

CEROC Impact Report

An ROI Analysis of Operational Years FY 16 – FY 21

July 16, 2021

Submitted by

**Dr. Ambareen Siraj, CEROC Director
Mr. Eric Brown, CEROC Asst. Director**

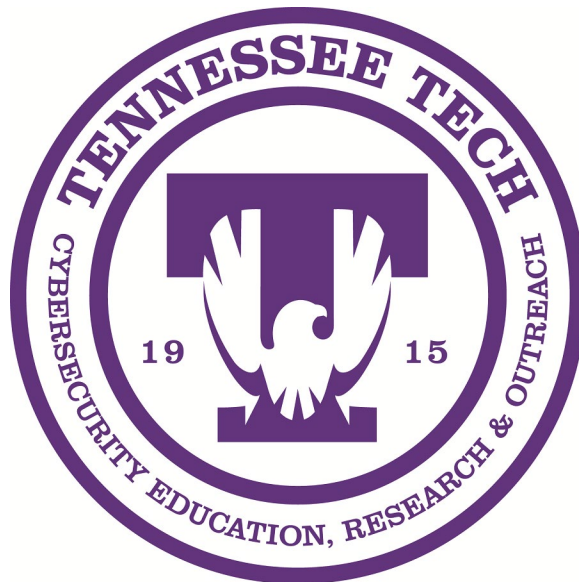


Table of Contents

Table of Figures.....	2
Executive Summary.....	3
Introduction	5
(Informal/Supplementary) Education.....	5
Direct Educational Impacts.....	5
Indirect Educational Impacts.....	6
Scholarship Program Impacts.....	8
CyberCorps Scholarship for Service (SFS)	8
Department of Defense Cyber Scholarship Program (CySP).....	10
Research.....	11
Beyond Proposal Development.....	12
Impact on New CS Faculty Members.....	13
Collaboration with University Science Infrastructure Units.....	14
Summary of Impact - Research.....	14
Outreach	15
Influence of CEROC on CS Enrollment	15
Influence at Regional, National, and International Levels.....	18
State Level Impacts.....	18
Regional Impacts	19
National Level Impact.....	19
CEROC Focus Areas and Synergies.....	21
Conclusion.....	22
References	23

Table of Figures

Figure 1 - CEROC Cyberverses	6
Figure 2 – Cyber Workforce Development Model at CEROC.....	7
Figure 3 - Historical View of the CyberCorps SFS Program 1 st Cycle.....	9
Figure 4 - Five-Year Projection of CyberCorps SFS Program 2 nd Cycle.....	9
Figure 5 - CyberCorps SFS and DoD CySP Students in Washington, D.C.....	9
Figure 6 - CyberCorps SFS Tuition Revenues	10
Figure 7 - Department of Defense CySP Tuition Revenue	11
Figure 8 - CEROC Grant Activity Five Year Review	12
Figure 9 - Nationally recognized Cyber Patriot Team at Cookeville High School.....	13
Figure 10 - Feedback from New CS Faculty Hires	14
Figure 11 - CS Enrollment by Concentration 2015 - 2020.....	16
Figure 12 - Community College Transfers from 2016 - 2021	17
Figure 13 - Community College Transfers into	17
Figure 14 - Community College Transfers into Computer Science by Concentration	17

Executive Summary

The **Cybersecurity Education, Research and Outreach Center (CEROC)**[1] at Tennessee Tech University[2] is an NSA-designated Center of Academic Excellence in Cyber Defense Education[3] housed within the College of Engineering and operation since 2016. Since FY 17, the **center was awarded a total of \$2,000,000 funding over four years from the state of Tennessee** in non-recurring funds through the Tennessee Higher Education Commission budget[4] as a match to the CyberCorps SFS grant in support of center operational expenses.

Within the state funding community, it is an understanding that funded projects should have at least a 3:1 return on investment (ROI) – quantitatively, qualitatively, or both. **The following analysis in this impact report firmly demonstrates that in each operational area (and collectively), CEROC has achieved or exceeded the 3:1 ROI standard.** Quantitative data has been provided where available with qualitative narratives providing additional support. A brief summary of the ROI highlights is listed below:

- CEROC’s NSA designation criterion had direct impact on the cybersecurity concentration curriculum offered by CS department, which has seen **485% growth in cyber student enrollment** over a period of six years.
- CEROC’s community college outreach programming’s impact on community college cybersecurity pipeline recruitment is evident in the fact that over the past six academic years combined, **46.25% of the transfers have gone into the cybersecurity concentration.**
- Tennessee Tech is the **only institution in Tennessee** (and one among a select group in the nation) **to host both of the prestigious federal scholarship programs:** the NSF CyberCorps Scholarship for Service (SFS) and Department of Defense (DoD) Cyber Scholarship (CySP), both managed by CEROC.
- Tennessee Tech **SFS program is the first and largest in Tennessee.**
 - During the first, university record-setting, NSF SFS award period, 38 workforce ready professionals have been introduced into the pipeline. With 100% placement rate, all SFS alums are currently working on federal and state agencies such as NSA, DHS, FBI and many more.
 - The SFS scholarship has resulted in the infusion of approximately \$762,000 in tuition fees to Tennessee Tech, which does not account for other ancillary fees paid from Tennessee Tech University.
- Tennessee Tech is the **only institution in Tennessee** to have students currently in the **DoD CySP** program.
 - The CySP scholarship has resulted in the infusion of approximately \$168,000 in tuition fees to Tennessee Tech, which does not account for other ancillary fees paid from supplies funds.
- The SFS and CySP programs not only helped our institution attract more highly qualified students but also non-scholarship students. Without our scholarship programs at Tech, fewer students in Tennessee and the region would pursue cyber careers with the government.
- CEROC serves as the coordinating unit for the cybersecurity student organizations/clubs and cyber interest training groups at Tennessee Tech and annually reaches around 150 CS students with professional development activities in cyber.



- Since 2015, the center has submitted and/or managed **56 awarded proposals totaling \$7,695,889** providing research opportunities for cyber students and educational opportunities for K12 students.
- With permission being granted in FY 20 to originate grants directly from the center, CEROC has submitted over **50 proposals with 24 awards to date totaling over \$3.3 million** (despite a COVID-19 slowdown).
- Since its establishment in 2016, CEROC has launched, led or participated in a number of external grant funded pilot programs to expand the reach of the center in the cyber community in the state, region and nationally that includes the following (not limited to):
 - CAE re-designation pilot program (*1 among 9 in the nation*)
 - NSF community college pathway program (*1-of-10 in the nation*)
 - NSF SFS new scholar bootcamp (*one-of-its-kind in the nation*)
 - NSF's CReST faculty workshop (*one-of-its-kind in the nation*)
 - NSF Cyber Encounter for high school teachers and students (*one-of-its-kind in the nation*)
 - NSF JROTC summer cyber academy (*one among 5 in the nation*)
 - DoD Community College Cyber Enrichment (C3E) program for community colleges (*one-of-its-kind in state/nation*)
 - DoD Cyber Education Diversity Initiative (CEDI) (*one among 9 in the nation*)
 - NSA NSF GenCyber Program (*Longest running in Tennessee*)
 - Women in Cybersecurity (WiCyS) initiative (*one-of-its-kind in the world*)
- **Grant activities of the center** has contributed to
 - the university's R2 Carnegie classification
 - the ability to recruit five new faculty members into Computer Science
 - the synergistic activities with community college programs in cybersecurity
 - research supporting the protection of national cyber infrastructure
 - cybersecurity career and education awareness with multiple audiences in K12 which also increases the post-secondary student pipeline
 - diversity efforts within the cybersecurity sector
- Since the center's inception, **CEROC has engaged over 7,000 K-12 and community students (2,800 in FY 20 alone) through various programs.**

Currently, CEROC is on track to have a record year in accomplishments in its core mission which is to help create a pipeline of cyber defenders and researchers by providing them with an integrated experience in education, research, and outreach opportunities in cyber and in doing so, serving as one of the primary cybersecurity resources for different academic, government, and business institutions in the state and the region.

