Program Progress Performance Report
for University Transportation Centers

Agency: US DOT
       Research and Innovative Technology Administration
       UTC Program

Federal Grant Number: DTRT12GUTC11

Project Title: Technologies for Safe and Efficient Transportation (T-SET)
               Tier 1 University Transportation Center

Program Director: Dr. Raj Rajkumar
                  raj@ece.cmu.edu
                  412-268-8707

Submission Date: July 13, 2012

DUNS Number: 05-218-4116

EIN Number: 25-0969449

Recipient Organization: Carnegie Mellon University
                        5000 Forbes Avenue
                        Pittsburgh, PA 15213

Recipient ID Number: 27484.x.1080266

Project Grant Period: 1/1/2012 - 1/31/2014

Reporting Period End Date: June 30, 2012

Report Term or Frequency: Quarterly (This first report is six months)

Signature: [Signature]
1. Accomplishments

**Major Goals and Objectives of the Program**

**Research, Development and Deployment by the T-SET UTC**

The CMU-Penn T-SET UTC focuses on research, development and ultimately deployment of technologies for safe and efficient transportation. The thrusts of the T-SET UTC are structured along 5 core areas: In-Vehicle Technologies, Infrastructure Technologies, Human-Vehicle Interactions, Mobility/Data Analytics and Policy. Each of the 16 research projects has identified Year 1 and Year 2 Desired Outcomes and Metrics.

**Metrics**
- Number of publications and citations of faculty work in transportation-related areas.
- Number of new hires, new research initiatives, and special projects that build on intellectual leadership in fields related to the mission of the UTC.
- Research collaborations in related fields.
- Quantified impact of technology deployments and transfers.

**Education and Workforce Development**

Education and workforce development are important compliments of the T-SET research program.

**Metrics**
- Number of institutional educational partnerships
- Number of participants in workforce and educational programs
- Number of related degrees awarded at our institutions
- Number of new educational programs established
- Number of job placements through workforce development programs.

**Technology Transfer**

The CMU-Penn UTC will fully use the resources and experience of these university centers to promote enterprises arising from its research program. Faculty who have already created startups in the past will serve as mentors to colleagues interested in this activity.

**Metrics**
- Involvement of faculty in technology transfer activities.
  - Number of conferences, meetings, and formal discussions that focus on end users of ITS
  - Number of patent applications filed
  - Number of startups created
  - Number of technology licenses issued

**Collaboration**

Collaboration is the heart of the entire T-SET program. Carnegie Mellon and the University of Pennsylvania seek to ensure our research and development program leads to deployment of technologies in the transportation systems serving our communities and state, providing pilots applications for global use. The CMU-Penn team will collaborate with related centers on the two campuses, state and local public partners, non-profit community partners, educational partners and industry partners.

**Metrics**
- Number and diversity of members of the T-SET Consortium
- Number and impact of deployments achieved through collaboration
Diversity
* T-SET projects will focus on transportation users in both rural areas and center cities, in suburban commuters and on residents of small communities with limited transportation options.

**Metrics**
- Participation by students and faculty of color and women in UTC research projects
- Projects focused on rural, city, and suburban residents
- Number of projects targeted at aging populations and persons with disabilities

**Accomplishments Under the Major Goals**
See Appendix A for specific research project accomplishments.

**Education and Workforce Development**
Carnegie Mellon is in the process of developing Masters Degree concentrations in transportation in the College of Engineering and the Heinz College School of Public Policy and Management and School of Information Systems Management.

In workforce development Carnegie Mellon has begun discussions with the following organizations to identify transportation workforce needs and opportunities:
- Three Rivers Workforce Investment Board
- Community College of Allegheny County
- Pennsylvania Department of Transportation
- Pittsburgh Technology Council
- American Association of State Highway and Transportation Officials
- American Public Transportation Association
- Conference of Minority Transportation Officials
- City of Pittsburgh Public Works
- Allegheny County Public Works
- Greater Pittsburgh Chamber of Commerce
- Southwestern Pennsylvania Commission (Pittsburgh’s MPO)
- RITA, Mac Lister, Program Manager of Knowledge and Technology Transfer

CMU UTC personnel served as a panelist in the April 2012 CUTC National Transportation Workforce Summit in Washington, DC.

Various UTC personnel advised CMU student research projects this semester for the City of Pittsburgh on transit oriented development, safe routes to schools, bike sharing, environmental benefits of congestion management actions, and creation of a sustainable practices assessment tool.

