



NATIONAL CENTER FOR TRANSPORTATION CYBERSECURITY AND RESILIENCY

A USDOT National University Transportation Center

Semi-Annual Progress Report

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Project Title: National Center for Transportation Cybersecurity and Resiliency (TraCR)

Center Director: Mashrur “Ronnie” Chowdhury, Ph.D., P.E., F.ASCE

Eugene Douglas Mays Chair of Transportation

Director, USDOT Center for Connected Multimodal Mobility (C²M²)

Clemson University, SC 29634

864-656-3313 (Phone), Email: mac@clemson.edu

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1. ACCOMPLISHMENTS:

1.1. What are the major goals and objectives of the program?

The “National Center for Transportation Cybersecurity and Resiliency,” or TraCR’s mission is to build an ironclad defense for the nation’s transportation systems against cyberattacks. The primary goal of TraCR is to address the vulnerabilities of today’s and tomorrow’s transportation cyber-physical-social systems (TCPSS) holistically. TraCR continuously monitors the fast-moving world of TCPSS cybersecurity, identifying challenges and threats as they appear across transportation modes, geographies, and applications.

TraCR’s foundational project is dedicated to developing a systems platform integrating hardware and software security to protect our nation’s transportation infrastructure (as presented in Figure 1). Once deployed, the TraCR systems platform will be used to conduct an in-depth vulnerability assessment of any transportation system or infrastructure, followed by the identification, development, and deployment of customized security and privacy solutions for that system or infrastructure. As threats evolve, and, over time, newer ones emerge, the methods and tools within the TraCR systems platform will be continuously updated with new defense strategies. The systems platform will thus serve as a reference architecture and design blueprint for the development of future secure and resilient transportation systems. TraCR also conducts research on the following four thrusts, the products and outcomes of which will support the development of the TraCR systems platform:

- Security and Resilience,
- User and Data Privacy,
- Society and Environment, and
- Evolving Quantum Computing Threats and Opportunities.

TraCR will support research projects starting January 2024 in the four thrust areas through a competitive funding program. The selected projects will span from fundamental research to creating ready-to-deploy and cost-effective products, procedures, and policies that are analyzed to ensure their benefits far

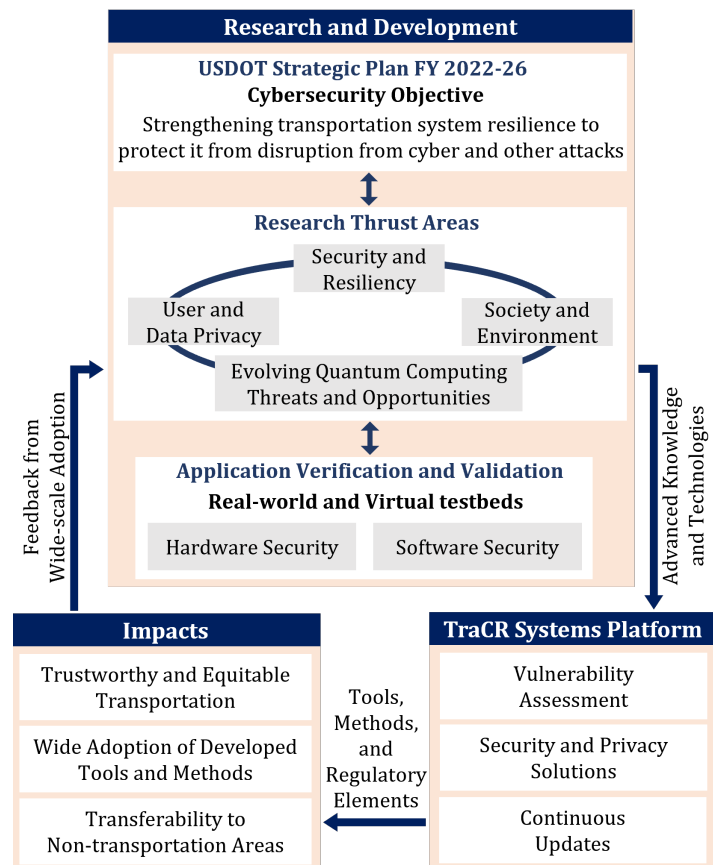


Figure 1. TraCR's Research Outlook and Impacts.



exceed their costs. Many of these will be tested at existing testbeds at our member institutions, piloted in the communities using TraCR members' proven technology transfer expertise.

