PROGRAM PROGRESS PERFORMANCE REPORT

Awarding Federal Agency: US Department of Transportation, Office of the Assistant Secretary for Research and Technology of the Department of Transportation (OST-R)

Federal Grant Number: DTRT13-G-UTC28

Project Title: Center for Advanced Infrastructure and Transportation (CAIT) National UTC Consortium Led by Rutgers, The State University of New Jersey

Center Director Name, Dr. Ali Maher, CAIT Director. **E-mail address:** mmaher@soe.rutgers.edu **Phone number:** 848-445-2951

Name of Submitting Official, Title, and Contact Information (e-mail address and phone number), if other than PD: Dr. Patrick Szary, CAIT Associate Director. **E-mail address:** szary@soe.rutgers.edu **Phone number:** 848-445-2999

Recipient Organization (Name and Address): Rutgers, The State University of New Jersey, Center for Advanced Infrastructure and Transportation, 100 Brett Road, Piscataway, NJ 08854-8058

DUNS Number: 001912864000

EIN Number: 1226001086A1

Recipient Identifying Number or Account Number, if any: Rutgers' account #436362

Project/Grant Period: September 30, 2013 through September 30, 2018

Reporting Period End Date: September 30, 2017

Report Term or Frequency: Semiannual

Submission Date: October 30, 2017

Signature of Submitting Official:

1. ACCOMPLISHMENTS: What was done? What was learned?

What are the major goals of the program?

The major goal of the CAIT National UTC Consortium is to build a program that will: 1) have a sharp focus on maintaining state of good repair of the nation's infrastructure and the interrelated activities of the Secretary of Transportation's strategic goals where the consortium can make significant impacts, and 2) foster intelligent, effective, and meaningful leveraging between institutions and stakeholders to achieve program goals and objectives.

State of Good Repair (SGR) has been identified as the consortium's **primary area of research** and Safety & Economic Competitiveness as secondary areas in which we believe our team's capabilities, resources, past experience, and track record qualify us to make significant impacts toward reaching the goals of the USDOT. To help fulfill these goals and objectives we will:

- **Sharply focus our research portfolio** to make significant and meaningful impacts during the lifetime of the grant. The UTC designation will be a catalyst for generating relevant and sustainable operations that can aid USDOT in fulfilling the objectives of its strategic plan.
- **Develop effective leveraging** with centers of critical mass and establish networks of researchers, laboratories, test-beds, proving grounds, and all other resources necessary to address the objectives of the strategic plan. Through intelligent leveraging, we will minimize potential duplication of effort and promote and encourage meaningful team work and collaboration.
- **Develop and enhance meaningful relationships with local, regional, national, and international stakeholders** to stay abreast of new problems and best practices; work together to address local challenges and needs; and partner in implementing research results and products.

The consortium will cultivate interest in the transportation industry through a comprehensive **education and workforce development program**. The education and workforce goals are to:

- Develop an educational program that will prepare current and future transportation professionals and researchers to be responsive to changes in the transportation field.
- Develop a strong multidisciplinary component that reflects changes in the organizational, intermodal, and global character of transportation, as well as the use of advanced materials and technologies relative to infrastructure.
- Develop educational activities with a focus on K-12 to foster an initial interest in transportation and create opportunities for the students to continue onto other programs, thereby sustaining awareness in transportation careers beyond the initial exposure.

The consortium supports knowledge sharing and is committed to move research results into practice through its **technology transfer initiatives**. The technology transfer goals are to:

- Ensure all research proposals include feasible implementation plans.
- Provide a forum to discuss the state of practice and innovative new technologies that support State of Good Repair, through conferences and symposiums.
- Continuously post reports and research findings in multiple online repositories and clearinghouses, such as the USDOT Research Clusters and CAIT website.

What was accomplished under these goals?

Major Goal Area	Major Activities	Specific Objectives	Significant Results	Key Outcomes
Research	Research Selection	Select projects that make significant and meaningful impacts during the lifetime of the grant	Several new projects have cleared the pre-proposal stage and are now being developed by the PI for full submission and review.	No new projects were selected during this cycle.
	Targeted Hits for Modal Parameter Estimation (THMPER™)	This portable bridge evaluation tool that provides faster, cheaper, and less disruptive than conventional methods was created by Dr. Franklin Moon and his research team. THMPER™ could revolutionize how America's 600,000 plus bridges are regularly assessed, rated, and prioritized for repair or replacement. THMPER™'s rapid testing is groundbreaking because it uses three advanced load-capacity estimating methods: modal impact testing, refined analysis and calibration of finite element models, In addition, it is portable, performs the whole operation on site and provides, in just one day, accurate results about how much load a bridge can safely carry. ASCE recognized the value and ingenuity of THMPER™ by awarding it the 2016 Charles Pankow Award for Innovation.		To date, THMPER™ has been used to assess more than 30 bridges in Delaware, Maryland, New Jersey, Pennsylvania, Oregon, and Washington under pilot programs with federal, state, and local transportation agencies.
	Development of accelerated infrastructure testing facility: Bridge Evaluation Accelerated System Testing (BEAST)	Supported by funding from NJDOT, FHWA, and Rutgers, CAIT construct a brand new facility that will create knowledge through UTC research projects and can validate existing research through and facility that will test the effects of heavy loads, extreme temperatures, and active weather on a full-scale concrete bridge deck. To reliably accomplish this, CAIT and its DOT and university partners are constructing the first full-scale accelerated infrastructure testing facility for the evaluation of new and advanced materials and devices: the Bridge Evaluation Using Accelerated System Testing (BEAST) facility. The facility will finally resolve unknown questions about the longevity and performance of preservation treatments and materials exposed to decades of heavy traffic loads and extreme weather patterns. The construction of the facility was completed in May 2015.		BEAST will provide new and valuable information about the longevity and effectiveness of preservation treatments and concrete materials used across the United States. The study will also provide answers about the long-term effects of weight, weather, and temperature variations on bridges in a short period of time.
	Utilization of Pneumatic Flow Tube Mixing	Supported by funding from NJDOT and leveraging our investments in sediment research, this project is going to		The ultimate aim of the project is to determine if

	Technique (PFTM) for Processing and Stabilization of Contaminated Soft Sediments in the NY/NJ Harbor	demonstrate the viability of the Pneumatic Flow Tube Mixing (PFTM) method for the processing and handling of contaminated navigational dredged materials from the NY/NJ harbor complex. The Center for Advanced Infrastructure and Transportation (CAIT) will implement a pilot project at the Koppers Seaboard site, New Jersey. Rutgers Soil and Sediment Management Laboratory in collaboration with international partners will test the raw and amended DM throughout the entire process to initially determine the optimum design of the mix and subsequently monitor the produced amended DM to document the results and quality control parameters. The entire process will be managed by Rutgers CAIT.	Pneumatic Flow Tube Mixing more efficiently achieves structural and environmental properties for amended dredged material while decreasing cost per cubic yard for dredged material amendment and placement than existing methods.

