CARNATIONS

Center for Assured & Resilient Navigation in Advanced Transportation Systems

ILLINOIS INSTITUTE OF TECHNOLOGY · CHICAGO STATE UNIVERSITY · UC RIVERSIDE · Stanford · VIRGINIA TECH

USDOT Tier 1 University Transportation Center
Semi-Annual Progress Report – No. 1

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Center Director:	Boris Pervan, Ph.D. | pervan@iit.edu | (630) 853-6689 Professor of Mechanical and Aerospace Engineering Illinois Institute of Technology
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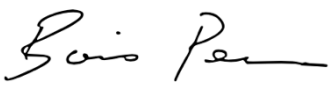
Signature:	

1 ACCOMPLISHMENTS

1.1 What are the major goals of the program?

The Center for Assured and Resilient Navigation in Advanced TransportatION Systems (CARNATIONS) is a Tier-1 University Transportation Center (UTC) created to address the USDOT's research priority area of *Reducing Transportation Cybersecurity Risks.* CARNATIONS is specifically focused on Resilient Positioning, Navigation, and Timing (R-PNT) and resilient vehicle-to-everything (V2X) PNT-relevant communications in multimodal transportation. The Center will benefit existing and emerging transportation systems by addressing PNT's evolving vulnerabilities. Our education and workforce development programs will support underserved communities. We will collaborate with stakeholders to develop demonstrable R-PNT performance metrics, rigorous standards, and open evaluation methods to enable seamless technology transfer.

1.1.1 Research

CARNATIONS will perform transformative research, fundamental and applied, to develop and deploy the technology that will enable PNT and transportation infrastructure to withstand cyber-physical disruption and manipulation.

1.1.2 Leadership

CARNATIONS will become the world's premier source for R-PNT research, education and workforce development.

1.1.3 Education and Workforce Development

CARNATIONS will train a diverse body of students, with stakeholder engagement, to advance R-PNT knowledge and tools pertaining to future transportation systems.

1.1.4 Technology Transfer and Collaboration

CARNATIONS will engage public agencies and industry with innovative design and testing of R-PNT solutions, and by developing standards and best practices.

1.2 What was accomplished under these goals?[1]

1.2.1 Research

Research Performance Metrics	Since last report
Number of new technologies, procedures/policies, and standards/design practices influenced by the research and adopted by organizations.	1

[1] *This is CARNATIONS first reporting period, and only Illinois Tech was under contract until September 2023. Therefore, in this report, except for the number of leadership positions listed in 1.2.2, only Illinois Tech's accomplishments are provided. Future reports will share the accomplishments of all of the Center's member institutions.*

Number of research projects funded by sources other than UTC and matching fund sources.	2[2]
Number of research articles presented in conferences and published in peer-reviewed journals.	3[3]

1.2.2 Leadership

Leadership Performance Metrics	Since last report
Number of keynote speeches/invited presentations at academic and professional conferences.	0
Number of leadership positions in local, national and international organizations.	11
Number of CARNATIONS-affiliated students in scholar and professional leadership positions.	0

1.2.3 Education and Workforce Development

Education/Workforce Development Performance Metrics	Since last report
Student enrollment numbers and grades in CARNATIONS courses.	0
Number of participants logging in simulated "war-games," and student participation scores.	0
Program score on students' course evaluation surveys, and as evaluated by the Advisory Board.	n/a[4]

1.2.4 Technology Transfer and Collaboration

Technology Transfer and Collaboration Performance Metrics	Since last report
Number of CARNATIONS research efforts successfully transferred to partners and stakeholders.	0
Number of new collaborative efforts between institutions formed as a result of CARNATIONS.	9
Number of CARNATIONS-affiliated attendees at the annual meeting.	23
Number of CARNATIONS-related students joining partners or collaborators.	0
Estimated number of transportation professionals reached by "Don't mess my GPS".	0

[2] The research was jointly supported by the Federal Aviation Administration.
[3] One of these is a journal article that has been accepted but not yet published. See Section 3.1.
[4] No courses have been taught yet.

1.3 How have the results been disseminated?

We presented two conference papers at the Institute of Navigations ION GNSS+ Conference in Denver, CO in September 2023. The papers were published in the conference proceedings.

1.4 What do you plan to do during the next reporting period to accomplish the goals?

As of October 2023, all CARNATIONS member universities except Stanford are under contract. Stanford's subcontract from Illinois Tech is in the final stages. We expect to be fully active on all research projects by the first week of November.

In September 2023, we had our first meeting with the CARNATIONS External Advisory Board (CAB). In the next reporting period we will create three CAB subcommittees, each co-chaired by a CAB member and a CARNATIONS PI, to collaboratively plan paths forward on future research, education and workforce development, and technology transfer.

In October 2023, the CARNATIONS Executive Committee (CEC) held its first meeting. Two members, Freeman (Director of Education and Workforce Development) and Ayyash (Director of Diversity, Equity and Inclusion) agreed to develop preliminary plans for the CARNATIONS education program and to report back to the CEC in November 2023. Our goal is to have a CEC-endorsed plan in place by early 2024 and then take the necessary steps to initiate our program in the Fall of 2024.