TraCR's work will extend beyond hardware and software; we will also utilize the social sciences and other disciplines to address the policies, procedures, standards, social factors, legal aspects, and financing tools required to deploy cybersecurity tools in the public and private sectors. We will be just as committed to education, from elementary school through the doctoral level. In addition to offering courses, research opportunities, and mentoring programs at partner institutions, we will provide workforce training in other venues, such as two-year colleges. Utilizing the unique insights of our minority-serving institution partners (MSIs), we will reach out to those who might not otherwise participate in cybersecurity.

1.2. What was accomplished under these goals?

In the first three-month period of TraCR's existence, several administrative goals were accomplished, including:

- Establishment of a Board of Directors:
 - Dr. Mashrur "Ronnie" Chowdhury, Director, Clemson University, Clemson, SC
 - Dr. Gurcan Comert, Associate Director, Benedict College, Columbia, SC
 - Dr. M Hadi Amini, Associate Director, Florida International University, Miami, FL
 - Dr. Mansoureh Jeihani, Associate Director, Morgan State University, Baltimore, MD
 - Dr. Satish Ukkusuri, Associate Director, Purdue University, West Lafayette, IN
 - Dr. Judith Mwakalonge, Associate Director, South Carolina State University, Orangeburg, SC
 - Dr. Steven Jones, Associate Director, The University of Alabama at Tuscaloosa, Tuscaloosa, AL
 - Dr. Alvaro Cardenas, Associate Director, The University of California at Santa Cruz, Santa Cruz, CA
 - Dr. Bhavani Thuraisingham, Associate Director, The University of Texas at Dallas, Richardson, TX
- Formation of an Advisory Board made up of industry and academic members from the transportation community:
 - Dr. Kerry Buckley, MITRE Corp.
 - Cale Thorne, DMI Inc.
 - Dr. Richard S. Wilkins, Phoenix Technologies Inc.
 - Dr. Anuja Sonalker, STEER Tech.
 - Dr. Alireza Abbaspour, Qualcomm

More members will be added to the Advisory Board within the next reporting period.



- The Director and Associate Directors met with USDOT representatives in Washington, D.C., for a kick-off meeting for the center. (March 05, 2023)
- A bi-weekly recurring web meeting with the center's leadership (Board of Directors and administrative staff) to discuss TraCR's progress and upcoming activities has been set up, which started in August 2023.
- A bi-weekly recurring web meeting with the center's leadership (Board of Directors and administrative staff) and selected faculty and students has been set up, which started in October 2023, to discuss plans, task assignments, and progress related to TraCR's foundational project.
- Ms. Megha Patel was brought on board as the Senior Program Manager on July 24, 2023.
- Dr. Sabbir Salek was brought on board as a Senior Engineer/Tech Transfer Coordinator on August 25, 2023.
- A temporary office was set up for TraCR on Clemson University's main campus. The temporary office is in Lowry Hall on Clemson's main campus. The permanent TraCR office space is under construction at One Research Drive, Greenville, SC, with an expected move-in date of mid-November 2023.
- A call for research proposals for competitively funded projects was sent to the Associate Directors, which was disseminated to their respective institutions on August 15, 2023. A total of 15 research proposals were received by the September 29, 2023, deadline. The received proposals have been sent out to reviewers for a double-blind peer-review, and by mid-November 2023, we expect to make selections of the projects that will be supported through TraCR.

1.3. What opportunities for training and professional development has the program provided?

As part of our workforce development/training activities, TraCR hosts monthly webinars from experts in the transportation sector or from TraCR researchers. In September, we initiated our webinar series with an inaugural webinar from Ms. Tracy Hockstad from the University of Alabama, who discussed our collaborative work and analysis on bridging the communication gap between transportation experts, stakeholders, and state/federal legislators. Our second webinar featured Dr. Feng Luo and his work on deep learning for science and engineering. Recordings of both webinars are available on our YouTube channel. (<https://www.youtube.com/@TraCR-UTC>)

1.4. How have the results been disseminated? If so, in what way/s?



So far, TraCR researchers have published one journal article, one conference paper, and several other papers have been accepted for conference presentations.