More information about our center can be obtained at <https://www.tntech.edu/ceroc>.



Introduction

The Cybersecurity Education, Research and Outreach Center (CEROC) at Tennessee Tech University was established as a virtual center in early 2015 by Dr. Ambareen Siraj from the Computer Science department. The center received the designation from the National Security Agency in late 2015 and **operational as a physical center from January 2016** with the award of the national Science Foundation CyberCorps Scholarship for Service grant. The CyberCorps SFS grant was significant milestone for not only the center but the university in that it is the largest single grant awarded to the university to date. With extensions, the grant is valued at over \$5,000,000. **In FY 17, the state of Tennessee through THEC's budget allocated a grant match of \$500,000 per year (non-recurring) for up to four years (total \$2,000,000) matching the CyberCorps SFS grant.**

CEROC's name is significant in that it outlines the pillars by which all our activities are aligned – namely education, research, and outreach. The goal of these synergistic activities is to increase capacity and diversity of the cybersecurity workforce pipeline. **Since our initial state funding beginning FY 17, CEROC has established itself as a well-known brand not only in the state of Tennessee but in regional and national circles as well.** The following analysis will provide a picture of the return on investment of the state's \$2 million-dollar allocation to the center aligned with the centers mission of education, research, and outreach.

(Informal/Supplementary) Education

Generally, when the term education is used in the context of center operations, we refer to the supplementary extracurricular (or hands-on, outside the classroom) activities that complement education provided by the Computer Science (CS) department as part of their academic curriculum. These activities include supports for student organizations in cyber, special cyber interest groups, training and competition support.

Direct Educational Impacts

At the time of this report, CEROC is completing its first, five-year designation cycle with NSA. The center participated in a pilot program in 2021 with ten other universities to complete re-designation under the new criteria and evaluation model. As part of the pilot program, CEROC actively contributed to the CAE community (consisting of over 300 colleges and universities nationwide) providing structural content for the evaluation, serving on the project steering committee, as well as beta testing the new application portal providing feedback for system challenges. CEROC has completed phase 1 (program of study application and site review) and phase 2 (center operations application) successfully. We are waiting for a final site review to complete the re-designation for the next five-year cycle.

The NSA designation criterion had direct impact on the cybersecurity concentration curriculum offered by CS department. CS cybersecurity curriculum was designed to meet the designation criterion when it was first created in 2014 and then redesigned in 2021 to upkeep with the new and revised knowledge units as part of the re-designation criterion of the center. Dr. Ambareen Siraj, in her role as full professor in the CS department, leads a committee of cybersecurity CS faculty members in the regular review and revision of the CS courses contributing to the cybersecurity concentration within the program. This CS faculty committee is charged with the following tasks:

1020 Stadium Drive • POB 5134 • PRSC 414 • Cookeville, TN 38505 • (931) 372-3519
ceroc@tntech.edu • <http://www.tntech.edu/ceroc> • @TNTechCEROC

1. Assure that all cyber-related courses are consistent with the ACM/IEEE and ABET guideline as followed by the CS Department
2. Assure that cyber-related courses align with CAE-CDE knowledge units declared in the center’s CAE-CDE designation[5] plan.
3. Revise course material to align with current education cybersecurity norms and standards

Indirect Educational Impacts

CEROC student affiliates are primarily students with cybersecurity focus within computer science program who are engaged with center activities and are at the center of all that we do. Their informal education, peer mentoring opportunities, scholarly activities, and service to the cyber community are cultured during their affiliation and time with the center.

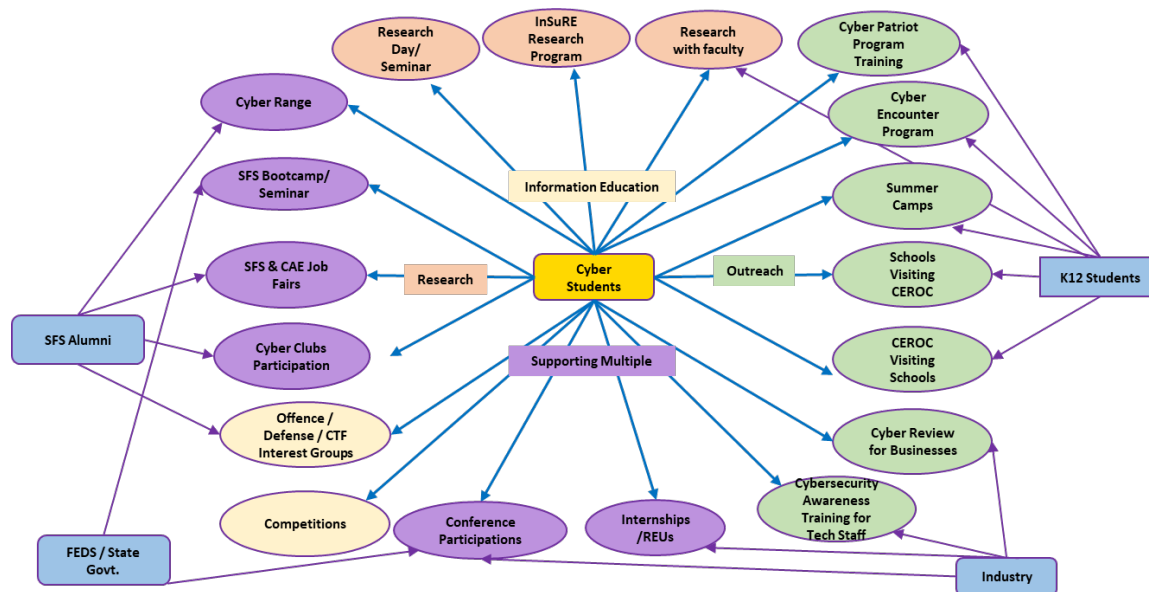


Figure 1 - CEROC Cyberverse

CEROC serves as the coordinating unit for the cybersecurity student organizations/clubs at Tennessee Tech. These clubs include CyberEagles (NCSA affiliate)[6] and CyberEagles-W (first Women in Cybersecurity, a.k.a. WiCyS, student chapter in the nation)[7]. **Annually around 150 students are reached through the activities of these two clubs.** These student organizations provide bi-weekly meetings for students from all majors with an interest in cybersecurity. Programming for these meetings may include external speakers for government or industry and internal speakers including faculty researchers, students, and competition teams. These meetings provide an opportunity for students to better understand and reach out for opportunities in the cybersecurity field. These have also helped with recruitment and retention of students in the field.

CEROC additionally provides coordination for a collection of cybersecurity interest groups (CIGs) in offensive and defensive security as well as capture the flag (CTF) competitions. These interest groups provide students the opportunity to participate in extra-curricular learning within the subject area. These groups are peer-led providing mentoring opportunities and developing leadership skills for senior

1020 Stadium Drive • POB 5134 • PRSC 414 • Cookeville, TN 38505 • (931) 372-3519
ceroc@tntech.edu • <http://www.tntech.edu/ceroc> • @TNTechCEROC

and graduate level students. Like the CyberEagles/CyberEagles-W meetings, these interest groups provide another point of interaction with industry professionals through competitions and trainings. Some of these students, individually and/or as a member of a team, have been nationally ranked in their respective focus area. These opportunities provide considerable resume-worthy content and is desirable by government and industry employers.

Specifically, all these opportunities facilitate the following for cybersecurity students:

- Professional development events (club, CIG and CEROC events)
- Service learning opportunities (CIGs, CEROC outreach events, competition training)
- Leadership training (via clubs, CIGs and competition teams)
- Faculty and staff mentoring with club members
- Peer mentoring (primarily via cyber interest groups, a.k.a. CIGs)

CEROC support students, including SFS Scholars, to participate in several security competitions including regional CCDC and CPTC, NCL, and various CTF competitions. Articles about the competition accomplishments of these groups can be found in the CEROC blog[8], which speaks to the quality of TNTech students based on their competitive performances at various competitions.