2 PARTICPANTS & COLLABORATING ORGANIZATIONS

2.1 What organizations have been involved as partners?

Illinois Tech (Boris Pervan, Samer Khanafseh, Matthew Spenko)
Virginia Tech (Mathieu Joerger, Mark Psiaki, Hesham Rakha, Walid Saad)
UC—Riverside (Jay Farrell, Matthew Barth)
Chicago State (Mousa Ayyash)
Stanford (Todd Walter, Sherman Lo, Sam Pullen, Juan Blanch)

2.2 Have other collaborators or contacts been involved?

Yes, the following table lists the CARNATIONS Advisory Board and External Stakeholders attending our CAB Kick-off meeting in Denver in September 2023.

CAB Members in Attendance		
NovAtel (Hexagon)	Sandy Kennedy	in person
Spirent	Jeremy Bennington Chris Coromelas	in person
Qualcomm	Guttorm Opshaug	virtual
UrsaNav	Charles Schue	in person

Satelles	Michael O'Connor	in person
Xona	Tyler Reid Kurt Zimmerman	in person
Bosch	Boubeker Belabbas	in person
IS4S	John Raquet	in person
The Aerospace Corporation	Steven Lewis	in person
The Mitre Corporation	Chris Hegarty Steven Langel	in person
The Port of Virginia	Mark Higgins	virtual
SAE International	Tim Weisenberger	virtual
External Members in Attendance		
Volpe	Andrew Hansen Hadi Wassaf	in person
US DOT	Karen Van Dyke James Aviles	in person
Sierra Space	Ali Hassani	in person
German Aerospace Center	Michael Meurer	in person
Seoul National University	Changdon Kee	in person
Illinois Institute of Technology	Seebany Datta-Barua	in person

3 OUTPUTS

3.1 Publications, conference, and presentations

Conference papers

Ahmed, S., Khanafseh, S., and Pervan, B., "GNSS Spoofing Detection and Exclusion by Decomposition of the Complex Cross Ambiguity Function with INS Aiding," *Proceedings of ION GNSS+ 2023*, Denver, CO, September 2023. Federal support acknowledged.

Bednarz, L., Khanafseh, S., and Pervan, B., "Improving Tracking Robustness Through Interference Using Pilot Signals with a Deeply Coupled Estimator," *Proceedings of ION GNSS+ 2023*, Denver, CO, September 2023. Federal support acknowledged.

Journal Papers

Kujur, B., Khanafseh, S., and Pervan, B., "Optimal INS Monitor for GNSS Spoofer Tracking Error Detection," *NAVIGATION*, accepted but not yet published. Federal support acknowledged.

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

https://www.iitcarnations.org/: This is the CARNATIONS website built following USDOT UTC requirements.

3.3 Technologies or techniques

Nothing to report.

3.4 Inventions, patent applications, and/or licenses

Nothing to report.

4 OUTCOMES

As this is our first reporting period, and the outputs are less than two months old, we have nothing to report regarding:

- new policies, regulation, rulemaking, or legislation,
- enlargement of the pool of transportation professionals, or
- adoption of new technologies, techniques or practices.

However, our publications (in 3.1 above) and corresponding conference presentations have produced direct outcomes in:

- increasing understanding and awareness of transportation issues,
- increases in the body of knowledge, and
- improved processes, technologies, techniques and skills in addressing transportation issues.

5 IMPACTS

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

Our first meeting with the CARNATIONS Advisory Board (CAB) helped increase awareness of the current and future challenges in achieving truly Resilient PNT in the transportation system. It also provided an opportunity for the CAB to better understand and weigh in on our current R-PNT research projects.

5.2 What is the impact of technology transfer on industry and government entities, on the adoption of new practices, or on research outcome which have led to initiating a start-up company?

We are early in our work, so haven't had any measurable impacts in these areas yet, but we have received important feedback from the CAB to emphasize the following:

- Encourage adoption of open standards with research projects.
- Pursue joint efforts for standardization, e.g., harmonized threat models which can be brought to international groups both from the EU & US sides.
- Integrated LEO/GNSS spoofing detection and mitigation at the observable level (pseudorange/Doppler). Practical/experimental/demonstrations (not simulation)
- Bring PNT technology from offline testing to real-time prototype operation at TRL 6-7.
- Work with DOT to demonstrate effectiveness in non-nominal and challenged conditions for red-team/blue-team operations

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

During the reporting period we presented and published a paper (Ahmed, et al.) describing a new method using advanced signal processing technique to detect and exclude counterfeit GNSS signals. We also presented and published a conference paper (Bednarz, et al.) describing new method to track GNSS pilot signals through broadband interference. A third paper (Kujur, et al.) on using inertial sensors to detect GNSS spoofing was accepted for publication in NAVIGATION (Journal of the Institute of Navigation). We except it will be published in the next reporting period.

5.4 What is the impact on transportation workforce development?

We are early in our work, so haven't had any measurable impacts in these areas yet, but we have received important feedback from the CAB to emphasize the following:

- MS and PhDs, especially in Navigation
- Internships and post-graduation employment
- Certificate programs and credentials
- Joint Center-industry workshops and employer-run seminars and presentations
- Industry motivated capstone projects

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

Nothing to report.

7 SPECIAL REPORTING REQUIREMENTS

Nothing to Report.