In collaboration with the Center for Connected Multimodal Mobility (C²M²), TraCR's students attended the IEEE Fusion conference in Charleston, SC, from June 27th - 30th, 2023. They presented their research paper titled "Hybrid quantum-classical neural network for incident detection." Additionally, they demonstrated virtual traffic light and adversarial attack applications at the conference.

TraCR's senior engineer, Dr. M Sabbir Salek, attended the Professional Engineers of North Carolina (PENC) conference in Charlotte, NC, from June 1st – 3rd, 2023. Dr. Salek and Dr. Chowdhury were invited as speakers to one of the breakout sessions at the conference to present C²M² and TraCR researchers' work on cybersecurity and resiliency for connected and autonomous vehicles.

In collaboration with the Center for Connected Multimodal Mobility (C²M²), TraCR hosted a technology demonstration for a group of Hickory Tavern Middle School (Gray Court, SC) students on September 6, 2023. The day started with a presentation from Dr. Ronnie Chowdhury, TraCR and C²M² Director, introducing students to TCPSS and self-driving cars. The students learned about the following applications:

- Hybrid classical-quantum deep learning models to detect adversarial attacks that affect the performance of the traffic sign classification module of autonomous vehicles,
- Virtual traffic signal control using quantum computer-based traffic signal timing optimization, and
- Distributed machine learning models for environmental emission detection with unmanned aerial vehicles.

The students also gained autonomous vehicle user experience through a virtual reality (V.R.) demonstration.

1.5. What do you plan to do during the next reporting period to accomplish the goals and objectives?

- The TraCR board of directors will meet between early- and mid-November to discuss the research proposals and reviews from external reviewers to decide which competitive projects to support during the current fiscal year. The funding recipients will be notified shortly after the meeting. Selected research proposals will be funded through TraCR to begin research activities in January 2024.
- A comprehensive review of existing studies, technologies, pilot deployments, standards,



policies, and guidelines will be reviewed by the TraCR foundational research committee members that will help set up a concrete plan for developing the TraCR systems platform.

- Dr. Ronnie Chowdhury (Center Director), Dr. Sabbir Salek (Senior Engineer/Tech Transfer Coordinator), and Ms. Megha Patel (Senior Program Manager) will attend the Transportation Research Board (TRB) Annual Meeting in Washington, D.C. (January 7th-11th, 2024).
- We will set up several committees for each of our goals. These committees are listed below. We have already started identifying who will lead and be members of these committees.
 - Research Committee,
 - Education Committee,
 - Technology Transfer Committee,
 - MSI Advance Program and Diversity and Inclusions Committee, and
 - Workforce Development Committee.
- TraCR's affiliates will continue their Scholar and Distinguished Speaker webinar series. They will sponsor notable transportation researchers whose talks will be available via webinars and announced on our social media platforms. Currently, we have scheduled the following speakers.
 - Dr. Gurcan Comert of Benedict College, South Carolina, will present on Simple Analytical Models For Estimating the Queue Lengths from Probe Vehicles at Traffic Signals II: A Combinatorial Approach for Nonparametric Models, on October 26, 2023.
 - Dr. Bhavani Thuraisingham, from the University of Texas at Dallas, is scheduled to speak in November 2023 (date to be decided)
- TraCR plans to organize a hands-on workshop on quantum computing for undergraduate students at the Men of Color National Summit (2024). In addition, TraCR's Director, Dr. Ronnie Chowdhury, along with the Associate Directors Dr. Judith Mwakalonge and Dr. Gurcan Comert, plans to host a session on career and professional development titled "Opportunities for Careers and Capacity Building Resources in the Emerging Quantum Information Science" at the Men of Color National Summit (2024).

2. PARTICIPANTS & COLLABORATING ORGANIZATIONS:

TraCR is a diverse, experienced, and geographically distributed consortium of nine partners. The nine partner institutions are Clemson University (C.U.) as the Lead, Benedict College (B.C.), Florida International University (FIU), Morgan State University (MSU), Purdue University (P.U.),



South Carolina State University (SCSU), the University of Alabama at Tuscaloosa (U.A.), the University of California at Santa Cruz (UCSC), and the University of Texas at Dallas (UTD).

TraCR has initiated collaboration with the South Carolina Department of Transportation (SCDOT). We have established collaboration with the South Carolina Research Authority (SCRA), a public, non-profit corporation chartered in South Carolina that focuses on enabling research and development that fuels South Carolina's economy. In addition, we have collaborated with Innova E.V., an electric vehicle company, to work on pilot deployments of connected vehicle technologies at C.U., developed by the C²M² and TraCR researchers. We have also partnered with the International Alliance for Mobility Testing and Standardization (IAMTS).