HIGHLIGHTS

Rutgers Naviator Conducts First Combination Aerial and Underwater Bridge Inspection

Rutgers' Naviator, a unique autonomous device that can both fly and maneuver underwater, conducted the first combination aerial and underwater bridge inspection of the Delaware Memorial Bridge Twin Spans on June 18. CAIT has been assisting with development of the Naviator for more than a year, providing piloting and logistics support. The Naviator was created at Rutgers School of Engineering (SOE) by mechanical and aerospace engineering professor Dr. F. Javier Diez and his team, who launched the first prototype in 2013 after receiving a grant contract from the Office of Naval Research (ONR).
The bridge inspection test flight was a cooperative venture of the Delaware River and Bay Authority (DRBA), Rutgers SOE, CAIT, and SubUAS LLC.

Photos ©Rutgers/DRBA/SubUAS, LLC

CAIT assistant research engineer Michael O'Connell was the pilot in command and Marco Maia was at the controls. Additional support for the inspection was provided by numerous DRBA bridge and ferry employees and Rutgers Center for Ocean Observing Leadership.

The original ONR project conceived Naviator as a tool for surveillance of ports or other homeland security targets, especially during emergencies when other safety systems may be compromised. Now, in addition to bridge inspections and keeping an eye on high-priority transportation assets, applications that already have been identified for Naviator include mapping of the ocean floor, search and rescue operations, humanitarian missions, and evaluation of environmental incidents like oil spills and algae blooms.

Civil and Environmental Engineering Emerging Technology and Research Symposium

CAIT was a major contributor at the Emerging Technologies in Civil and Environmental Engineering Symposium hosted by the Rutgers Department of Civil and Environmental Engineering (CEE) to showcase important Rutgers-developed technologies and products. The Emerging Technologies symposium held in May was a three-way dialogue between agencies' top management, industry leaders, and the academic community about the future of transportation, its current needs and challenges. Discussion panels comprised several highly respected industry leaders: Anthony Bartolomeo (president and CEO, Pennoni), Michael Cobelli (president and CEO, Skanska USA Civil), Robert Fischer (chief engineer, NJ Turnpike Authority) David Lambert (assistant commissioner, NJDOT), Patrick Natale (VP, Mott MacDonald), Edward Schmeltz (senior VP, AECOM), James Starace (chief engineer, Port Authority of New York and New Jersey), Gardner Tabon (chief safety officer, NJ Transit), Andrew J. Ciancia (principal and COB, Langan), Stephen Dilts (NJ office leader, HNTB), Scott Douglas (dredging program manager, NJDOT), Mitchell Erickson (science Advisor, DHS/FEMA), Daniel Kennedy (assistant commissioner, NJDEP), C. William Kingsland (assistant commissioner, NJDOT), and John Scheri (senior VP, Mott MacDonald) and Bob Prieto (chairman and CEO, Strategic Program Management).

This event gave researchers the opportunity to present concrete evidence of the practical, applicable benefits of research and the product it bears. Unique projects and creations shared by CAIT include BEAST™ accelerated bridge testing lab, RABIT™ robotic bridge-deck inspection tool, Targeted Hits For Modal Parameter Estimation and Rating (THMPER™) and a relatively new lab led by Dr. Gong, the Advanced Construction Technology (ACT) which is using spatial sensing and large spatial data sets for mapping and virtual reality visualization in civil engineering.

The Emerging Technologies symposium galvanized both researchers and business to champion change in the transportation industry. The plan is to gather again in two years, but it opened pathways for immediate and ongoing discussion between thought leaders in all three realms: industry, agency and academic.

Day of Resiliency Symposium

CAIT was well represented in the 1st Annual - Day of Resiliency Symposium: "Keeping NJ shorelines safe" hosted by the Flood Alert Resiliency Team in the Department of Civil & Environmental Engineering in the Henry M. Rowan College of Engineering at Rowan University in June, 2017. As a designated USDOT Beyond Traffic Innovation Center for the Northeastern Megaregion tasked with identifying transportation and infrastructure vulnerabilities and taking actions to address them over the next 30 years, CAIT was very interested in participating in this gathering with scientists, researchers and land use planners who are invested in improving resiliency of the environment, infrastructure, and transportation in the State of New jersey with a focus on coastal communities. Indications are that extreme weather and natural disasters are becoming more frequent and more intense. For example, only weeks before the five-year anniversary of Hurricane Sandy, the 2012 superstorm that devastated our region, two category 4 storms (Harvey and Irma) made history by making landfall in the United States within one year. Refineries and the Houston shipping channel shut down due to the catastrophic flooding caused by

Harvey. In Florida, Irma was responsible for knocking out electricity to at least 6 million residents and for the destruction of 80 to 90 percent of the crops, per some reports. Harvey's economic impact are conservatively estimated to be $130 billion and close to $100 billion for Irma, without taking into account regional impacts such as stalled businesses, layoffs, degraded environments, negative health effects and ruined lives. Infrastructure is threatened in all these events; thus how to prepare better and recover faster is essential. To that end, CAIT and its partners are developing and deploying more advanced technologies for evaluating and monitoring the health of our assets; collecting and analyzing data that is crucial for understanding everything from concrete deterioration to human safety factors, and improving materials and engineering methods that extend the life of existing structures and make new construction stand stronger and last longer.

T-Rex Visits CAIT

The Natural Hazards Engineering Research Infrastructure program at the University of Texas at Austin (NHERI@UTexas) brought T-Rex to Rutgers for a two-day structural testing workshop it cohosted with CAIT as part of an NSF project that is examining dynamic soil interaction as it pertains to our entire built environment. This unique piece of equipment is a high-force triaxial shaker used to simulate earthquakes and to do structural forced-vibration testing. The workshop highlighted a potential use of NHERI@UTexas equipment for non-destructive, in-situ testing of soil-foundation-structure systems. During the workshop, T-Rex was used to generate small-strain dynamic loading on the bridge deck. Data collected from this demonstration was provided to the participants and other researchers for use in development of future studies. CAIT is grateful to the whole NHERI@UTexas team and the New Jersey Department of Transportation for identifying a bridge and for facilitating the day's field testing.