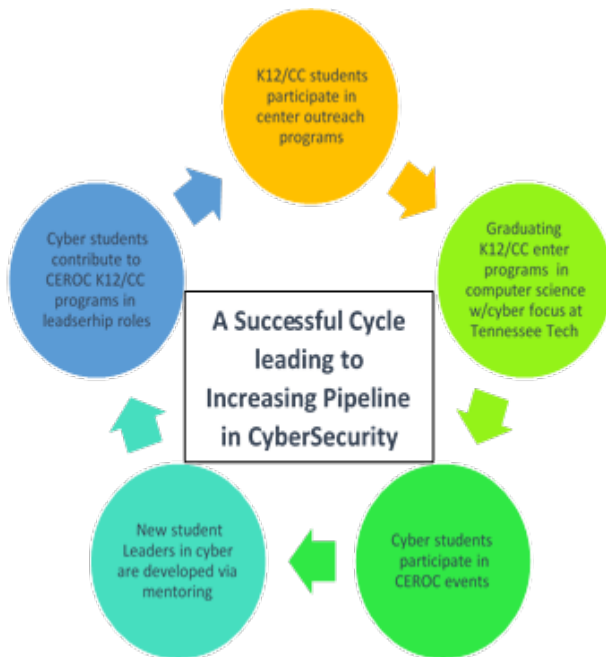


Figure 2 – Cyber Workforce Development Model at CEROC

While mentioned previously, the peer-mentor structure of these groups has been a significant point of interest for perspective employers. We have received this feedback from multiple sources. The developed, student leaders apply their skillsets to cyber interest group training and center-related camps focused on K12 and post-secondary school populations which feeds the education pipeline for future four-year and graduate program participants which in turn feeds the cybersecurity workforce pipeline. We have at least one student who attended GenCyber camp in 2017, joined our program in 2018, served as a leader in outreach program in 2020, became an SFS scholar in 2020, served as a guest speaker in GenCyber camp in 2021 and joining graduate program in 2021 with 2022 expected graduation to serve a federal agency.

This is a natural outcome of the “pay it forward” culture encouraged by the center and demonstrated by students over the years.



Scholarship Program Impacts

The educational impacts of the center cannot be discussed without considering the funding of student sponsorships. CEROC provides scholarship and student supports through a combination federal grant and local funds. Consider these examples of current student support for our graduate program:

- Out of the 12 current Fast Track[9] CS students, 8 (67%) are/has been supported by CEROC grants/scholarships
- Out of the 22 current Masters students, 14 (64%) are/has been supported by CEROC grants/scholarships
- Out of the 28 current Ph.D. students, 7 (25%) are/has been supported by CEROC grants/scholarships

The federal scholarship programs in which CEROC participates has become an essential element of the center's activities. While only a select number of students will participate in these programs due to their high academic rigor, these programs are the target goal of many of our undergraduates and prospective students and are viewed as the pinnacle of academic excellence, cyber community service, and leadership development. **Tennessee Tech is the only institution in Tennessee (and one among a select group in the nation) to host both of the prestigious federal scholarship programs: the NSF CyberCorps Scholarship for Service (SFS) and Department of Defense Cyber Scholarship (CySP).** The uniqueness of our management approach and mentoring programs have been commended by both the National Science Foundation and Department of Defense program offices.

CyberCorps Scholarship for Service (SFS)

As briefly discussed in the document introduction, the CyberCorps SFS[10] program is a grant funded through the National Science Foundation. There are 93 (8 community colleges, 85 colleges/universities) schools in the nation which have met the standards to receive the grant. Each grant award cycle is a five-year project through which students earn a cybersecurity-focused degree and later assume cybersecurity roles within the executive branch of the federal government, state or local government, and FFRDC organizations for the same number of years (up to three) for which they received the scholarship.

Tennessee Tech has been an SFS institution since 2016 being the first of its kind in Tennessee. We are still largest and one of two of such programs in Tennessee. We have reapplied, and subsequently expect award, of another five-year grant in 2021. During the first, university record-setting, award period, 38 workforce ready professionals have been introduced into the pipeline. With 100% placement rate, our SFS alums are currently working on federal agencies such as NSA, DHS, FBI and many more. Almost all participants in the program complete a M.S. degree in computer science which qualifies them for that upper 20% of the cybersecurity market opportunities[11].

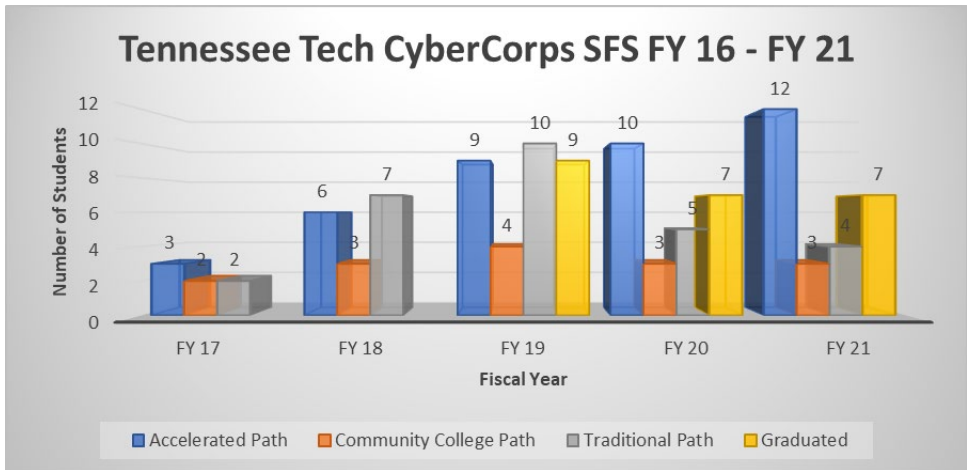


Figure 3 - Historical View of the CyberCorps SFS Program 1st Cycle

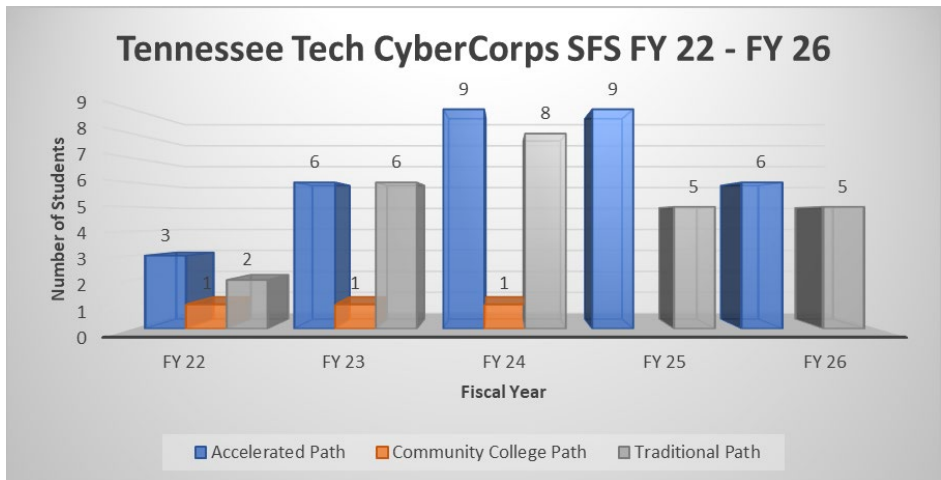


Figure 4 - Five-Year Projection of CyberCorps SFS Program 2nd Cycle



Figure 5 - CyberCorps SFS and DoD CySP Students in Washington, D.C.