TraCR's Associate Director, Dr. Hadi Amini from FIU, attended the Florida Automated Vehicles Summit (<https://favsummit.com/>) that brought together stakeholders from the transportation industry and government to discuss the pressing issues related to autonomous vehicles and ITS technologies. This productive event helped us identify potential opportunities to work with other parties. We have scheduled introductory meetings with some of them (including a representative from SUNTRAX Test Facility - <https://suntraxfl.com>) and will include more details about materialized collaborations in our upcoming reports.

The University of Alabama at Tuscaloosa has an existing collaboration with Hexagon/NovAtel Inc. Hexagon is a global leader in digital reality solutions, combining sensor, software, and autonomous technologies. NovAtel, part of Hexagon, is a global technology leader pioneering end-to-end solutions for assured autonomy and positioning on land, sea, and air. This ongoing collaboration between the University of Alabama at Tuscaloosa and NovAtel will be helpful for TraCR's research on GNSS-based cyber-resilient navigation for autonomous systems.

3. OUTPUTS:

3.1. Publications, conference papers, and presentations

Publications

1. Moore, E., Imteaj, A., Rezapour, S., and Hadi Amini, M. A Survey on Secure and Private Federated Learning Using Blockchain: Theory and Application in Resource-constrained Computing, IEEE Internet of Things Journal, 2023, in press.
2. Shakib, K.H., Rahman, M., Islam, M., and Chowdhury, M. Quantum Shor's Algorithm-based Impersonation Attack on Blockchain-based Vehicular Ad-hoc Network, Special Issue on Cybersecurity and Resiliency for Transportation Cyber-Physical System, ACM Journal on Autonomous Transportation Systems (JATS), Under Review.

Presentations

1. Hockstad, T., Rahman, M., Jones, S., Chowdhury, M. A Regulatory Gap Analysis in



- Transportation Cybersecurity and Data Privacy. Accepted for presentation in the 103rd Annual Meeting of the Transportation Research Board, Washington, D.C., January 2024.
2. Dasgupta, S., Hassan Shakib, K., Rahman, M. Experimental Validation of Sensor Fusion-based GNSS Spoofing Attack Detection Framework for Autonomous Vehicles. Accepted for presentation in the 103rd Annual Meeting of the Transportation Research Board, Washington, D.C., January 2024.
 3. Hassan Shakib, K., Kiesewetter, L., Rahman, M., Shah, K. Examining Safety and Cybersecurity for Urban Air Mobility Operations. Accepted for presentation in the 103rd Annual Meeting of the Transportation Research Board, Washington, D.C., January 2024.
 4. Dasgupta, S., Ahmed, A., Rahman, M. Unveiling the Stealthy Threat: Analyzing Slow Drift GPS Spoofing Attacks for Autonomous Vehicles in Urban Environments and Enabling the Resilience. Accepted for presentation in the 103rd Annual Meeting of the Transportation Research Board, Washington, D.C., January 2024.
 5. Ameen Noman, S., Atkison, T., Sami Irfan, M., Rahman, M. A Predictive Approach for Sybil attack Detection for a Waiting Time-Based Adaptive Traffic Signal Controller. Accepted for presentation in the 103rd Annual Meeting of the Transportation Research Board, Washington, D.C., January 2024.
 6. Xue, J., Ukkusuri, S. Generating Network-Level Dynamic Traffic Equations Using Symbolic Regression. Accepted for presentation in the 103rd Annual Meeting of the Transportation Research Board, Washington, D.C., January 2024.
 7. Salek, M.S., Mamun, A.A., Chowdhury, M. AR-GAN: Generative Adversarial Network-Based Defense Method Against Adversarial Attacks on the Traffic Sign Classification System of Autonomous Vehicles. Accepted for presentation in the 103rd Annual Meeting of the Transportation Research Board, Washington, D.C., January 2024.