©Drew Noel Photography for Rutgers CAIT

UTC Spotlight Newsletter

In its September 2017 Spotlight newsletter, the University Transportation Centers Program, an initiative of the USDOT Office of the Assistant Secretary for Research and Technology, featured the Targeted Hits for Modal Parameter Estimation and Rating (THMPER™), device created by Drs. Franklin Moon, and fellows Ph.D.s John DeVitis, David Masceri, and Emin Aktan. CAIT is spreading the use of this new portable bridge evaluation technology that could revolutionize how America's 600,000 plus bridges are regularly assessed, rated, and prioritized for repair or replacement. Full text can be accessed at https://www.transportation.gov/sites/dot.gov/files/docs/utc/285131/utcnewsletter114september.pdf

Rising Star

CAIT research associate Dr. Mohammad Jalayer's hard work and engagement in professional activities and organizations are getting him noticed. One recent example: he received the Institute of Transportation Engineers (ITE) Rising Star Program Award at the Joint ITE/CITE 2017 Annual Meeting and Exhibit, held July 30–August 2 in Toronto, Ontario. ITE is an international community of transportation professionals comprising more than 14,000 engineers, planners, consultants, educators, researchers, and technologists from more than 90 countries. The Rising Stars Program identifies young people who show promise as "next generation" leaders in transportation. It is designed to recognize members under the age of 35 who have already made an impact, demonstrated leadership, and have implemented innovative techniques to solve transportation problems. Each annual Rising Stars Class consists of representatives from ITE's 10 U.S. districts. In 2016, Jalayer was the first-place winner of the National Highway Safety Information System (HSIS) Research Paper competition, which is jointly administrated by the Federal Highway Administration and ITE. He is currently co-PI on a New Jersey Department of Transportation project with Dr. Peter Jin that will identify and establish metrics, guidelines, and deployment strategies needed to monitor traffic signal performance in real time, working within the constraints of existing infrastructure and NJDOT resources. In the first months of 2017, Jalayer published three peer-reviewed journal articles having to do with motorcycle and wrong-way crashes, and nine peer reviewed conference proceedings, also dealing with roadway safety, crash modeling, and crash prevention. He serves on the editorial boards of the Journal of Safety Studies, Journal of Sustainable Development of Transport and Logistics, and Journal of Civil and Environmental Engineering, and is a technical reviewer for more than a dozen other professional journals

NJ New Legislation for Better Mobility for Adults with ASD

A new law signed by Governor Chris Christie last May arose from the final report of a two-year research project led by CAIT project manager Dr. Cecilia Feeley and coauthors Dr. Devajyoti Deka and Andrea Lubin from the Voorhees Transportation Center (VTC), and Melanie McGackin of Autism Family Services of New Jersey. The legislation is an important step toward meeting transportation needs of New Jersey citizens with developmental disabilities. The new law (S-1825/A-3432) calls for an 11-member task force to study and make recommendations concerning mobility and support services that would improve transportation options for adults with autism spectrum disorder (ASD).

For 70,000 adults with autism in New Jersey, getting to and from work, medical appointments, continuing education classes, and social or community activities, is not as simple as hopping on a bus or summoning Uber. The Rutgers research study supported with funding from the Governor's Council for Medical Research and Treatment of Autism and in partnership with the Voorhees Transportation Institute and Autism Family Services of New Jersey, surveyed more than 700 adults with autism and family members about their transportation habits and the challenges they face securing adequate travel options. In addition to the surveys, the team held listening sessions with 25 public and private organizations that serve the autism community and conducted structured interviews and focus groups

comprising adults with ASD and their parents or guardians. The research report, *Detour to the Right Place: A Study with Recommendations for Addressing the Transportation Needs and Barriers of Adults on the Autism Spectrum in New Jersey*, details obstacles that those with developmental disabilities—and their caregivers—must overcome to carry out normal daily activities. The report also offers recommendations on how to remove transportation-related barriers that often stand in the way of this population living independently, holding a job, and engaging socially.

Education and Workforce Development	Planning for the New Jersey State League of Municipalities Conference to be held November 2018	Generate knowledge and skills for the municipal and county transportation community	This program promoted a safety culture within the workplace for public agencies.	Attendees will learn about proper worker safety within their public works departments.
Technology Transfer	CAIT E Newsletter (Next issue to be published Oct 2017)	Generate knowledge and support research projects and programs that have significant and meaningful impacts.	CAIT recorded and delivered newsworthy items to showcase since January 2016.	Disseminated information about transportation research initiatives, applications, and training opportunities to practicing professionals.
	2017 UTC Spotlight Conference: Rebuilding and Retrofitting the Transportation Infrastructure (September 2017)	Brings together the ideas of those who generate new concepts that address transportation problems and opportunities, and those who own and manage transportation systems.	CAIT's Director, Dr. Ali Maher is a member of the planning committee, an honor that recognizes the center's contribution and leadership role in the areas of infrastructure and transportation.	CAIT presented on rehabilitating and restoring the current transportation infrastructure that will deliver efficient and effective performance and preserve resources for future generations.
	Hosted ITS NJ Annual Meeting (September 2017)	Support collaborative efforts and technology transfer	This event, co-hosted by CAIT, facilitates communication and generates research collaborations for Intelligent Transportation Systems research.	Disseminated the most current information on ITS practices and plans for the future.
	Tech transfer activities for the National Center for Rural Road Safety	Support collaborative efforts and technology transfer with an impact on rural and local road safety.	As part of the NCRRS consortium, CAIT is leading several Tech Transfer efforts promoting rural and local road safety.	CAIT produced the center Safety Sidekick Newsletter and blog, as well as developed and maintained social media presence.
	Tech transfer for the Northeast Regional Transportation Center	Generate knowledge and support resource sharing transfer for workforce development issues in the NE.	As part of the NETWC team, CAIT is leading the communication efforts for the project and developing and promoting tech transfer events.	CAIT maintains the NETWC website and social media presence.

	Planning for the Rutgers NJ Asphalt Paving Conference (March 2018)	Further the professional and technical expertise of the asphalt paving industry.	As a co-sponsor of the Rutgers Asphalt Paving Conference, CAIT co-chaired and administered the conference planning committee.	Highlights the most current information on asphalt practices, technologies, specifications, and projects.

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

This information has been integrated into the table above for the "what was accomplished under these goals?" section. Please see table above.

How have the results been disseminated?

This information has been integrated into the table above for the "what was accomplished under these goals?" section. Please see table above.