UTC personnel served an advisor for a Masters Class project at the CMU campus in Washington evaluating factors that affect the effectiveness of TOD applications.

Provided an overview of the UTC research program and a tour of CMU’s UTC research labs to high school students.

UTC personnel gave guest lecturers on the UTC program to CMU’s Masters of Information Systems Management class.
Technology Transfer and Collaboration
T-SET recruited over 30 public and private members into the T-SET Consortium. We held a full-day symposium at CMU on May 18, 2012 with over 50 consortium participants including faculty and researchers from CMU and Penn. At the symposium we:

- Presented the entire UTC research program
- Discussed UTC workforce, education, technology transfer and diversity goals
- Convened a consortium member panel “Perspectives on Partnering with Universities”
- Held a plenary discussion on specific ideas for partnering with the UTC on technology transfer, workforce development, diversity and research
- Hosted a networking session with UTC researchers and consortium members

For the goal of collaboration, we also have begun follow-up conversations with consortium members on specific technology transfer and workforce development opportunities that came out of the May 18th symposium including the Pittsburgh Tech Council and Innovation Works.

Below are additional Tech Transfer and Collaboration accomplishments and efforts:

- Tiramisu Transit, spin-off from T-SET researchers, received a $102,000 SBIR Grant.

- In promoting collaboration with regional university transportation researchers, both CMU and Penn UTC personnel presented T-SET research at a meeting of Pennsylvania Transportation Research Universities hosted by Penn State. Both CMU and Penn UTC personnel also attended (with Penn presenting) the Connected Vehicle Test Bed Development & Integration Workshop in Buffalo, NY hosted by the Region 2 UTC.

- UTC personnel have been active in the host committee planning the ITS Pennsylvania Annual Meeting which will be held in Pittsburgh in August 2012.

- UTC personnel collaborated with the Port of Pittsburgh Commission on an unsuccessful USDOT TIGER IV application for a Wireless Waterways proposal and a with the Pittsburgh Urban Redevelopment Authority’s successful $15 million dollar USDOT TIGER IV application for the East Liberty Intermodal Transit Center.

- UTC personnel were integral in the development of the City of Pittsburgh’s successful IBM Smarter Cities Challenge grant which focused on Intelligent Transportation Systems.

- UTC personnel worked collaboratively with a non-profit organization (East Liberty Development Inc) to facilitate installation and testing of a grid patterned adaptive traffic signal application. Bench testing predicts significant improvement in flow and environmental benefits. Field testing in June corroborated the theoretical results with very impressive levels of reduction in delay and emissions. We are planning a media event in July to announce the results. The Heinz Endowments are considering funding to expand this application.

- UTC personnel have been actively engaged in organizing the Association of Unmanned Vehicle Systems International Pittsburgh Chapter which incorporated this spring.

- UTC personnel served as advisors to a Masters Class in Environment and Public Policy which is exploring the use of massive vehicle data to inform decisions about transportation funding policy scenarios.
• Various UTC personnel were involved in the PennDOT’s State Transportation Innovation Council (response to FHWA’s Every Day Counts initiative.)

• UTC personnel serve in leadership of the newly elected Allegheny County Executive’s Transportation Visioning Committee.

• UTC personnel participated on Deputy Secretary Porcari’s Multi-modal Safety Panel in March 2012.

• Prof. Raj Rajkumar, Director of the T-SET UTC is currently serving on US DOT Secretary La Hood’s Advisory Council on Intelligent Transportation Systems.

• UTC personnel are advising Pittsburgh City Council on a smart parking meter initiative.

• UTC researchers have engaged with SEPTA personnel about potential joint projects to pursue on bus and train data mining and modeling.

**Diversity**

Carnegie Mellon had a significant presence at the National Black Engineers Society’s Annual Conference in Pittsburgh in March 2012 including UTC personnel attending and an exhibit of a CMU autonomous vehicle with window stickers promoting its association with the US DOT UTC Program.

Discussions have been held about possible workforce development opportunities with the:

• Conference of Minority Transportation Officials
• Community College of Allegheny County
• African American Chamber of Commerce of Western Pennsylvania
• Women’s Transportation Seminar

The UTC has been working with Indiana University of Pennsylvania and the Indiana Transit Authority to transfer UTC technology to transit serving rural populations in Pennsylvania.

UTC personnel have been actively engaged in research projects with the Accessible Transportation and Workforce Interagency Cooperative which is the organization in Pittsburgh that manages the USDOT New Freedoms and Job Access Reverse Commute programs.