1020 Stadium Drive • POB 5134 • PRSC 414 • Cookeville, TN 38505 • (931) 372-3519
ceroc@tntech.edu • <http://www.tntech.edu/ceroc> • @TNTechCEROC

Summary of Impact - SFS

The CyberCorps SFS program at Tennessee Tech University has been the catalyst for a number of efforts which can be evaluated either qualitatively or quantitatively. In terms of quantitative measures, the scholarship has resulted in the infusion of approximately \$762,000 in tuition fees to Tennessee Tech and does not account for other ancillary fees paid from supplies funds. Stipend and professional development funds have contributed to the local economy through normal living expenses as well as nationally through procurement of cyber training and support of conference/workshop fees where SFS students were content contributors. The research and presentation contributions of these students and their faculty advisors helped in the reputation of the center and the university as a R2 Carnegie-class[12] research institution as well a distinction of cyber research within the greater cyber community.

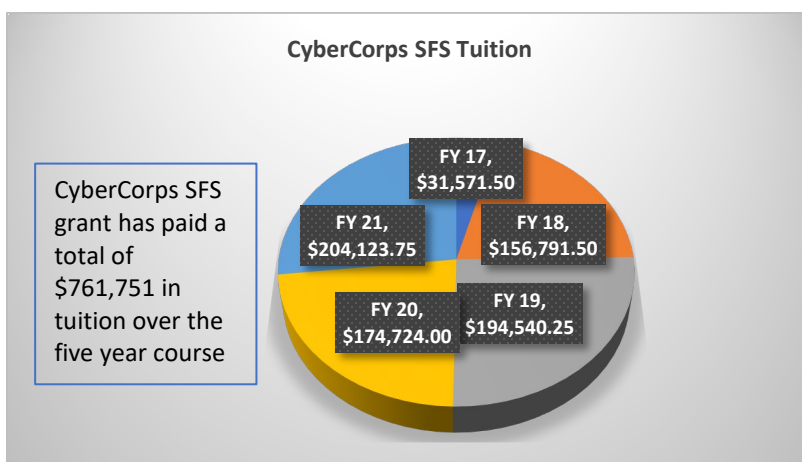


Figure 6 - CyberCorps SFS Tuition Revenues

Department of Defense Cyber Scholarship Program (CySP)

CEROC has participated in the Department of Defense Cyber Scholarship Program (CySP) since 2018. To date seven students have participated in the program with four graduates placed in cybersecurity roles with the Department of Defense agency umbrella including at least two placements within the DoD intelligence community. While the recruitment aspect of this program works significantly different from the CyberCorps SFS program, the payment packages, summer internships, and end goals are relatively similar. Where SFS students pick their agency, CySP students are selected by their agencies upon entry into the program. Another distinction in this program is that the scholarship is awarded annually rather than for a two or three-year period. Prior year participants are essentially assured of renewal assuming the academic and conduct standards are maintained. This program shares the same accountability, dissemination, and mentoring structures used by CEROC for the CyberCorps SFS program.

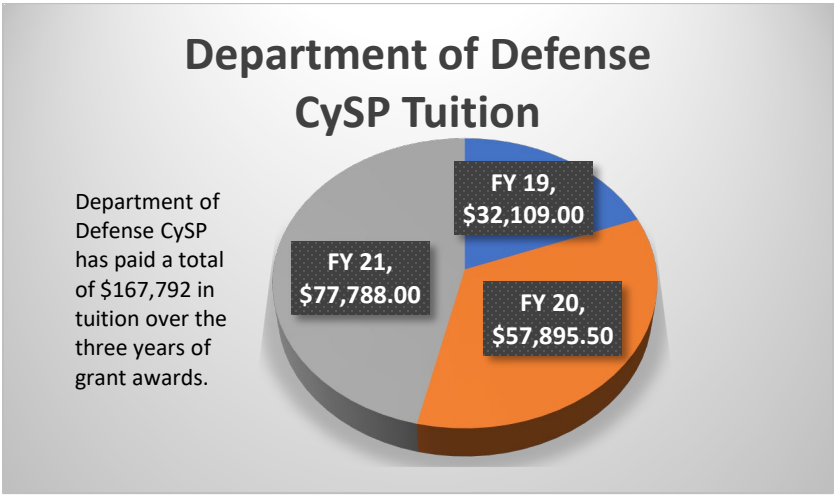


Figure 7 - Department of Defense CySP Tuition Revenue

Summary of Impact – CySP

The Department of Defense CySP program at Tennessee Tech University has been quality addition to our center’s portfolio. In terms of quantitative measures, the scholarship has resulted in the infusion of approximately \$168,000 in tuition fees to Tennessee Tech and does not account for other ancillary fees paid from supplies funds. As with SFS, CEROC has actively contributed back to this community in terms of policy and procedure development as well as contributing the new logo used for the program.

Stipend funds have contributed to the local economy through normal living expenses as well as nationally through procurement of cyber training and support of conference/workshop fees where CySP students were content contributors. The research and presentation contributions of these students and their faculty advisors help in the reputation of the center and the university as a R2 Carnegie-class research institution as well a distinction of cyber research within the greater cyber community.

The SFS and CySP programs not only helped our institution attract more highly qualified students but also non-scholarship students. Without our scholarship programs at Tech, fewer students in Tennessee and the region would pursue cyber careers with the government.

Research

Since 2015, the center has submitted and/or managed 56 awarded proposals totaling \$7,695,889 providing research opportunities for cyber students and educational opportunities for K12 students. With permission being granted in FY 20 to originate grants directly from the center, CEROC has submitted over 50 proposals with 24 awards to date totaling over \$3.3 million (despite a COVID-19 slowdown). Secondly, CEROC has led or participated in a number of pilot programs to expand the reach of the center in the cyber community with the NSF community college (CC) pathway program, CAE re-designation pilot program, NSF SFS Bootcamp, NSF’s CReST, NSF Cyber Encounter, NSF JROTC Summer Cyber Academy and Women in Cybersecurity (WiCyS) programs.

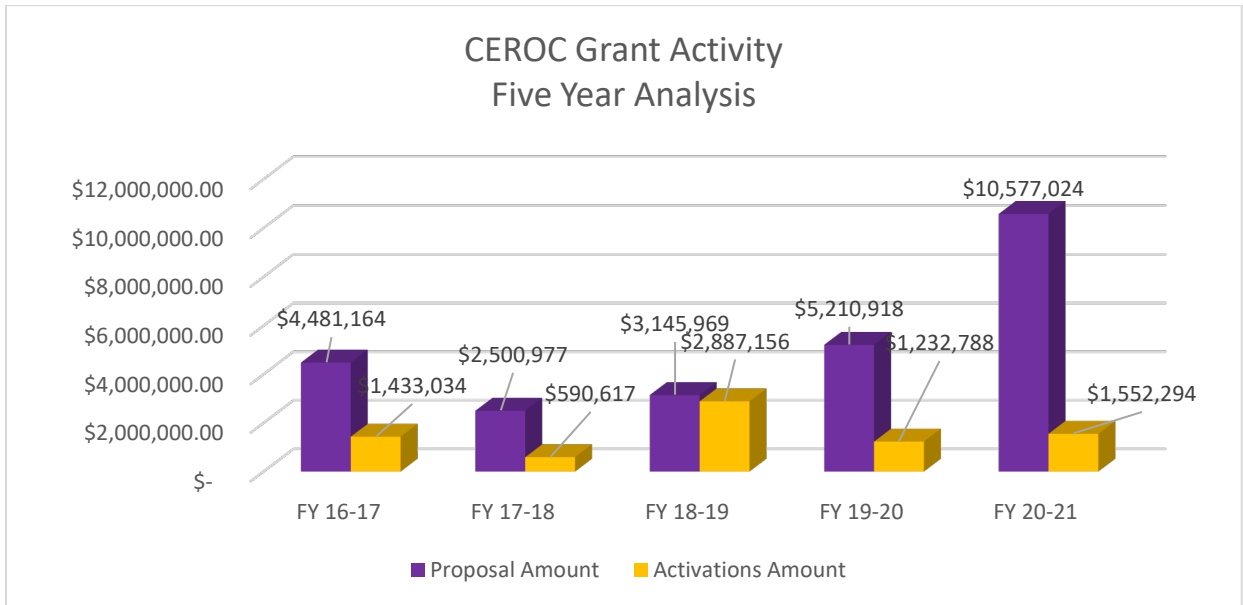


Figure 8 - CEROC Grant Activity Five Year Review

Beyond Proposal Development

Research activity goes well beyond proposal development. Grants processed by the center generally include funding to enhance undergraduate and graduate participation in the research process. Many of the grants sought by the center included funding for on-site and virtual events for K12 facilities such as the GenCyber on Wheels events (the TNTech STEMmobile rebranded and loaded with cyber activities). As mentioned earlier, the interaction between current TNTech students and potential college students rising through the K12 sector is an important continuity element in the pipeline and provides leadership training for our students. These K12 / post-secondary intersections have yield significant returns such as the development of new Cyber Patriot[13] outreach and training programs for K12. Some of these teams have already become nationally recognized for their competition efforts. For example, most members of this highly accomplished Cyber Patriot team at the local Cookeville High School participants in our GenCyber camps, and CEROC has helped to set up and support their team in various ways.