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

- **RESEARCH ACTIVITIES:**
  - **Ongoing Review of Research projects by the Research Advisory Board:** As previously described.
  - **Modify Agreements to Approve expenditure of Research Funds:** No research activities can start until the projects have been reviewed and approved as outlined in the prime proposal submitted to OST-R. CAIT has and will continue to issue modifications to the master agreements with each partner as research projects are approved.
  - **Ongoing Research:** Each of the consortium members will continue to perform SGR oriented research.
- **EDUCATION AND WORKFORCE DEVELOPMENT ACTIVITIES:**
  - Continue planning for the upcoming summer T.A.R.G.E.T. and other K-12 programs to support STEM and workforce development goals for the consortium.
  - Work with partner schools to develop new training seminars based on research.
  - Five University of Delaware graduate students, Ahmed Lasisi, Silvia Galvan Nunez, Emmanuel Martey, Yuanchi Liu and Tian Bai participated in the 13th Annual Interuniversity Symposium on Infrastructure Management held at Purdue University in June 2017.
  - Princeton University Ph.D. students created the knowledge basis needed to address the challenges, and presented the results of research project titled "Arrangement of sensors and Probability of Detection for Sensing Sheets Based on Large -area Electronics for Reliable Structural Health Monitoring" to other researchers in the group and visiting researchers through internal seminars and short course.
- **TECHNOLOGY TRANSFER ACTIVITIES:**
  - Continue to promote consortium research and applications through vehicles like UTC Spotlight and quarterly newsletter.

2. <u>PRODUCTS</u>: What has the program produced?

Research projects awarded:

The Research Advisory Board has not reviewed any new research projects during this cycle.

Publications, conference papers, and presentations

Journal publications.

- *Higgins, C., Liu, X. (2017)* "Modeling of track geometry degradation and decisions on safety and maintenance: A literature review and possible future research directions." *Journal of Rail and Rapid Transit*, 0(0): 1-13.
- *Liu, X., Liu, C., Hong, Y.L.* (2017) "Analysis of multiple tank car releases in train accidents." *Accident Analysis and Prevention,* 107: 164–172.
- *Liu, X.* (2017) "Optimizing rail defect inspection frequency to reduce the risk of hazardous materials transportation by rail." *Journal of Loss Prevention in the Process Industries*, 48: 151-161.
- *Leli, J., 2017* "National network for technology transfer to local agencies: The local and tribal technical assistance programs," TR News, July-August 2017, pp.46-51
- *Abera K., Manahiloh K.N., and Motalleb Nejad M.* (2017) "The Effectiveness of Global Thresholding Techniques in Segmenting Two-Phase Porous Media." Journal of Construction and Building Materials. 142:256-267. DOI: 10.1016/j.conbuildmat.2017.03.046.
- *H. Abdel-Jaber and B. Glisic*, "Monitoring of prestressing forces in prestressed concrete structures– an overview," Journal of Bridge Engineering (submitted, revised versions under review)
- *H. Abdel-Jaber and B. Glisic*, "Monitoring of long-term prestress losses in prestressed concrete structures using fiber optic sensors," Structural Health Monitoring (submitted, revised versions under review)

Books or other non-periodical, one-time publications.

"Nothing to Report"

Other publications, conference papers and presentations.

- *Bai, T. and McConnell, J.* "Data Analysis of Steel Bridge Infrastructure Including Climate and Traffic Effects"*, Annual Inter-University Symposium on Infrastructure Management, West Lafayette, IN, June. 23, 2017. (presentation and paper)*
- *Liu, Yuanchi, Sue McNeil and Gordana Herning. (2017).* "Integrating Resilience Concepts with Pavement Management: Two Case Studies*," World Conference on Pavement and Asset Management (WCPAM2017), Italy, June 12-16. (presentation)*
- *Liu, Yuanchi, Sue McNeil and Rusty Lee. (2017). "*Operationalizing the Concept of Resilience: A Case Study of Flooding in North Carolina*," 2017 MAIREINFRA, Seoul, South Korea, July 19-21. (presentation and paper)*
- *Liu, YuanChi, Rachel Chiquoine, Sue McNeil, and Rusty Lee, (2017). "*Infrastructure Resilience: Exploring and Interpreting Measures for Roads and Bridges*," Resilience Week, Wilmington, Delaware, September, 2017.*
- *McNeil, S. and Y. Liu,* "Infrastructure Resilience: New Objective, Added Constraint or New Performance Measure?*" 2nd International Symposium on Infrastructure Asset Management, June 29-30th, 2017, Zurich, Switzerland* (presentation and paper)
- *McNeil, Sue (2017), "*Concepts to Maintenance and Inspection Decisions for Infrastructure Systems*," 2017 MAIREINFRA, Seoul, South Korea, July 19-21* (presentation and paper)
- *McNeil, Sue (2017),* "Asset Management and Resilience: Connecting the Concepts to Building and Rebuilding Decisions*," UTC Spotlight Conference 2017, Rebuilding and Retrofitting Transportation Infrastructure, Washington, DC, September 26, 2017* (presentation)
- *Abera, Kokeb, "*Global Image Segmentation for Two-phase and Multi-phase Geomaterial Characterization,*" MCE Thesis, Department of Civil and Environmental Engineering, University of Delaware, May, 2017. (thesis)*

- *Masoud, Emal,* "Application of Lean Philosophy to Routine Inspection of Bridges*" MCE Thesis, Department of Civil and Environmental Engineering, University of Delaware, August, 2017. (thesis)*
- *Dorafshan S., Maguire, M., and Chang, M. (2017).* "Comparing Automated Image-Based Crack Detection Techniques in Spatial and Frequency Domains," *26th ASNT Research Symposium, March 13-16, 2017, Jacksonville, Florida.*
- *Dorafshan, S., Maguire, M. (2017).* "Autonomous Detection of Concrete Cracks on Bridge Decks and Fatigue Cracks on Steel Members," *20th Digital Imaging conference, June 26-28, 2017, Mashantucket, CT.*
- *H. Abdel-Jaber and B. Glisic, "*Method for Validation of long-term Temperature Measurements from Sensors*," in 39th IABSE Symposium – Engineering the Future, September 21-23 2017, Vancouver, Canada.*
- *H. Abdel-Jaber and B. Glisic, "*Prestress Loss Monitoring Using Long-Gauge Fiber Optic Sensors," in 39th IABSE Symposium – Engineering the Future," *September 21-23 2017, Vancouver, Canada.*

Website(s) or other Internet site(s)

CAIT has established two internet sites:

- http://cait.rutgers.edu/cait/research to disseminate research results
- http://cait.rutgers.edu/cait/program-sites to inform about consortium program activities

Technologies or techniques

- CAIT and multiple DOT and university partners are creating the nation's first full-scale accelerated bridge deck testing facility in Piscataway, New Jersey. This facility, called the Bridge Evaluation Using Accelerated System Testing (BEAST), will test the effects of many years of heavy loads and extreme temperature and weather patterns on a full-scale concrete bridge deck over a short period of time. To leave the experiments undisturbed, observations will be recorded using a 24-hour closed circuit video recording system. The results of the study will give bridge engineers valuable new information about the longevity of preservation treatments and concrete materials that can be incorporated into future bridge repair and construction projects. Recently, the testing facility has been completed, and CAIT and its partners are working toward developing the first bridge deck sample for testing in the BEAST facility.

