud** and M. Younis, "Efficient Multi-Keyword Ranked Search over Encrypted Data for Multi-Data-Owner Settings," 2018 IEEE International Conference on Communications (ICC), Kansas City, MO, 2018, pp. 1-6.
19. M. Nabil, M. Ismail, **M. Mahmoud**, M. Shahin, K. Qaraqe and E. Serpedin, "Deep Recurrent Electricity Theft Detection in AMI Networks with Random Tuning of Hyper-parameters," 2018 24th International Conference on Pattern Recognition (ICPR), Beijing, 2018, pp. 740-745.
20. Shafee, Ahmed, Mohamed Baza, **Douglas A. Talbert**, Mostafa M. Fouda, Mahmoud Nabil, and **Mohamed Mahmoud**. "Mimic learning to generate a shareable network intrusion detection model." *arXiv preprint arXiv:1905.00919* (2019).
21. Baza, Mohamed, Mahmoud Nabil, Niclas Bewermeier, Kemal Fidan, **Mohamed Mahmoud**, and Mohamed Abdallah. "Detecting sybil attacks using proofs of work and location in vanets." *arXiv preprint arXiv:1904.05845* (2019).

22. Amiri, Wesam Al, Mohamed Baza, Karim Banawan, **Mohamed Mahmoud**, Waleed Alasmay, and Kemal Akkaya. "Privacy-preserving smart parking system using blockchain and private information retrieval." *arXiv preprint arXiv:1904.09703* (2019).
23. Sherif, Ahmed, Muhammad Ismail, Marbin Pazos-Revilla, **Mohamed Mahmoud**, Kemal Akkaya, Erchin Serpedin, and Khalid Qaraq. "Privacy preserving power charging coordination scheme in the smart grid." *Transportation and Power Grid in Smart Cities: Communication Networks and Services* (2018): 555-576.
24. A. Sherif, A. Alsharif, **M. Mahmoud**, M. Abdallah and M. Song, "Efficient Privacy-Preserving Aggregation Scheme for Data Sets," 2018 25th International Conference on Telecommunications (ICT), St. Malo, 2018, pp. 191-195.
25. M. Nabil, M. Ismail, **M. M. E. A. Mahmoud**, W. Alasmay and E. Serpedin, "PPETD: Privacy-Preserving Electricity Theft Detection Scheme With Load Monitoring and Billing for AMI Networks," in *IEEE Access*, vol. 7, pp. 96334-96348, 2019.
26. **T. Guo** and **M. Mahmoud**, "Performance Analysis of Physical-Layer-Based Authentication for Electric Vehicle Dynamic Charging," 2018 IEEE 88th Vehicular Technology Conference (VTC-Fall), Chicago, IL, USA, 2018, pp. 1-7.
27. **Pazos-Revilla, Marbin**, Ahmad Alsharif, Surya Gunukula, **Terry N. Guo, Mohamed Mahmoud**, and Xuemin Sherman Shen. "Privacy-Preserving Physical-Layer-Assisted Charging Authorization Scheme for EV Dynamic Charging System."
28. E. M. Radi, N. Lasla, S. Bakiras and **M. Mahmoud**, "Privacy-Preserving Electric Vehicle Charging for Peer-to-Peer Energy Trading Ecosystems," ICC 2019 - 2019 IEEE International Conference on Communications (ICC), Shanghai, China, 2019, pp. 1-6.
29. A. Alsharif, M. Nabil, S. Tonyali, H. Mohammed, **M. Mahmoud** and K. Akkaya, "EPIC: Efficient Privacy-Preserving Scheme With EtoE Data Integrity and Authenticity for AMI Networks," in *IEEE Internet of Things Journal*, vol. 6, no. 2, pp. 3309-3321, April 2019.
30. **A. Bhattarai** and **A. Siraj**, "Increasing Accuracy of Hand-Motion Based Continuous Authentication Systems," 2018 9th IEEE Annual Ubiquitous Computing, Electronics & Mobile Communication Conference (UEMCON), New York City, NY, USA, 2018, pp. 70-76.
31. **Ford, Vitaly, Daniel Tyler**, and **Ambareen Siraj**. "AMIsim: application-layer advanced metering infrastructure simulation framework for secure communication protocol performance evaluation." In *11th {USENIX} Workshop on Cyber Security Experimentation and Test ({CSET} 18)*. 2018.
32. **Ford, Vitaly**, and **Ambareen Siraj**. "GenCyberCoin: an engaging, customizable, and gamified web platform for cybersecurity summer camps and classrooms." *Journal of Computing Sciences in Colleges* 35, no. 3 (2019): 87-96.
33. Paudel, Ramesh, Peter Harlan, and **William Eberle**. "Detecting the onset of a network layer dos attack with a graph-based approach." In *The Thirty-Second International Flairs Conference*. 2019.