Figure 9 - Nationally recognized Cyber Patriot Team at Cookeville High School

Grant awards have been of multiple benefits to the center. In addition to the progression of research and educational outreach activities, release time is used to offset center staff salaries. Indirect costs funds are distributed to various university units based upon a distribution scheme established by university policy. There have been discussions of including research centers in that distribution. Increased grant activity has also created stronger ties with funding organizations such as Oak Ridge National Labs, National Security Agency, Department of Defense, National Science Foundation, and others.

Impact on New CS Faculty Members

CEROC has assisted in the Computer Science department's efforts to hire five, new faculty members active in cybersecurity. These faculty members were added to the Computer Science Department in FY 19. This was a tremendous accomplishment for a university of the size of Tennessee Tech and in a market where these positions are very difficult to fill. These faculty members have had a significant impact on overall research production over the past two fiscal years. Additionally, their contributions to educational (formal and informal) projects in the center and Computer Science cannot be understated. As per anonymous feedback from these individuals, CEROC was an influential consideration in these faculty members' decision to join Tennessee Tech and have helped them to be successful with their goals as faculty members at Tech.

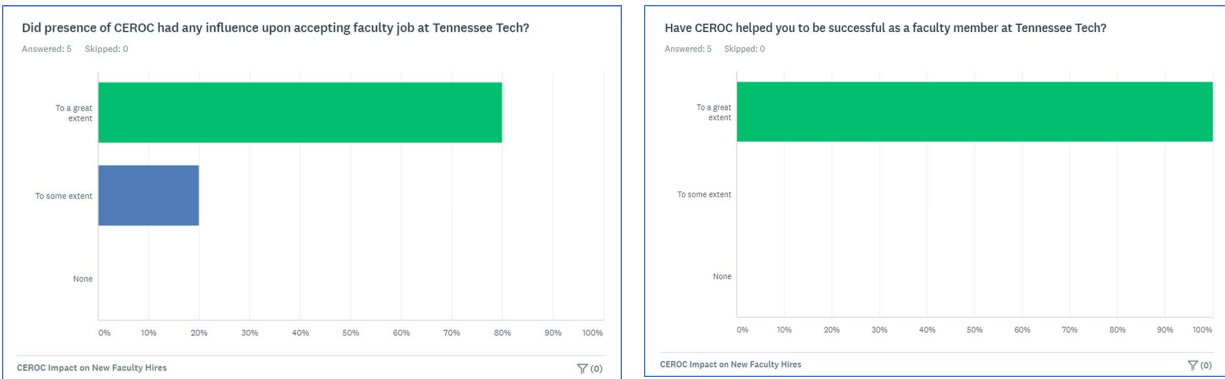


Figure 10 - Feedback from New CS Faculty Hires

Collaboration with University Science Infrastructure Units

Statement from Dr. Mike Renfro, High Performance Computing Engineer

“CEROC has a positive impact on TN Tech’s Information Technology Services (ITS) group in four primary areas. First, the Cyber Range provides a proving ground and pre-production environment for new releases of virtualization software and hyperconverged infrastructure architectures. This allows for real-world testing of new technologies before they are implemented on ITS production systems supporting university academic, research, and administrative functions.

Second, CEROC has provided science drivers and valuable administrative support for multiple proposals to expand high performance computing and networking facilities at TN Tech. One proposal resulted in NSF award 2018373, ‘CC* Networking Infrastructure: Creation of a Science DMZ and 10Gb/s Connection to Internet2 for Tennessee Tech University’. CEROC strengthened the DMZ proposal in a highly competitive environment and allowed ITS staff to focus on the technical implementation of the DMZ rather than the associated paperwork.

Third, CEROC is one of the sources collaborating with ITS to maintain awareness of active cybersecurity threats with potential impact to university resources.

Fourth, CEROC provides both staff and students to conduct training workshops with ITS for the university community. One set of workshops improves research computing skills that benefit both CEROC projects and students, faculty, and staff in multiple colleges. These workshops help move the university toward an environment promoting both reproducible research and open science. Another set of cybersecurity awareness workshops focused on university staff to improve the organization’s cybersecurity resilience. “

Summary of Impact - Research

As stated earlier, a **quantitative measure of \$7,695,889 has been generated through grant awards.** While the golden standard of state funding is a 3:1 ROI, this measure alone yields a 3:1 ROI. From a qualitative perspective, the research activity of the center has contributed to

- the university’s R2 Carnegie classification
- the ability to recruit five new faculty members into Computer Science

1020 Stadium Drive • POB 5134 • PRSC 414 • Cookeville, TN 38505 • (931) 372-3519
ceroc@tntech.edu • <http://www.tntech.edu/ceroc> • @TNTechCEROC



- the synergistic activities with community college programs in cybersecurity
- research supporting the protection of national cyber infrastructure
- cybersecurity career and education awareness with multiple audiences in K12 which also increases the post-secondary student pipeline
- diversity efforts within the cybersecurity sector

Outreach

Both locally and nationally, CEROC has a track record of various outreach activities in CS and cybersecurity for both secondary and post-secondary education, including public and private industry sectors. **Since the center's inception, we have engaged over 7,000 K-12 and CC students (2,800 in FY 20 alone) through various programs.** These numbers do not include the numerous cyber information emails sent to K12 district superintendents and school principals in TN. The topic of outreach has many focal points from the standpoint of CEROC's operations. Examples include (but not limited to):

- Visit to an elementary school teaching Internet safety
- Visit by school groups to learn about cyber
- Cyber camp for high school students
- STEMMobile school visits
- Workshops for K12 students and teachers and guidance counselors
- Workshop for college faculty on integrating cyber
- CyberPatriot outreach program
- Training workshops for college students in offense, defense and CTF skills
- Webinars and workshops for community college students on cyber
- WiCyS conference
- Workshop dissemination of a research project

In short, outreach is any activity in which interest can be sparked in cybersecurity and/or use of resources in cybersecurity. The following outlines data points used to evaluate the center's effectiveness in outreach and center's visibility and reputation that might have resulted in recruitment success for our CS program.

Influence of CEROC on CS Enrollment

The cybersecurity concentration within the computer science program at Tennessee Tech has steadily grown since the center's creation (485% growth over a period of six years). Impact of cyber program and CEROC is evident in the adjacent chart that demonstrates this growth. Note: The increase in enrollment in the cybersecurity concentration when viewed over 2015 – 2020 represents a 3.7:1 increase exceeding the 3:1 ROI standard adding additional, shovel-ready cybersecurity professionals to the workforce pipeline.