Inventions, patent applications, and/or licenses

"Nothing to Report"

Other products: outreach activities, courses and workshops

- CAIT was a major contributor at the Emerging Technologies in Civil and Environmental Engineering Symposium hosted by the Rutgers Department of Civil and Environmental Engineering (CEE) to showcase important Rutgers-developed technologies and products. This event was a three-way dialogue between agencies, industry and academia about the future of transportation, its currents needs and challenges. Unique projects and creations shared by CAIT include BEAST™ accelerated bridge testing lab, RABIT™ robotic bridge-deck inspection tool, Targeted Hits For Modal Parameter Estimation and rating (THMPER™) and a relatively new lab led by Dr. Gong, the Advanced Construction Technology (ACT) which is using spatial sensing and large spatial data sets for mapping and virtual reality visualization in civil engineering.
- University of Delaware presented biochar-amendment data to Tom Schueler, President of the Chesapeake Bay Stormwater Network (http://chesapeakestormwater.net/about/the-team/) in a half-day meeting on August 11, 2017. Results were also discussed in a

presentation to the Scientific and Technical Advisory Committee for the Delaware Center for the Inland Bays (https://www.inlandbays.org/about/committees/stac/) on September 8, 2017 in Lewes, DE. Interest in the use of biochar continues to grow and UD will co-host a biochar conference in the spring.

- The UTEP team working on research project "New Methodology for Evaluating Incompatibility of Concrete Mixes in Laboratory: A Feasibility Study" developed and evaluated a fully-automated computer-controlled device that at user-defined time intervals can collect the shear and compression wave velocities as well as the temperature of the material up to an age of seven days. This resulted in a robust system for assessing the curing of concrete.
- The UTEP team working on research project "Evaluating Corrosivity of Geomaterials in MSE walls: Determination of Resistivity from Pore Water Chemistry" is developing a spreadsheet model to predict the electrical conductivity of a soil-water mixture as an indicator for the rate of corrosion in metal reinforcements in mechanically stabilized earthen (MSE) walls.
- Results from Princeton research project titled "Arrangement of sensors and Probability of Detection for Sensing Sheets Based on Large -area Electronics for Reliable Structural Health Monitoring" are included in an annual short course on SHM and in university graduate and undergraduate course CEE 539/CEE 439 Structural Health Monitoring, starting with Fall 2017.
- Silvia Nunez and Ahmed Lasisi from Utah State University received best presentation awards at AISIM 2017.
- Rachel Chiquoine from the University of Delaware was the recipient of the Carmen E. Turner Graduate Scholarship awarded by WTS Philadelphia.
- The New Jersey Department of Transportation (NJDOT) in partnership with the New Jersey Institute of Technology (NJIT) is in the process of developing a Freight Management System (FMS) software tool that enables state transportation practitioners to determine the level of importance of a particular project(s) or roadway segment(s) related to freight movement.

3. <u>PARTICIPANTS & OTHER COLLABORATING ORGANIZATIONS</u>:

What individuals have worked on the program?

Program Director: Dr. Ali Maher

Project Directors: Dr. Sue McNeil (University of Delaware), Dr. Marvin Halling (Utah State University), Dr. Raimondo Betti (Columbia University), Dr. Lazar N. Spasovic (NJIT), Dr. Branko Glisic (Princeton University), Dr. Abdul R. Pinjari (University of South Florida), Dr. Soheil Nazarian (University of Texas at El Paso, Dr. Carin Roberts-Wollmann and Dr. Gerardo Flintsch (Virginia Polytechnic Institute).

Consortium Universities Involved:

Rutgers, The State University of New Jersey (Lead)
University of Delaware, Newark, DE
Utah State University, Logan, UT
Columbia University, New York, NY
New Jersey Institute of Technology, Newark, NJ
Princeton University, Princeton, NJ
University of Texas, El Paso, TX
University of South Florida, Tampa, FL
Virginia Polytechnic Institute, Blacksburg, VA

What other organizations have been involved as partners?

The consortium has collaborated with a number of external agencies across the United States:

New Jersey Department of Transportation	Trenton, NJ	Financial support and collaborative research on multiple projects, including ITS research and a time-accelerated infrastructure testing facility that will simulate extreme loads and environmental conditions in on a real bridge deck
Virginia Department of Transportation Virginia Center for Transportation Innovation and Research (VCTIR)	Richmond, VA	Collaborative research on multiple projects, including a time-accelerated infrastructure testing facility that will simulate extreme loads and environmental conditions in on a real bridge deck
Applied Research Associates, Inc.	Panama City, FL	Collaborative research on multiple projects, including a time-accelerated infrastructure testing facility that will simulate extreme loads and environmental conditions in on a real bridge deck
Drexel University	Philadelphia, PA	Collaborative research on multiple projects, including a time-accelerated infrastructure testing facility that will simulate extreme loads and environmental conditions in on a real bridge deck
ITS New Jersey (a state chapter of ITS America)	Trenton, NJ	Collaborative research and personnel exchanges for workshops, meetings, and conferences on ITS research
Parsons Brinckerhoff	New York, NY	Collaborative research and support on a number of research and technology transfer activities, including workshops, meetings, and conferences on ITS research
New Jersey Asphalt Paving Association	Trenton, NJ	Personnel resources, knowledge exchange, and technology transfer collaboration for annual paving conference
New Jersey metropolitan planning organizations (North Jersey Transportation Planning Authority, Delaware Valley Regional Planning Commission, and South Jersey Transportation Planning Organization)	Newark, NJ; Philadelphia, PA; Vineland, NJ	Collaborative research and knowledge exchange for freight advisory committee and other improvement task forces and projects
New York State Department of Transportation	Albany, NY	Personnel resources, knowledge exchange
Maryland State Highway Agency	Baltimore, MD	Personnel resources, knowledge exchange
Utah Department of Transportation	Salt Lake City, UT	Personnel resources, knowledge exchange, financial support
Idaho Department of Transportation	Boise, ID	Personnel resources, knowledge exchange, financial support
American Aerospace Technologies, Inc.	Bridgeport, PA	Personnel resources, knowledge exchange
University of Vermont	Burlington, VT	Collaborative research and partnership in the Northeast Regional Surface Transportation Workforce Center
Montana State University	Bozeman, MT	Collaborative research and partnership in the development of the National Center for Excellence in Roadway Safety
Clean Earth Dredging Technologies Inc.	Jersey City, NJ	Collaborative research, personnel exchange
JAFEC USA Inc.	San Jose, CA	Collaborative research, personnel exchange
ArtsBridge	Newark, DE	Collaborative research, personnel exchange
Cape May County	Cape May, NJ	Collaborative research on technology transfer events.