FY 19 CEROC Organized Events

Event Name	Event Date	Event Description	Target Audience	Audience Impact
2018 GenCyber Non-Residential Camp	July 2018	Cybersecurity camp featuring a week of cybersecurity exercises, competitions, and guest speakers	middle and high school students, teachers, and school counselors	42 students, 7 teachers, 7 school counselors
2018 CyberCorps SFS Bootcamp	August 2018	Third annual CyberCorps SFS Bootcamp providing new SFS students with 1.5 days of soft skills training including resume development, research ethics and skills, and life management	new CyberCorps SFS students from across the nation	50 students
Jackson County High School (TnTech STEM visit)	August 2018	Presentation to high school juniors/seniors providing an introduction to the cybersecurity program at Tennessee Tech and conducting a CTF unplugged exercise.	high school seniors	18 students
2018 Cyber Discovery Day	September 2018	A one-day workshop to introduce the areas of cybersecurity to all TNTech Computer Science students. Activities included CTF unplugged exercises, penetration testing exercises, CSC faculty presenting their research area, and a number of high-profile external speakers.	TNTech Computer Science majors	75 participants
Overton County Middle School (TNTech STEM visit - 5 dates)	October 2018	(5 different engagement dates) Presentation to 8th grade students providing an introduction to the cybersecurity program at Tennessee Tech and conducting a Stonehunt exercise.	upper middle school students	250 students
Livingston Academy STEM Night	October 2018	Presentation of a web exploits exercise using the Raspberry Pi platform	high school seniors	50 students
White County Middle School (on-site visit)	November 2018	Presentation to the 7th and 8th students providing an introduction to the cybersecurity program at Tennessee Tech and conducting a Stonehunt exercise.	upper middle school students	300 students
Cyber Risk Assessment for Putnam County Schools	November 2018	First annual cyber risk workshop focusing on cybersecurity concerns for small to mid-size businesses in the Upper Cumberland region	client	report delivered to technology department staff

Columbia Central High School (school visit)	February 2019	Presentation to college bound high school students providing an introduction to the cybersecurity program at Tennessee Tech	high school students	100 students
Columbia Central High School (CEROC visit)	March 2019	CEROC visit by select members of the freshman class from CCHS. Students were introduced to the university and cybersecurity program. Students also participated in a beta test of the next version of the Stone Hunt game hosted from the CEROC cyber range. Students were also provided a Q&A opportunity with our DoD and SFS students.	high school freshmen	40 students
2019 Women in Cybersecurity Conference	March 2019	Annual Women in Cybersecurity Conference focusing on diversity efforts within the cybersecurity community featuring keynote speakers, workshops, and a job fair. This year's event was held in Pittsburg, PA in coordination with CMU.	underrepresented populations in the field of cybersecurity within academic, government, and industry	1100 attendees
Overton County Career and Program of Study Summit @ CHEC	March 2019	Joint presentation with Digital Dream Forge for rising high school freshmen focusing on cybersecurity education opportunities at Tennessee Tech and information about the software industry	rising high school freshmen	125 students
2019 East and Middle Tennessee NCWIT Aspiration Award	April 2019	Awards ceremony recognizing rising female high school students working in the STEM area (https://www.aspirations.org/aspirations-community/tennessee-central-and-east).	female high school juniors/seniors	30 participants
Community College Cybersecurity Outreach Program	March 2019	Current CEROC students which came from the community college transfer program presented to four regional two-year schools about four-year program and career opportunities in cybersecurity. CEROC ambassadors help to create new outreach material for these engagements.	community college students	120 students
Pickett County High School Career Development Program	April 2019	CEROC ambassadors presented to high school students about education and career opportunities in cybersecurity.	high school students	150 students