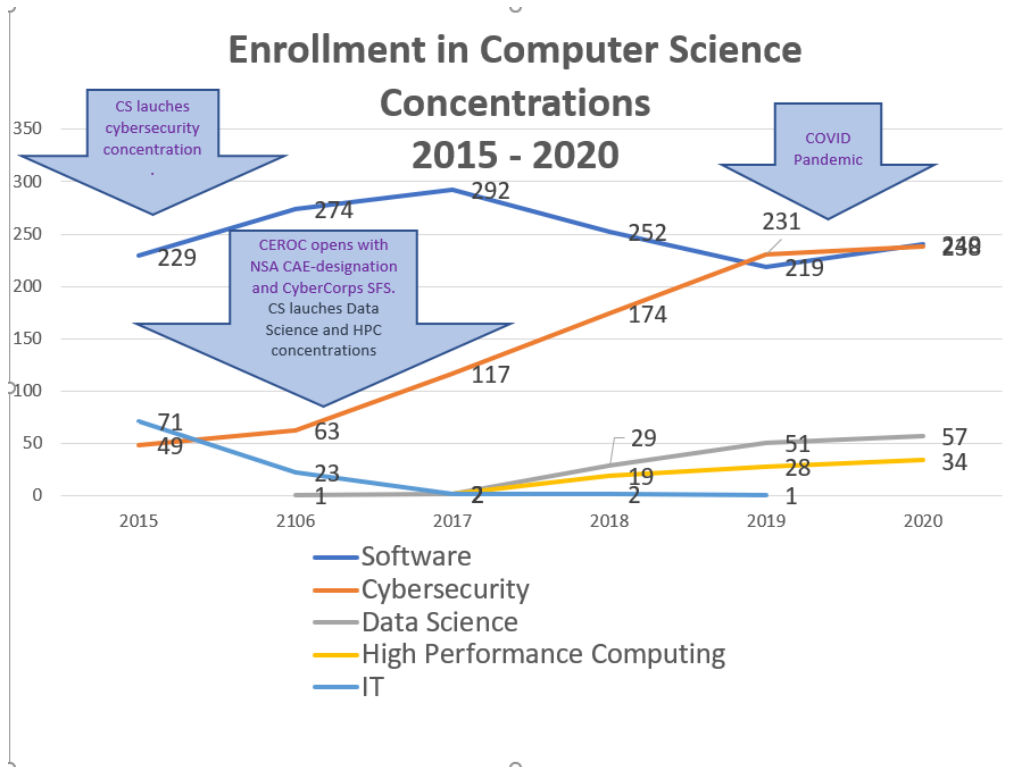


Figure 11 - CS Enrollment by Concentration 2015 - 2020

As indicated earlier, CEROC has implemented several programs focused on engagement of our community college partners. These programs have included simple, direct outreach using our CEROC student ambassadors ranging to our DoD-funded Community College Cybersecurity Enrichment Program (C3E) program and NSF funded Summer Bridge program which engaged community college students through virtual workshops examining topics such as the creation of student cyber organizations, cyber range activities, competition training frameworks and events, as well as discussions about bridging from two to four-year programs.

Quantitative evidence suggests that these programs are having a positive effect on the education pipeline. The following charts indicate the two to four-year transfer rates over the period of time in which the center has been in operation. **These charts examine the overall effect on Computer Science enrollment as well as effects on cybersecurity recruitment specifically.** Note the similar forms comparing peaks on the general transfer chart to those on the cybersecurity transfer chart.

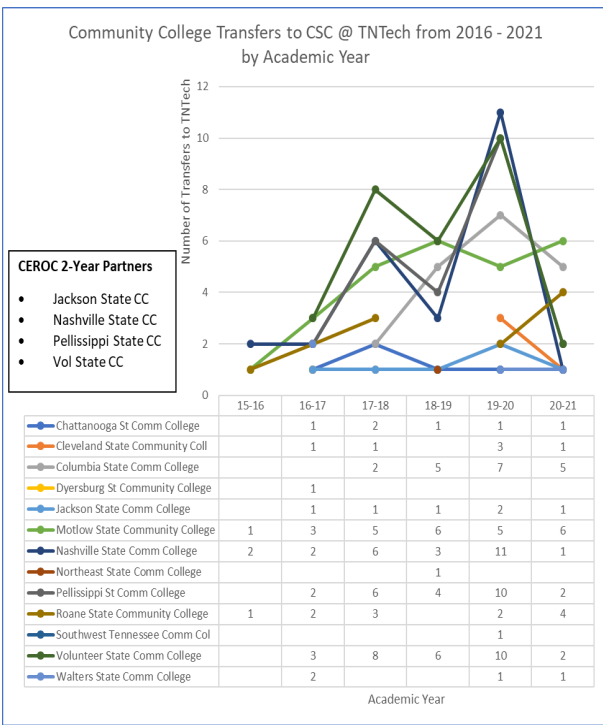


Figure 12 - Community College Transfers from 2016 - 2021

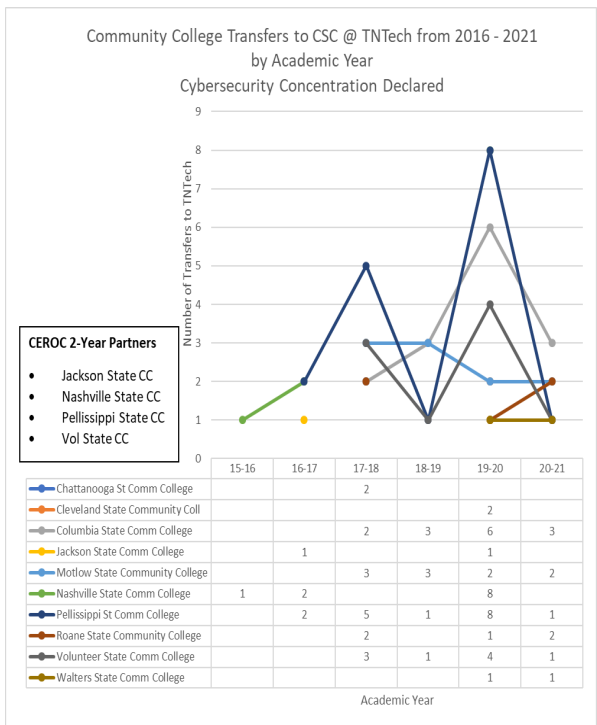


Figure 13 - Community College Transfers into Cybersecurity Concentration 2016 - 2021

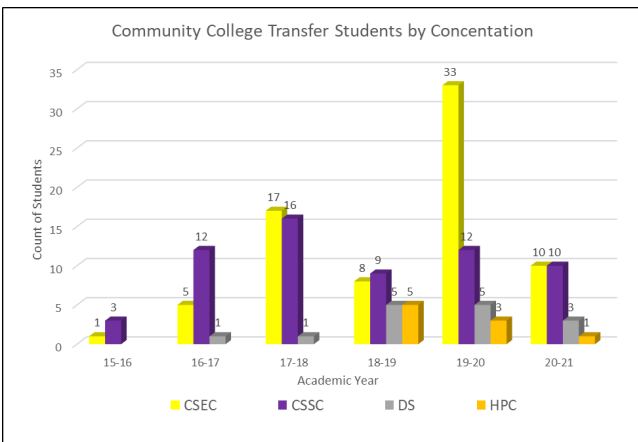


Figure 14 - Community College Transfers into Computer Science by Concentration

Annual Year	CSEC	CSSC	DS	HPC
15-16	25.00%	75.00%	0.00%	0.00%
16-17	27.78%	66.67%	5.56%	0.00%
17-18	50.00%	47.06%	2.94%	0.00%
18-19	29.63%	33.33%	18.52%	18.52%
19-20	62.26%	22.64%	9.43%	5.66%
20-21	41.67%	41.67%	12.50%	4.17%
Grand Total	46.25%	38.75%	9.38%	5.63%

Table 1 - Community College Transfer Percentages (six-year history)

Further focusing on quantitative metrics regarding CEROC’s impact on community college cybersecurity pipeline recruitment, consider that over the past six academic years combined, 46.25% of the transfers have gone into the cybersecurity concentration. The peak year (possibly skewed by COVID-19 in AY 20-21) was AY 19-20 with 62.26% of transferring students entering the cybersecurity concentration. **This is a demonstrated positive outcome of the center’s continued outreach efforts to the community colleges in the state.**



CEROC has also been very involved with institutional recruiting programs including activities conducted by the Office of Admissions and the College of Engineering (CoE) Student Success Center (SSC). Consider the following statement from the CoE SSC.