Delaware River Bay Authority	New Castle, DE	Collaborative research on technology transfer events.
MAGTUG	MidAtlantic	Served as a partner in delivering one-day meeting, helped with contacts, logistical support
Delaware T^2/LTAP	Newark, DE	Served as partner in delivering one-day meeting, helped with contacts and logistical support
Florida Department of Transportation	Tallahassee, FL	Financial support, knowledge exchange
Florida DOT District 7 office	Tampa, Florida	Financial support, knowledge exchange
Delaware Department of Transportation	Dover, DE	Collaborative research and financial support
National Cooperative Highway Research Program (NCHRP)	Washington, D.C.	Financial Support
McMahon & Mann Consulting Engineers, PC	Buffalo, NY	Collaborative research
University of Texas at Austin	Austin, TX	Collaborative research
American Transportation Research Institute (ATRI)	USA	Provided large streams of valuable GPS data on truck-movements in Tampa region.
Clemson University	Clemson, SC	Collaborative research
McMahon & Mann Consulting Engineers, PC	Buffalo, NY	Collaborative research

Have other collaborators or contacts been involved?

- **collaborations with others within the lead or partner universities; especially interdepartmental or interdisciplinary collaborations**

Partner Meeting/Communication: The UTC partners communicated regularly throughout this reporting period.

Research Collaborations: The research selection process will yield many collaborative proposals to perform joint research with partners.

Ongoing collaborations for this reporting period include:

Accelerated Infrastructure Testing Facility: Bridge Evaluation Using Accelerated System Testing (BEAST)	• Utah State University • University of Delaware • NJDOT • VDOT • Applied Research Associates • Drexel University	The consortium created a working group to exchange ideas and knowledge about the construction of a massive, time-compressed facility that will study the effects of extreme weather and temperatures on real concrete bridge decks.

- **collaborations or contacts with others outside the UTC**

Multiple DOT and University Partners

Additional ongoing collaborations include:

Northeast Regional Surface Transportation Workforce Center	• University of Vermont • CAIT	The objective of the new center is to forge relationships between private and public transportation agencies and an extensive network of education, labor, and workforce enrichment organizations to develop programs, resources, and opportunities

		aiming to prepare future transportation workers and provide current transportation workers with chances for career development.
National Center for Excellence in Roadway Safety	• Western Transportation Institute at Montana State University • CAIT	The center will offer training, technical support, and easily accessible information to transportation practitioners around the country, and provide national leadership in finding solutions to critical safety issues, especially on rural roads.
Natural Hazards Engineering Research Infrastructure Equipment Facility at the University of Texas at Austin (NHERI@UTexas).	• University of Texas at Austin • CAIT	The Natural Hazards Engineering Research Infrastructure program at the University of Texas at Austin (NHERI@UTexas) brought T-Rex to Rutgers for a two-day structural testing workshop it cohosted with CAIT as part of an NSF project that is examining dynamic soil interaction as it pertains to our entire built environment.

- **collaborations or contacts with others outside the United States or with an international organization (country(ies) of collaborations or contacts).**
  University of Delaware presentations based on finding from the project "The Connection Between State of Good Repair and Resilience: Measures for Pavements and Bridges" have led to an emerging collaboration with the American Society of Civil Engineers Infrastructure Resilience Division (IRD) and the Japanese Society of Civil Engineers (JSCE) and the project team. The focus is on how to operationalize the concept of resilience for practitioners. The IRD is particularly interested in integrating resilience into design and the JSCE has a long history of developing design standards that integrate resilience to earthquakes.

  Previously reported collaboration currently ongoing:
  The Tokyo Institute of Technology is a research collaborator on the project titled "Utilization of Pneumatic Flow Tube Mixing Technique (PFTM) for Processing and Stabilization of Contaminated Soft Sediments in the NY/NJ Harbor"

4. <u>IMPACT:</u> What is the impact of the program? How has it contributed to transportation education, research and technology transfer?
The consortium's research activities and conclusions will be made available through workforce development and technology transfer efforts and reach over 12,000 transportation professionals nationwide, including consortium members, external university partners, government officials, and private industry partners.

What is the impact on the development of the principal discipline(s) of the program?

ONGOING RESEARCH PROJECTS DURING CURRENT REPORTING PERIOD

Outputs	Expected Outcomes	Impacts
"Long-Term Evaluation of Prestress Losses in Concrete Bridges using Long-Gauge Fiber Optic Sensors (Princeton University)	Potential products derived from this study include (1) the methodology for determination of prestress loss in a real structure and (2) methodology for the validation of long-term temperature and strain monitoring data. An outline of the methodologies will be available for future use	Potential future implementations of this methodology include an integrated monitoring system for bridges and other structures with prestressed elements, and a research tool for better understanding of prestress losses in new concrete mixes (such as high performance concrete, "green" concrete and non-cementitious