Overton County Career Awareness Grant Program	May 2019	High school students participating in a grant-based workforce development program were introduced to the center's work and participated in a cybersecurity game.	high school juniors/seniors	50 students
Putnam County Schools Ready to Go	June 2019	High school students participating in a summer program were introduced to the center's work and participated in a cybersecurity game.	high school juniors/seniors	20 participants
2019 GenCyber Residential Camp	June 2019	Cybersecurity camp featuring a week of cybersecurity exercises, competitions, and guest speakers	high school students	36 students

FY 19 CEROC Student Events

Student Competitions

Event Name	Event Date	Event Description	Target Audience	Audience Impact
eSentinel CTF	Aug-18	Online CTF competition.	TTU's CTF team.	25
CPTC Regionals	Oct-18	Regional round of competition for the Collegiate Penetration Testing Competition.	TTU's red team.	8
CPTC Nationals	Nov-18	National round of competition for the Collegiate Penetration Testing Competition.	TTU's red team.	8
DoE CyberForce (Formerly CDC) Blue Team	Nov-18	Department of Energy's cyber defense competition.	TTU's blue team.	8
DoE CyberForce (Formerly CDC) Red Team	Nov-18	Volunteer opportunity for students to represent pen tests for the DoE CyberForce competition.	TTU's red team.	10+
CCDC Prelims	Feb-19	Preliminary competition for the Collegiate Cyber Defense Competition.	TTU's blue team.	8
Summit CTF	Mar-19	Virginia Tech Cybersecurity Summit CTF Competition	TTU's CTF team.	12
National Cyber League (NCL)	Year Round	Season style, online competition where students can practice their CTF skills.	TTU's CTF team.	20+

Student Clubs

Event Name	Frequency	Event Description	Target Audience	Audience Impact
CyberEagles Meetings	6 per semester	Student led organization that presents current topics in cyber, demonstrate tools and techniques, or host guest speaker visits.	Any TTU student, faculty, or staff is welcome to attend.	90+

CyberEagles W Meetings	3 per semester	All women led student organization that discusses current events in cyber as well as hosts guest speakers.	Any TTU student, faculty, or staff is welcome to attend.	25
OCIG Workshop	4 per semester	Offense Cyber Interest Group that leads 2+ hour sessions that teach offensive tools and techniques as well as write their own learning modules for new students.	Any TTU student interested in learning Pentesting or Risk Assessments.	15
DCIG Workshop	4 per semester	Defense Cyber Interest Group that leads 2+ hour sessions that practice defensive techniques to protect an environment as well as write their own learning modules for new students.	Any TTU student interested in learning defensive techniques.	20

FY 19 CEROC Participated Events

Event Name	Event Date	Event Description	Nature of Participation
Annual National Cyber Summit	June 2018	Preeminent event for cyber training, education and workforce development aimed at protecting our nation's infrastructure from the ever-evolving cyber threat. Also included CAE meeting.	Participant
Tennessee Digital Government Summit 2018	June 2018	This workshop organized by the U.S. Chamber of Commerce in cooperation with the Tennessee Department of Commerce focused on raising awareness of cybersecurity threats to Tennessee businesses.	Participant
Annual Community College Cyber Summit (3CS)	June 2018	Only national academic conference focused on cybersecurity education at community colleges.	Career Fair
Annual Colloquium for Information Systems Security Education	June 2018	A forum for dialogue among leading figures in government, industry, and academia in cybersecurity education.	Board member
SECC Conference - Orlando	July 2018	Regional CAE meeting for the SouthEast region	Presenter
eSentinel CTF - CIAS and CCDC	August 2018	An online network assessment and network defense competition combined into a single event. Teams of students compete for control of common resources and the critical services on those resources in a "King of the Hill" fashion.	Participant
Volkswagen Academy	August 2018	Presented center material and provided CTF Unplugged exercise.	60 students
CAE Virtual Career Fair	October 2018	Hosted virtual table at the CAE career fair	Presenter
National Collegiate Penetration Testing Competition (CPTC) Regionals	October 2018	The Collegiate Penetration Testing Competition (CPTC) provides a vehicle for up and coming cybersecurity student teams to build and hone the skills required to effectively discover, triage, and mitigate critical security vulnerabilities.	Participant