**Dissemination of Results**

In addition to the outreach activities mentioned above and UTC researcher activity in Appendix A, UTC leadership personnel attended the following conferences and meetings to promote UTC research, technology transfer, education and workforce activities:

• Traffic21 Research Presentation to the Shanghai delegation visit hosted by the Mayor of Pittsburgh, 1/2012
• Meeting with the staff director of the PA House Transportation Committee, 1/2012
• Meeting with the PennDOT Director of the Intelligent Transportation Systems, 1/2012
• Presentation of UTC research to the Accessible Transportation and Workforce Interagency Cooperative, 1/2012
• Presentation of ITS research to the Port Authority of Allegheny County Bus Rapid Transit Planning Committee, 1/2012
• Connected Vehicle Conference, Detroit, 1/2012
• Southwest Pennsylvania Air Quality Partnership Winter Meeting, 1/2012
• Annual TRB Conference and UTC meeting in Washington, DC, 1/2012
• CMU Hosted the kick-off meeting of the Pittsburgh’s’ MovePGH Transportation Plan, 2/2012
• Hosted PA Department of Community and Economic Development Deputy Secretary at CMU and presented UTC research, 2/2012
• Interview with IBM and the Mayor of Pittsburgh for the IBM Smarter Cities Challenge Grant Competition, 2/2012
• University of Pittsburgh Transportation Forum, 3/2012
• CMU/Penn UTC administrative meeting in Philadelphia, 3/2012
• Presented at the Southwestern PA Commission (MPO) annual meeting, 3/2012
• Kick-off meeting of the Transportation for the Mon Valley Initiative, 3/2012
• Meeting with Chief Operating Officer of Pennsylvania Turnpike to discuss ITS deployment interests 3/2012
• State Transportation Innovation Council (PennDOT and FHWA Every Day Counts) meeting in Harrisburg, 3/2012
• Hosted Chief of Staff of PA Senate President Pro Tempore at CMU and presented UTC research, 4/2012
• Presentation of UTC program at State Smart Transportation Initiative meeting (meeting of 10 State DOT CEO’s), 4/2012
• Participated in Secretary LaHood’s Safety Data press event at the White House, 5/2012
• Presentation of UTC program at the CMU Pennsylvania Smart Infrastructure Incubator Partners Symposium, 5/2012
• Presented at ITS America annual meeting in Maryland, 5/2012
• One-on-one meeting with PennDOT Secretary in Harrisburg to present UTC program, 6/2012
• UTC/CUTC summer meeting in Michigan, 6/2012

**Plans for Next Reporting Period**

**Third Quarter UTC Plans:**

• Continue progress on the research projects
• Plan a UTC Advisory Committee Meeting
• Update the UTC web site
• Continue individual follow-up with consortium members on workforce and technology transfer initiatives
• Plan a technology transfer symposium for UTC faculty and students involving campus affiliates and consortium members who provide technology transfer assistance
• Continue efforts on developing transportation masters programs
• Develop STEM and diversity initiatives
• Focus on research deployment of UTC projects
• Increase media exposure of upcoming newsworthy research activity
• Pursue research activity with PennDOT
• Support the City of Pittsburgh on the IBM Smarter Cities Challenge Initiative
• Develop UTC marketing brochure and information for the web site
• Plan a meeting of campus affiliates
• Plan symposium in Philadelphia to target our southeastern PA consortium members
2. Products
See Appendix A for specific research project products including publications, technologies, inventions, etc.

**General Program Products**
UTC website [www.utc.ices.cmu.edu](http://www.utc.ices.cmu.edu)
- 530 blog postings since January 2012
- Consistent weekly distribution of T-SET email newsletter
- Research Descriptions posted on site
- Updated weekly announcements

Logo, letterhead and business cards
Custom web portal for UTC researchers to report progress
Research Project Descriptions
Promotion of various CMU and Penn research news articles in the T-SET blog and newsletter
Publication of the ParkPGH research project in the May UTC newsletter
Feature article of the UTC in the CMU ICES quarterly magazine
Media stories for Tiramisu SBIR grant acknowledging RITA
Generated additional media stories on CMU and Penn transportation efforts and posted on the blog

3. Participants and Other Collaborating Organizations
See Appendix A for participants & other collaborating organizations for each specific research project.
NOTE: No foreign travel was conducted with UTC funds this reporting period.