	in other projects.	concrete).
"Utilizing Unmanned Aircraft Systems for Infrastructure Management" (Rutgers University)	This project could result in a training program for engineers regarding the best practices of how to implement UAS into their interchange inspections. It could provide additional information regarding flight planning, image distances, sensor types, altitude, and safe distances necessary for a safe and productive inspection.	This research could lead to additional projects in identifying and developing best practices for other types of infrastructure assets. This could include utilizing UAS for traffic monitoring, highway inspections, bridge inspections, railway inspections, and other transportation assets.
"Refined Load Rating through Rapid Modal Testing" (Rutgers University)	The THMPER System might provide owners with an additional, cost-effective tool to address bridges that do not rate based on simplified procedures. The research team anticipates marketing the use of THMPER to perform rapid load rating of such bridges, and plans to provide webinars to help disseminate the results of this project and promote the use of THMPER.	Once validated, adopted as standard practice, and implemented at a large scale, the system is anticipated to significantly reduce the population of bridges that require posting. This reduction of posted bridges is expected to occur primarily due to the increased accuracy (decreased conservatism) associated with the ratings produced by THMPER. This will serve to significantly aid bridge owners in resource allocation and better prioritize bridge repair/replacement.
"Evaluating Electrical Resistivity as a Performance based Test for Utah Bridge Deck Concrete" (Utah State University)	The purpose of this research is to identify to what extent concrete resistivity measurements (bulk and/or surface) can be used as a performance based lab test to improve the quality of concrete in Utah bridge decks. By allowing UDOT to specify a required resistivity, concrete bridge deck concrete quality will increase and future maintenance costs will decrease.	From the developed protocols, engineers will have a faster, more economical, data driven performance based test for evaluating the durability of bridge deck concretes with respect to chloride induced corrosion and, potentially, other concrete attack phenomena.
"New Methodology for Evaluating Incompatibility of Concrete Mixes in Laboratory: A Feasibility Study" (University of Texas at El Paso)	The objective of this research project is to develop an easy to use, relatively inexpensive laboratory test and equipment to determine potential concrete mixture incompatibilities among the sulfate system, mineral and chemical admixtures.	It is the desire of the research team that the resulting test method to be practical enough so that it can be performed, ideally by the concrete producers, but also by a district laboratory during the mix design process.
"Evaluating Corrosivity of Geomaterials in MSE Walls: Determination of Resistivity from Power Water Chemistry" (University of Texas at El Paso)	The goal of this research is to develop a fundamentals-based model for calculating the electrical conductivity of pore water and moist soil. These models would allow evaluators to confidently judge the corrosivity of a geomaterial based on pore water chemistry.	This research will also allow the development of rigorous acceptance criteria for MSE backfill materials, and these acceptance criteria will be implemented in state and national protocols.
"Development of a Robust Framework for Assessing	The primary product from this research is a robust, flexible framework to integrating	The proposed framework will be valuable not only for management decision-making for bridge

Bridge Performance using a Multiple Model Approach" (University of Texas at El Paso)	disparate quantitative data sources on bridge performance using non physics-based models to provide reliable assessment and performance forecasting. This framework would be flexible in that it can readily integrate new data sources and multiple model forms if needed.	owners at the state DOT level, but will also be valuable for research efforts into predictions of bridge performance. Adoption of the approach by state DOTs is dependent on showing value, and integrating smoothly with their existing management workflow.
"Experimental Evaluation of the Engineering Behavior of Soil-biochar Mixture as a Roadway Construction Material" (University of Delaware)	The objective of this work is to advance a fundamental and mechanistic understanding of biochar's influence on soil strength-, deformation-, and flow-behaviors.	The long-term outcomes will impact some important policies and products that have practical significance to local and federal agencies that constantly deal with road-construction materials. The PI identifies Delaware Department of Transportation as the primary external client.
"Sustainable Geotextiles for Transportation Applications from Recycled Textiles" (University of Delaware)	The goal of this project is to explore the use of waste stream textiles as potential replacements for engineered geosynthetics in various transportation applications.	Collaborations with Goodwill of Delaware and Delaware County's Recycled Goods Manufacturing Initiative and SMART (Secondary Materials and Recycled Textiles) Industry Association will be established in order to disseminate research results and to interest recycled textile manufactures in exploring producing of a new product, geotextiles from waste stream textiles.
"Reducing Stormwater Runoff Volumes with Biochar Addition to Highway Soils" (University of Delaware)	The goal of this proposed research is to test the hypothesis that biochar addition to highway soils increases water infiltration, thus reducing stormwater runoff volume for treatment. Further, we hypothesize that biochar increases water infiltration through a multistep process: microbial populations are altered and increase, these population generate more extrapolymeric substances (EPS) that "glue" soil particles into aggregates, and soil aggregates increase preferential water flow and thus water infiltration.	The research proposed here will advance a new and environmentally sustainable stormwater technology that can potentially help the USDOT meet the challenges of nutrient reduction in stormwater volume with at reduced costs. Results of this research will have important implications for the design, maintenance, and long-term performance of stormwater treatment systems containing biochar.
"Collaborative Proposal: The Connection Between State of Good Repair and Resilience: Measures for Pavements and Bridges" (Delaware, Virginia Tech, and Rutgers)	The goal of this research is to demonstrate the relationships among the concepts of resilience, other performance measures particularly related to state of good repair, and decisions related to improvement of pavements and bridges.	This research is most likely to inform policy and decision making. We will work with our clients at DelDOT and NJDOT to explore these ideas and present them in a form of value to DOTs.
"Prediction of Hydroplaning Risk of Trucks on Roadways" (Rutgers University)	The research goal is to develop an integrated hydroplaning model that can be used by transportation agencies to help reduce hydroplaning risk under various tire	The research results will help state agencies better understand the mechanism of tire hydroplaning and design safer roadway considering comprehensive roadway

	configurations and roadway conditions.	characteristics (such as geometric design, drainage, pavement surface texture and groove, etc.). The quantification of pavement surface effects on hydroplaning will be useful in the selection of appropriate surface mixture and planning of pavement maintenance strategies.
"National University Transportation Consortium: A Speaker Recognition Based Damage Detection" (Columbia University)	In this proposal, we intend to cast the SHM problem within a statistical pattern recognition framework. It is an approach only based on data recorded during regular service operation and relies on the use of dense sensor arrays. With properly defined "damage sensitive features" (dsf), it would be possible to correlate these features from a dense array of data sets and establish their correlations. By looking at the variation in time of such correlations, it would be possible to learn about the regular operation of the bridge and determine events when damage has occurred.	The advances in computer and sensor technologies are pushing many areas (including structural health monitoring of civil structures) towards a greater use of measurement data, machine learning and statistical tools. This project will build on the results of a previous project and will continue the effort to extend to the diagnosis of the health of bridges and buildings methodologies that are currently used in other sectors of our society (e.g. bank security). If successful, it will represent a breakthrough in the way bridge inspections will be conducted in the future.
"Developing a Low Shrinkage, High Creep Concrete for Infrastructure Repair" (Utah State University)	The objective of this study is to develop concrete mixture that optimizes time dependent strains.	Concrete repairs represent a large tax payer burden, and the improvement of the lifetime performance of concrete repairs could save state DOTs a significant amount of maintenance funding.
"Unmanned Aerial Vehicle Augmented Bridge Inspection Feasibility Study" (Utah State University)	The results of this project will determine the feasibility of the application of unmanned aerial vehicles for the purposes of bridge inspection.	Pending the results of the research, the techniques can be easily implemented by a state DOT with their own UAVs and UAV operators or through contractors. Ideally, the results will be adopted into a best practices type document through ITD. Other DOTs or local agencies can use these results as well.