“The Cybersecurity Education, Research, and Outreach Center (CEROC) has been an integral part of our continued recruitment and outreach efforts. CEROC has assisted with numerous recruitment events such as high school visits as well as meeting with families and school groups that are visiting campus. They also take part in the College of Engineering Explorations in Engineering and Computing Summer Camp, a camp targeting rising 12th grade students in the hope of increasing diversity, by leading a session with these prospective students. Additionally, CEROC has assisted with outreach events in communities across Tennessee by speaking to students of all ages about the importance of cybersecurity. They also helped to facilitate student learning through the Makers on the Move program, a program sponsored by the College of Engineering Clay N. Hixson Student Success Center. Through CEROC’s continued efforts to connect with and educate students, they are a true asset to our success in recruiting students”

Influence at Regional, National, and International Levels

TNTech’s reputation in education and workforce development extends beyond Tennessee. Here are some examples.

State Level Impacts

Tennessee Tech has been awarded funds from NSA and NSF to conduct GenCyber camps since 2016 and continues to be the longest running GenCyber program in the State. **Over the last four years, we have directly interacted with 510 students through this program.** Additionally, we have directly interacted with 12 teachers and 13 school counselors in the Middle and East Tennessee regions. **These specific teachers and school counselor program participants have indirectly influenced thousands of students over the past three years and continues to do so.**

Dr. Siraj is an ***active member of the Workforce Development working group under the Tennessee Cybersecurity Advisory Council*** to identify and address workforce cybersecurity gaps for public and private sector and preparedness and coordinated response to cybersecurity incidents. She and her student have helped CISO’s office to organize information for college students within the state’s cyber site: <http://cybertn.gov/>

We established a ***Community College (CC) pathway program*** with Pellissippi State, Volunteer State and Jackson State as part of the NSF CyberCorps SFS Community College program pilot study with four-year programs (1 of 10 universities in the nation to participate). As per NSF, we are the **ONLY** school that has been successful in this study by creating a program that has successfully enabled CC students into federal workforce pipeline.

In the DoD-funded ***Community College Cyber Enrichment (C3E) Program***, CEROC has been providing opportunities and knowledge about cybersecurity to students currently enrolled in community colleges across the state. The primary goal of C3E is to grow the pipeline of community college students in

1020 Stadium Drive • POB 5134 • PRSC 414 • Cookeville, TN 38505 • (931) 372-3519
ceroc@tntech.edu • <http://www.tntech.edu/ceroc> • @TNTechCEROC



Tennessee to join the cybersecurity workforce with baccalaureate degrees at the least. The C3E project is undertaking multiple initiatives to foster an interest in cybersecurity and provide community college students exposure to careers available in this field, which are: seminars, workshops, funded professional development opportunities and a summer bridge program. So far, the project has reached around 100 community college students in Tennessee.

Funded by Department of Energy and in partnership with the Industrial Assessment Center at Tennessee Tech, CEROC has been conducting **Cybersecurity Risk Assessments for small to mid-sized businesses and manufacturing companies** on techniques to improve their cybersecurity posture. Since 2016, we have served seven organizations through this initiative.

Regional Impacts

CEROC is an **active member of the Southeast CAE regional consortium** led by University of West Florida, where we are working with our partner universities to establish and amplify local initiatives at regional level. Additional examples of collaborations include:

- NSF CReST faculty development workshops with Towson University
- Multiple Cybersecurity research projects with the SimCenter, University of Tennessee at Chattanooga
- NSF SANS Training with CISO project participation with New York University
- Serving on Regional Steering Committee with a staff member serving as regional K12 liaison

In partnership with Rochester Institute of Technology, CEROC has been **hosting the Regional Collegiate Penetration Testing Competition (CPTC) for the Central region** since 2019[14]. In addition to hosting, CEROC student team is active in the competition.

CEROC affiliated faculty and students have been conducting **research with the scientists and engineers at the Oak Ridge National Lab (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 cannot to CAN: Attack Prevention & In-situ Detection of Advanced Attacks on Controller Area Networks, and 4) Intrusion Detection Using Multimodal Machine Learning. CEROC also collaborated with ORNL to jointly host the 6th International Conference on Cyber Warfare and Security (ICCWS)[15]. Ultimately, this conference was conducted virtually due to COVID-19 restrictions early 2021.

National Level Impact

CEROC is nationally recognized for its efforts in integrating education, research, and outreach and broadening participation in such. In Spring 2020, Dr. Siraj **testified in congressional hearing** before the US Cybersecurity workforce, Subcommittee on Research and Technology, on the topic “More Hires, Fewer Hacks: Developing the U.S. Cybersecurity Workforce” and submitted a written testimony to the US Congress, which can be found at: <https://science.house.gov/hearings/more-hires-fewer-hacks-developing-the-us-cybersecurity-workforce>.



As part of this nine partner NCAE-C designated academic institutions under DoD sponsored **Cyber Education Diversity Initiative (CEDI)**, CEROC has been serving as a resource for Minority Serving institutions (MSI)s and Historically Black Colleges and Universities (HBCU)s nationwide and providing various services to the students and faculty of these institutions that include: hands-on skill training opportunities for students, faculty workshops, facilitating and programming student remote participation in Cyber Interest groups (Capture the Flag, Defense and Offense), helping to establish/expand local cybersecurity student cohorts for students and CAE Designation Guidance for NCAE-C designations.

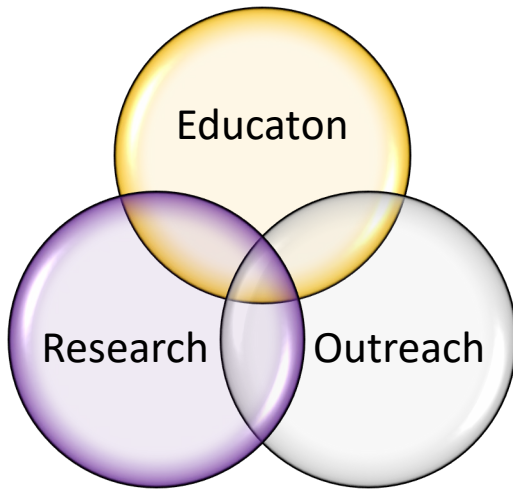
The **Cyber Encounters Project**, funded by NSF, was an initiative undertaken to increase student awareness and participation in cybersecurity programs at the K12 level. The project activities, targeted towards impacting teachers, provided teachers with the knowledge and tools needed to organize cybersecurity-related programs and encourage their students to participate in engaging cybersecurity programs and competitions. With training partnership with SANS, the project had 152 teachers and 342 students from five targeted states, New Jersey, Virginia, Indiana, Tennessee and Texas. In the second phase of the project, around 300 Junior ROTC cadets nationwide participated.

In summer of 2021, CEROC was part of a five University consortium sponsored by NSF where 16 **Junior ROTC cadets** out of 100 across the country went through a six-week long **summer cyber enrichment program** where they undertook a college credit cyber course along with additional professional development experiences.

CEROC has also contributed to the SFS and cyber education community nationwide. In 2016, CEROC launched the **national CyberCorps SFS bootcamp** which provides a 1.5-day orientation for newly recruited SFS scholars nationwide and has been managing the program since then. The event includes more than just detail orientation of the SFS program; it includes a review of research process, financial management, career development, and other related soft skills needed by successful candidates in the program. Currently we are working on expanding the program over a whole academic semester with NSF sponsorship.