**Individuals Involved in Program Management**
- **Name**: Raj Rajkumar  
  **Program Role**: Director  
  **Hours**: 15% of effort  
  **Contribution**: Program Management  
  **Funding**: UTC, NSF, GM Labs

- **Name**: Allen Biehler  
  **Program Role**: Executive Director  
  **Hours**: 90% of effort  
  **Contribution**: Program Management  
  **Funding**: Traffic21

- **Name**: Stan Caldwell  
  **Program Role**: Deputy Executive Director  
  **Hours**: 90% of effort  
  **Contribution**: Program Management  
  **Funding**: Traffic21

- **Name**: John Russell  
  **Program Role**: Upenn Administrator  
  **Hours**: 80 hours  
  **Contribution**: Program Management  
  **Funding**: UTC

**Collaborating Organizations**
Please refer above to the “Accomplishments Section” under our Major Goal of Collaboration for specific examples of our general program collaborating organizations.

Below is a current list of our 31 active T-SET Consortium Members. At our May 18, 2012 T-SET Consortium Symposium we had a very impressive turnout and the participants were genuinely excited about the opportunities to collaborate with the UTC and pursue real world applications for our research and education.

1. ACCESS  
2. Alco Parking  
3. Allegheny Conference on Community Development  
4. American Public Transportation Association  
5. Accessible Transportation and Workforce Interagency Cooperative  
6. Beth's Barricades  
7. Bike Pittsburgh  
8. Booz Allen Hamilton Inc.  
9. Bosch Research and Technology Center, North America
10. City of Philadelphia
11. City of Pittsburgh
12. Community College of Allegheny County
13. Conference of Minority Transportation Officials
14. County of Allegheny
15. Delaware Valley Regional Planning Commission
16. General Motors Global Research & Development Center
17. IBM
18. Innovation Works
19. Open Roads
20. Pennsylvania Department of Transportation
21. Pitt OHIO
22. Pittsburgh Technology Council
23. Port Authority of Allegheny County
24. Port of Pittsburgh Commission
25. Southeastern Pennsylvania Transportation Authority
26. Southwestern Pennsylvania Commission
27. Sustainable Pittsburgh
28. Takata
29. Three Rivers Workforce Development Board
30. University of Pittsburgh
31. Women’s Transportation Seminar

Appendix A – Research Projects Accomplishments, Products and Participants

Thrust Area #1 In-Vehicle Technologies for Safety

V2V for Safe Intersections (DOT Goal: Safety; Topic: Technology-Related Research)
Lead: Ozan Tonguz (CMU)

Publications
Author(s): Ozan K. Tonguz

Author(s): Till Neudecker, Natalya Ann, Ozan K. Tonguz, Tristan Gaugel, Jens Mittag,

Individuals Working on this Project
Name: Wantanee Viriyasitavat Project Role: PhD student (Research Assistant) Hours: 8 hours/week Contribution: The key researcher in the program in addition to Prof. Tonguz Funding Support: Full time RA

Other Organizations Involved as Partners
General Motors Corporation
Karlsruhe Institute of Technology, Germany

Other Collaborators
Yes. For example, Till Neudecker and Natalya An who are PhD students at Karlsruhe Institute of Technology were also involved in this work under PI supervision.
Impact on the Development of the Principal Discipline
Two major findings of my research are expected to have a major impact on fundamental transportation problems: 1-It has been shown that some of the key problems we are facing in transportation (such as mitigating congestion, more energy-efficient transportation, safer intersections, reduced commute time for urban workers during rush hours, reduced carbon footprint, etc.) can be addressed or solved by learning from nature and biological systems. This powerful approach holds the promise of solving key transportation problems. 2-The Virtual Traffic Lights that we have been investigating has been shown to be feasible even at the worst intersections which might have high rises or huge buildings that might obstruct the vehicle-to-vehicle (V2V) communications or RF propagation. Our results have shown that even at such intersections, V2V communications is sustainable between the cluster leaders and the required deceleration for the cluster leader that needs to come to a stop is NOT more than 3 meters/seconds square. This means that even under worst-case situations the proposed VTL scheme will be able to inform a cluster leader about 35-40 meters before the intersection that it needs to stop. This is a very important result as it shows that Virtual Traffic Lights is a feasible technology even under worst-case situations, i.e., under Non-Line-of-Sight Conditions.

Impact on Other Disciplines
The findings we have show that major transportation problems we are currently facing in the USA (as well as in other parts of the world) can be solved with a completely new approach which involves a new self-organized traffic control paradigm. This approach draws its inspiration from self-organizing biological systems.