3.2. Website(s) or other Internet site(s)

- The official website of TraCR is available at <https://www.clemson.edu/cecas/tracr/>. The website was launched in October 2023 and details the center's activities. The Research tab on the website provides details about the various thrusts for the center, while all Request for Proposals (RFPs) for competitive funding every year will also be posted here. We have already posted the first RFP on the TraCR website. Highlights from our outreach activities targeted towards under-represented students will be posted under the Diversity Initiatives tab. In the coming months, we will add more content to the website, including the data management plan, all center reports, and final reports from competitive projects selected every year.
- The Twitter/X page for TraCR was launched in September 2023 and is available at https://twitter.com/TraCR_UTC. This social media page aims to provide updates related to the center's activities – including announcements for webinars and the latest news from the center – to those in the broader transportation community.
- The YouTube channel for TraCR is available at <https://www.youtube.com/@TraCR-UTC>.



We will continue to share recordings of all TraCR Scholar Webinar series on the channel. We have uploaded our first two webinars and expect to add more soon. We will also share all videos related to the center through this YouTube channel.

- The LinkedIn page for TraCR is available at <http://www.linkedin.com/company/tracr-usdot-utc>. The LinkedIn page serves as a place to reach out to the professional community with the latest on TraCR's activities. This will also be the portal where we post all job openings related to TraCR to reach a wide range of potential applicants.

3.3. Technologies or techniques

Nothing to report yet.

3.4. Inventions, patent applications, and/or licenses

Nothing to report yet.

4. OUTCOMES:

As indicated by the increasing number and severity of cyberattacks on critical infrastructure systems, cybercrime poses a devastating threat to the transportation sector. In response to this recognition, our research assessed gaps in U.S. cybersecurity regulations related to transportation law and policy and revealed significant current shortcomings. Federal regulations are mostly sector-specific and focused on financial, medical, and other related industries, having a limited impact on transportation. State legislation appears better suited to address industry needs but still exhibits uneven attention to critical areas, as evidenced by varying legislative passage rates and a limited scope of action among states. This unequal focus leaves some states behind, and major transportation concerns, such as third-party vendor liability, cybersecurity tools, and supply chain risk management, are overlooked. Despite some enacted bills addressing workforce, ransomware, and cybersecurity-related privacy issues, low passage rates compared to the total number of bills proposed signal an urgent issue. A pressing need exists for further research to understand why vital industry concerns receive insufficient attention. Bridging the communication gap between transportation experts, stakeholders, and state/federal legislators is paramount. Our analysis identifies specific points of breakdown in this communication gap and provides two recommendations to remedy existing industry needs and vulnerabilities. Firstly, we recommend the establishment of a national entity led by the American Association of State Highway and Transportation Officials (AASHTO), which would develop comprehensive national policies and standards for transportation cybersecurity and privacy. Secondly, implementing a nationwide mandatory testing and certification process for multimodal transportation systems, including hardware and software, is necessary. These actions are essential to prioritize cybersecurity in the ever-evolving landscape of computerized transportation systems and the growing threats, which range from individual hackers to criminal gangs to hostile states, ensuring the industry's safety and resilience.



5. IMPACTS:

Although TraCR was established only three months before the end of this reporting period, we expect to see a significant impact in the near future with the initiation of the first round of TraCR-supported research projects.

5.1. What is the impact on the effectiveness of the transportation system?

With the current scope of research, we expect to see overarching impacts on the security and resiliency of transportation systems, the privacy of transportation systems' users and data, the society and environment, and the evolving threats and opportunities of quantum computing for transportation systems. Supported by our research on these areas, TraCR's foundational project (i.e., systems platform) is expected to impact the nation's transportation infrastructure through cost-effective and ready-to-deploy security tools and methods, standards and certifications, policy, and wide adoption guidelines. We also expect to see an impact on the diversity of up-and-coming engineering students directly related to its outreach activities to minority students from underserved communities and partnership with our various MSIs.

5.2. What is the impact on the adoption of new practices, or instances where research outcomes have led to the initiation of a start-up company?

Nothing to report yet.

5.3. What is the impact on the body of scientific knowledge?

Nothing to report yet.

6. CHANGES/PROBLEMS

6.1. Changes in approach and reasons for change

Nothing to report.

6.2. Actual or anticipated problems or delays and actions or plans to resolve them

Nothing to report.

6.3. Changes that have a significant impact on expenditures

Nothing to report.



6.4. Significant changes in use or care of human subjects, vertebrate animals, and/or biohazards

Nothing to report.

6.5. Change of primary performance site location from that originally proposed

Not applicable.

7. SPECIAL REPORTING REQUIREMENTS

None.