Annual Grace Hopper Women in Computing Conference	October 2018	World's largest gathering of women technologists.	Career Fair
Annual CAE PI Meetings	November 2018	Semi-annual meetings required of all NSA Center of Academic Excellence institutions. Presented new works from recent GenCyber camp.	Project PI
Annual NIST NICE Conference	November 2018	Features thought leaders from academia, industry, government, and non-profits who are addressing the cybersecurity education, training, and workforce needs of the nation.	Participant
Annual NIST K12 CyberSecurity Education Conference	December 2018	Brings together educators, curriculum specialists, professionals, researchers, students, non-profit organizations, foundations, government, and industry to address the challenges and opportunities of cybersecurity education in elementary and secondary education.	Presenter
U.S. Department of Energy CyberForce Competition	December 2018	A cyber defense-oriented competition that focuses on the defensive/hardening nature of Energy Cyber Infrastructure. Teams must maintain services for a role-playing Green Team of users while defending against a role-playing team of intruders. CEROC students participated in blue and red teams.	Participant
Annual SFS PI Meeting	January 2019	NSF and OPM organized PI meeting for SFS Schools.	Presenter
Southeast Collegiate Cyber Defense Competition CCDC	February 2019	Annual Southeast Regional Cyber Defense Competition, hosted and coordinated by the KSU Center for Information Security Education	Participant
NSF INSuRE PI Meeting	March 2019	NSF and Purdue University organized PI meeting for INSuRE Schools.	Project PI
Annual Women in CyberSecurity Conference	March 2019	Brings together women (students/faculty/researchers/professionals) in cybersecurity from academia, research and industry for sharing of knowledge/experience, networking and mentoring.	Various capacities

Virginia Tech Summit Capture the Flag Competition	March 2019	Regional Capture the Flag competition featuring over 20 schools and 30 teams.	Participant
National Cyber League	Spring 2019	National cyber competition based upon the CompTIA Security+ and EC-Council Certified Ethical Hacker (CEH) performance-based exam objectives.	20 students
Boys State Tech Night	May 2019	Participated in major's expo for Boys State participants at Tennessee Tech.	100 students
SANS 2019 Governors' Cybersecurity Talent Competition	May 2019	CTF hosted by SANS Institute for higher education students across the county.	47 students (19 moved to the quarter finals, 21st in nation)
Explorations in Engineering and Computing Camp	June 2019	Will provide cybersecurity introduction and unplugged activity to campers during one presentation period.	30 students
Engineering a Future	July 2019	Provided three afternoons of instruction featuring CyberStart CTF, Cyber Defense Against the Dark Arts, and CTF Unplugged exercises.	25 female high school students
Governor's School for Emerging Technologies	June 2019	Will provide cybersecurity introduction and unplugged activity to campers during 2 two-hour presentation periods.	35 students
GenCyber Meetings	Fall 2018 and Spring 2019	Semi-annual meetings required of all GenCyber institutions. Presented new works from recent GenCyber camp.	Project PI
DoD Cyber Scholarship PI Meeting	June 2019	Annual PI meeting for Department of Defense Cyber Scholarship grant participants. CEROC has 5 scholars in the program.	Project PI

FY 19 CEROC Year-Long Activities (beyond special events)

Event Name	Event Description
Competition Training and Technical Support	Cybersecurity special interest groups have been organized around the areas of CTF (Capture the Flag), defense, and offense with the goal of producing competition teams for events year-round. A standing competition environment is maintained for year-round training.
CS IT Security Course Infrastructure Support	Virtualization infrastructure and instructional content support for the Computer Science IT security course (100 virtual machines)
Cyber Range Development	Initial installation and continuing development of the virtualized cyber range environment to support all aspects of the center's education, research, and outreach pillars.
Cyber Patriot Competition Support	Financial, material and personnel support for startup of school CyberPatriot teams in regional schools
CEROC Scholarship Students' Professional Development Support	Bi-weekly meetings are conducted to provide guidance to all DoD and SFS scholars with regards to research participation, internship applications, and other professional development needs of the students.
CyberEagles and CyberEagles-W Events Support	The center provides support for the CyberEagles and CyberEagles-W events through speaker invitations, logistics support, and funding support through industry partners.
GenCyber Participant Follow-Ups	Follow-Up communications with school counselors and previous teacher participants about program additions at their school. Also facilitated conversations between these groups and the NICERC group.
Grant Proposal Submissions	DoD CySP, NSA GenCyber, NSF INSuRE, assistance with university cyber infrastructure grant application
Industry Cyber Review Support	The center maintains a rotating cyber risk assessment team to provide reviews for small to mid-sized business (primarily in the manufacturing sector).
K12 Instructional Material Maintenance and Dissemination	Multiple student teams provide material maintenance and outreach support for K12 events such as middle and high school student visits.
Media Advisories & Interviews	Multiple television, radio, and newspaper interviews focusing on current cybersecurity issues and center events. This work was coordinated with the Office of Communications and Marketing - Buddy Pearson.
Security Knitting Kit Material Maintenance and Dissemination	A student team continues the maintenance of the SecKnitKit project providing security modules which can be incorporated into a number of core computer science courses where the professor may not be a trained security professional.
Security Research Group Infrastructure Support	The center provides mini-grant support to researchers within the College of Engineering working on cybersecurity issues within a given discipline.