Tennessee Tech and CEROC are the originating entity of the **Women in Cybersecurity (WiCyS) initiative**. This conference was originally funded by the National Science Foundation to support diversity efforts within the cybersecurity workforce pipeline and related education efforts. This initiative has grown and is now an independent global non-profit organization consisting of more than 5000 members which supports diversity efforts in cyber through a variety of programming that includes various scholarships, internships, mentorships, apprenticeships programs for underrepresented population in cyber, affiliate groups (around 40 across the globe), student chapters (around 125 nationwide), and outreach efforts. More information can be found here: <https://www.wicys.org/>

CEROC Focus Areas and Synergies



As alluded to in previous sections, all CEROC activities are aligned to one or more of the center’s core values. Considering the adjacent Venn diagram, our goal is to create activities that target the interior sections of the diagram where areas overlap. While all activities will be grounded in at least one of the areas, greater synergies are achieved the closer we get to the intersections.

The following table outlines some of our activities and where they align to the diagram.

Area	Activities
(informal) Education	<ul style="list-style-type: none"> • Competition training • Cyber Interest Groups
Research	<ul style="list-style-type: none"> • Support for research in: Cyber Physical Systems, Agri-Cyber, Vehicular Networks, Malware analysis, Secure data containers
Outreach	<ul style="list-style-type: none"> • Community College Outreach (C3E) • Diversity Initiative (CEDI) • Cyber Encounter • Gen Cyber On-Wheels • CReST workshops • CyberEagles / CyberEagles-W
Education & Research	<ul style="list-style-type: none"> • INSuRE Program • Internet Security Curriculum • Quantum Computing Curriculum • CyberCorps SFS • DoD Cyber Scholarship Program
Education & Outreach	<ul style="list-style-type: none"> • Cyber Patriot Outreach Team • NSF Cyber Academy • GenCyber Camps
Research & Outreach	<ul style="list-style-type: none"> • XiveNet project • Enhanced Security Static Analysis
Education, Research & Outreach	<ul style="list-style-type: none"> • CEROC Cyber Range • SecKnitKit • AI Assisted Malware Analysis • ORNL Collaborations



An example of a cross-cutting program that affects all three areas is the **CEROC Cyber Range**[16]. 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. It cost \$150,000 to build but serves the purpose of a commercial cyber range valued at around half a million dollars. This range 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 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 outreach activities and research projects. The CEROC Cyber Range provides a comprehensive active learning experience for participants, students, and researchers.

Conclusion

The impact of the state appropriation fund of \$2,000,000 for CEROC over four-year period has been crucial in the establishment of CEROC as a physical center and is the primary source of its logistical operations. The funds are allocated each year in alignment with the center's three pillars of operation to serve the state and region, namely, education (20%), research (40%), and outreach (20%) with administrative overhead at approximately 20%. These funds contribute to salaries for center staff, research infrastructure, mini-grants for faculty researchers, support for graduate and research assistants, and support for the many community outreach activities conducted throughout the year.

As demonstrated through the analysis of each core area, CEROC has met and exceeded the usual standard of 3:1 ROI. The current success of CEROC is based upon five years of steady progress built on top of solid foundations. The center will be expanding staffing and infrastructure supports in FY 22 to address additional, supplementary education, research and outreach demands. These supports and future expansions will be dependent upon reliable, persistent funding streams which in turn seed experimental models creating new funding streams.

While numbers can provide solid evidence of outcomes, the true value of our center and programs we manage can absolutely be measured by a single, gold standard – success of our students. Our center, from its very beginning, made our student affiliates the primary focus and measure of quality in what we do. Throughout the history of the center, we have successfully delivered quality, cybersecurity professionals into key positions defending cyber infrastructures at the national, regional and local levels. These positions not only create an economic impact as would be consistent with quality paying jobs injecting revenues into commercial economic ecosystems as well as their related tax contributions; these positions also have a significant impact on the economic in terms of the protections provided from future cybersecurity intrusions.

Through CEROC's programs Tennessee Tech has developed a recognized brand in cybersecurity at the state and at national level in the education, government, and industry sectors. This has been possible only because of the support through competitive federal programs and most importantly, the 2-million-dollar appropriation fund from the State. Without it, CEROC might not have existed at its capacity today, and the wide impact of CEROC would not have happened. **We hope to contribute in our state's and nation's cyber agenda in increased capacity with our own strengths and through our own community.**

References

- [1] “Cybersecurity Education, Research & Outreach Center.” <https://www.tntech.edu/ceroc/> (accessed Jul. 27, 2020).
- [2] “About Tennessee Tech University.” <https://www.tntech.edu/about/> (accessed Feb. 08, 2020).
- [3] “What is a CAE? | CAE in Cybersecurity Community.” <https://www.caecommunity.org/content/what-is-a-cae> (accessed Jul. 27, 2020).
- [4] “Fiscal Year 2021-2022 Budget Publications.” <https://www.tn.gov/finance/fa/fa-budget-information/fa-budget-archive/fiscal-year-2021-2022-budget-publications.html> (accessed Jul. 13, 2021).
- [5] “A Hub for National Centers of Academic Excellence | CAE in Cybersecurity Community.” <https://www.caecommunity.org/> (accessed Feb. 08, 2020).
- [6] “Cyber Eagles – We Soar To Defend.” <http://cybereagles.org/> (accessed Jul. 13, 2021).
- [7] “WiCyS student chapters.” <https://www.wicys.org/initiatives/student-chapters/> (accessed Jul. 13, 2021).
- [8] “Cybersecurity Education, Research and Outreach Center @ TnTech – The place to be for cyber in Tennessee.” <https://sites.tntech.edu/ceroc/> (accessed Jul. 27, 2020).
- [9] “Computer Science - Fast-Track Program.” <https://www.tntech.edu/engineering/programs/csc/fast-track.php> (accessed Jul. 27, 2020).
- [10] “Cybersecurity Education, Research & Outreach Center - Tennessee CyberCorps: Scholarship For Service.” <https://www.tntech.edu/ceroc/education/sfs/> (accessed Jul. 27, 2020).
- [11] “Cybersecurity Career Pathway.” <https://www.cyberseek.org/pathway.html> (accessed Feb. 22, 2020).
- [12] “Carnegie Classifications | Institution Lookup.” https://carnegieclassifications.iu.edu/lookup/view_institution.php?unit_id=221847&start_page=lookup.php&clq=%7B%22ipug2005_ids%22%3A%22%22%2C%22ipgrad2005_ids%22%3A%22%22%2C%22enrprofile2005_ids%22%3A%22%22%2C%22ugprfile2005_ids%22%3A%22%22%2C%22sazeset2005_ids%22%3A%22%22%2C%22basic2005_ids%22%3A%22%22%2C%22eng2005_ids%22%3A%22%22%2C%22search_string%22%3A%22Tennessee+Tech+University%22%2C%22level%22%3A%22%22%2C%22control%22%3A%22%22%2C%22accred%22%3A%22%22%2C%22state%22%3A%22%22%2C%22region%22%3A%22%22%2C%22urbanicity%22%3A%22%22%2C%22womens%22%3A%22%22%2C%22hbcu%22%3A%22%22%2C%22hsi%22%3A%22%22%2C%22tribal%22%3A%22%22%2C%22msi%22%3A%22%22%2C%22landgrant%22%3A%22%22%2C%22coplac%22%3A%22%22%2C%22urban%22%3A%22%22%2C%22community%22%3A%22%22%7D (accessed Jul. 27, 2020).
- [13] A. F. Association, “AFA CyberPatriot Website.” <https://www.uscyberpatriot.org/> (accessed Mar. 18, 2021).
- [14] “Cybersecurity Education, Research & Outreach Center - Central Regional Collegiate Penetration Testing Competition.” <https://www.tntech.edu/ceroc/outreach/cptc/> (accessed Jul. 27, 2020).
- [15] “ICCWS 2021: Sixteenth International Conference on Cyber Warfare and Security | ORNL.” <https://www.ornl.gov/event/iccws-2021-sixteenth-international-conference-cyber-warfare-and-security> (accessed Jul. 27, 2020).
- [16] “CEROC Cyber Range.” https://www.tntech.edu/ceroc/cyber_range/index.php (accessed Jul. 13, 2021).