PROJECTS COMPLETED DURING CURRENT REPORTING PERIOD

- "Development of Protocols and Instrumentation Plan for Accelerated Structural Testing Facility" (Rutgers University)
- "Dynamic Effects and Friction Values of Bridge Moves for ABC Bridges" (Utah State University)
- "Piezoelectric Energy Harvesting in Airport Pavement" (Rutgers University)
- "Modeling the Impacts of Changes in Freight Demand, Infrastructure Improvements and Policy Measures on a Metropolitan Region" (NJIT)
- "Multi-Scale Condition and Structural Analysis of Steel Bridge Infrastructure" (University of Delaware)
- "Lean Construction Applications for Bridge Inspection" (University of Delaware)
- "Development & Implementation of NJ TRANSIT's Access Link Program" (Rutgers University)
- "The Hudson River Rail Tunnel Like Study" (Rutgers University)
- "Improving the Durability of the Inverted T-Beam Bridge System" (Virginia Tech)
- "Characterization and Modeling of Recycled Pavement Sections" (Virginia Tech)
- "Infrastructure Issues Related to In-Motion Electric Wireless Power Transfer" (Utah State University)
- "Truck Route Choice Modeling Using Large Streams of GPS Data" (University of South Florida)

- "Installation of Embedded Accelerometers in Precast Girders for the Nibley Utah Bridge" (Utah State University)
- "Installation of Thermocouples, and Analysis of Temperature Data from the 21st South Bridge" (Utah State University)
- "Investigating the effects of corrosion protection coatings on the ductility of welded wire reinforcement" (Utah State University)
- "The Impact of Tolls on Access and Travel Patterns of Different Socioeconomic Groups: A Study for the Greater New York Metropolitan Area" (Rutgers University)
- "Ultra-Compact and Rugged Electrochemical Sensor for Monitoring Toxic Metals in Natural Water Sources" (Rutgers University)

Projects Previously Reported Completed:

- "Optimization of Pavement Surface Characteristics" (Virginia Tech)
- "Satellite Assessment and Monitoring for Pavement Management" (University of Delaware)
- "Methodological Framework for Optimal Truck Highway Parking Location and Capacity Expansion" (Rutgers University)
- "Development of a Risk Assessment Tool for Rail Transport of Flammable Energy Resources" (Rutgers University)
- "Bridge Health Monitoring using a Machine-Learning Strategy" (Columbia University)
- "Arrangement of sensors and Probability of Detection for Sensing Sheets Based on Large -area Electronics for Reliable Structural Health Monitoring" (Princeton University)
- "Bridge Retrofit or Replacement Decisions: Tools to Assess Sustainability and Aid Decision-making" (University of Delaware)
- "Using Information at Different Spatial Scales to Estimate Demand to Support Asset Management Decision Making" (University of Delaware)
- "Load Testing and Analysis of 48 year old out-of-service Double Tee Girder Bridge" (Utah State University)
- "Carbon Fiber Shear Reinforcement for Prestressed Bridge Girders" (Virginia Tech)
- "Development of Concrete Mix Proportions for Minimizing/Eliminating Shrinkage Cracks in Slabs and High Performance Grouts" (Rutgers University)
- "Port Authority of New York and New Jersey Resiliency Initiative" (Rutgers University)
- "A Study on 3D Printing and its Effects on the Future of Transportation" Rutgers University)
- "Live-Load Testing and Finite-Element Modeling of a Fracture Critical Bridge" (Utah State University)
- "Unmanned Aerial Vehicle (UAV) based Traffic Monitoring and Management" (Rutgers University)
- "Initial Evaluation of the Albedo and Solar-Radiation Flux of Asphalt Pavements" (Rutgers University)
- "Long-Term Monitoring of a Geosynthetic Reinforced Soil Integrated Bridge System (GRS-IBS)" (University of Delaware)

What is the impact on other disciplines?

Previously Report Impacts on other disciplines:

"Sustainable Geotextiles for Transportation Applications from Recycled Textiles" (University of Delaware)	Geosynthetic fabrics and fibers are used in a wide variety of transportation applications including: silt fencing; soil stabilization of base and subbase layers; construction of reinforced earth retaining structures, stabilizing poor quality soils, and fiber-cement applications. Traditional geosynthetic fabrics and fibers are engineered with specific performance applications in mind but with a relatively high material cost. Apparel and home textiles are routinely landfilled, representing a large waste stream that is increasing drastically in volume. This waste stream is a potential feedstock that could improve the sustainability and reduce the cost of geotextiles/geosynthetics for a wide variety of transportation applications.

What is the impact on the development of transportation workforce development?

It is anticipated that research projects will lead to the adoption of new practices, policies, or methods that will be disseminated to the transportation workforce through training. These training events will enhance the transportation industry through the creation of new career paths and an industrywide

understanding of best practices and the USDOT state-of-good-repair mission. For example, the Virginia Tech master's student who worked on the inverted T-beam project has graduated and is now working for a consultant who does some bridge related work.

What is the impact on physical, institutional, and information resources at the university or other partner institutions?
It is anticipated that CAIT and its partners will share personnel and technological resources to streamline research, workforce development, and technology transfer efforts. For example, the UTC funding has resulted in a direct impact on the quality of both the graduate and undergraduate programs in Civil Engineering at Utah State University. The impact has been felt probably most markedly in the discipline of Structural Engineering and Bridge Engineering. There has been a steady flow of both PhD and Masters students that have participated in UTC projects due to the existence and activity of the Center. In addition, state and private funding sources have increased due to the opportunities to match funding which results in a beneficial relationship and leveraging of funds for all parties involved.

What is the impact on technology transfer?
It is anticipated that research projects will lead to the adoption of new or more efficient practices or inform policy. The creation by USF of a large database of truck route in Tampa in Tampa Bay region is expected that improved methods for analysis and forecasting of truck route choice will lead to improvements in travel conditions for freight movement.

What is the impact on society beyond science and technology?
Workshops and conferences on advanced technologies, materials, and best practices will lead to the maintenance and construction of intelligent, resilient infrastructure systems that enhance commercial vitality and improve the safety, security, and quality of life for Americans who depend on them.

5. CHANGES/PROBLEMS

Changes in approach and reasons for change
"Nothing to Report"
Actual or anticipated problems or delays and actions or plans to resolve them
"Nothing to Report"
Changes that have a significant impact on expenditures
"Nothing to Report"
Significant changes in use or care of human subjects, vertebrate animals, and/or biohazards
"Nothing to Report"
Change of primary performance site location from that originally proposed
"Nothing to Report"

6. SPECIAL REPORTING REQUIREMENTS

"Nothing to Report"