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Appendix A – 2018-19 CEROC Cyber Range Projects

Education

The cyber range supports the creation of virtual environments in support of the IT security (blue team) class, offensive security (red team) class, and malware re-engineering classes. Through IT automation frameworks, environments exceeding 300 virtual machines can be created in less than one hour with full software and networking configuration in place.

The range also supports standing training environments for the defensive (blue team), offensive (red team) and Capture the Flag (CTF) cyber interest groups. These environments are dynamic in nature as they must be reconfigured for the targeted competition. These environments can exceed 100 virtual machines at any given time.

Research

Nelma Research Project (Android Malware Research)

The Nelma Project focuses on the dynamic classification of Android-based malware using a combination of machine-learning techniques to develop new classifications and refine existing classifications based upon a gold learning set. This project also leverages the university high-performance compute cluster (HPC) by bursting signature packages to the HPC for distributed analysis and sending an informed response back to the cyber range for refined classification. This project logically and technologically combines the resources of air-gapped cyber range research with detached high-performance computing resource.

Outreach

CEROC conducts a lot of outreach events throughout the year. Beginning in FY 19, CEROC began to use the cyber range for outreach games support (including from remote locations such as the Women in Cybersecurity Conference for GenCyber Day). Among the games hosted on the range:

- **Stonehunt** – This game, themed around the Avengers fantasy world, allows students to learn the concept of chaffing and winnowing while they work together in teams to defeat Thanos and share the location of the Infinity stones. Coded secret messages are passed among team members while Thanos (who can see all messages) must determine the true messages from the false messages.
- **Cyber Patriot Material Development** – CEROC hosts a Cyber Patriot mentoring group which supports participating K12 middle and high schools attempting to develop new Cyber Patriot teams. The mentoring group has been successful in the establishment of teams at schools such as Avery Trace Middle School and Cookeville High School, both in Cookeville, TN. Avery Trace won state recognition their first year. This program created diverse teams encouraging under-represented population participation. Avery Trace has plans for an all-girls team for the next competition year.



Appendix B – Selected Cyber Competitions

Collegiate Penetration Testing Competition 2018 - 2nd place regionals; top 10 nationals; best presentation award

The team did a wonderful job and were extremely professional during the competition. They were also presented with an award for the best presentation.

Students: Joe Bivens, Connor Gannon, Sam Wehunt, David Yantis, Darren Cunningham, Max Layer

CyberForce 2018 - 26th /62 nationally and 5th/10 locally at Oak Ridge

The team did well at keeping attackers out until the very end when 3 / 5 machines were compromised.

Students: Derek Singh, Gustavo Angeles, Josh Vick, Lauren Good, Kirill Kozlov, Travis Lee

Collegiate Cyber Defense Competition 2019 – regionals only

The team was strong in technical security. The team did a great job at keeping threats and attackers away from the machines.

Students: Derek Singh, Gustavo Angeles, Josh Vick, Kirill Kozlov, Austin Brown, Jordan Johnson, Lauren Good, Travis Lee

SFSCon 2018 – 1st Place

A subset of TnTech CyberCorps SFS students participated in this CTF-style event. The team dominated the competition throughout the entire event.

National Cyber League (Fall 2018 / Spring 2019) – various rankings

CEROC students participated in both the individual and team competitions. Several students ranked in the upper 15% in the nation of their assigned brackets.

Virginia Tech Cyber Summit CTF (Spring 2019) – 3 teams, 3rd, 11th, 12th place

This CTF-style competition is hosted by the Virginia Tech CyberSecurity Student Organization. The competition hosted over 33 teams involving both virtualized and physical cybersecurity elements.