Automatic Recognition and Understanding the Driving Environment for Driver Feedback (DOT Goal: Safety; Topic: Technology-Related Research)
Lead: Martial Hebert (CMU)

Technologies and Techniques
We have worked on the development of software infrastructure with the purpose of transitioning our implementations of machine perception algorithms from their current research-oriented form into more robust applications, suitable for operation on our test vehicle. In particular, we have designed and commenced the implementation of a software library for object recognition using video as the primary sensor. This software will enable us to test the extended perception algorithms for automotive applications using data from real traffic situations. This library is still under development and is not being shared at the moment.

Individuals working on this project
Name: Luis E. Navarro-Serment Project Role: PI Hours: 5% effort May and June 2012 Contribution: Supervise project, provide guidance to students Funding Support: UTC

Name: Mengzhe Li Project Role: Summer undergrad student Hours: 137 Contribution: Analysis of requirements, definition of functions, data structures and classes, and implementation of object recognition code. Funding Support: UTC

Name: Xinwu Yang Project Role: Summer undergrad student Hours: 219 Contribution: Analysis of requirements, definition of functions, data structures and classes, and implementation of object recognition code. Funding Support: UTC

Name: Aniruddh Chaturvedi Project Role: Summer undergrad student Hours: 200 Contribution: Implementation of visualization function to support development of object recognition code, investigation of API for interfacing with street map database. Funding Support:
Impact on the Development of the Principal Discipline
Within the discipline of Robotics: expose students to issues involved in the design of machine perception algorithms for automotive applications.

Sensory Augmentation for Increased Awareness of Driving Environment (DOT Goal: Safety; Topic: Technology-Related Research)
Lead: Paul Rybski (CMU)

Individuals Working on the Project
Name: Paul E. Rybski Project Role: Project leader Hours: 44 Contribution: Supervising the development and design of an automotive-based tracking system for use on a semi-autonomous vehicle.
Funding Support: UTC

Impact on the Development of the Principal Discipline
Automated intent recognition for automotive applications has the potential to greatly improve safety systems in cars and on roadways. If a situation around the vehicle can be deemed potentially hazardous due to the driving conditions, actions of other drivers, the speed of the vehicles, and existence of blind spots, then automated systems can alert the driver to this before an unavoidable hazardous situation could occur.

V2V Cooperative Control and Coordination (DOT Goal: Safety; Topic: Technology-Related Research)
Lead: Vijay Kumar (Penn)

Publications
Authors: Matthew Turpin, Nathan Michael and Vijay Kumar
Title: Trajectory Planning and Assignment in Multirobot Systems.

Technologies and Techniques
We have developed a task allocation method that will allow for a number of cars on the road to negotiate spatial locations that is guaranteed to be collision free. Related research for robotic systems is awaiting publication after being presented at the Workshop on the Algorithmic Foundations in Robotics 2012.

Other Products
Software: Simulation environment for handling thousands of interacting agents solving the assignment problem.

Individuals Who Have Worked on this Project
Name: Vijay Kumar Project Role: PI Hours: ? Contribution Advisory Funding: No funding through this UTC

Name: Matthew Turpin Project Role: Lead Graduate Student Hours: 15/Month Contribution: Primary theoretical research on solving the assignment problem for large numbers of agents Funding: No funding through this UTC

Impact on the Development of the Principal Discipline
This research will be likely to influence how an intelligent car can communicate with other smart cars to provide the best feedback for the driver to avoid collisions with other cars.
Thrust Area #2 Smart Infrastructure

Smart Parking (DOT Goal: Livable Communities; Topic: Land Use Planning and Multi Modal Transportation Research)
Lead: Robert Hampshire (CMU)

Technologies and Techniques
We enhanced our parking prediction algorithm that uses historical parking and event data in a prediction model to provide information on the availability of parking. This enhancement includes a short term, minute-by-minute, prediction feature which is critical for the peer-to-peer parking application.

Other Organizations Involved as Partners
Numeritics LLC., Pittsburgh Cultural Trust, Pittsburgh Parking Authority, Alco Parking, Deep Local

Website: www.parkpgh.org

Continuous Road Surface Distress Detection (DOT Goal: State of Good Repair; Topic: Infrastructure Monitoring Research)
Lead: Christoph Mertz (CMU)

People working on this project
Name: Christoph Mertz Project Role: PI Hours: 10% effort May and June 2012 Contribution: Oversees project, gives guidance Funding: UTC

Name: Lars Wander Project Role: Summer undergrad student Hours: 167 Contribution: Investigated mapping APIs, programmed picture taking app for Android. Funding: UTC

Name: Ting Xu Project Role: Summer undergrad student Hours: 135 Contribution: Developed scripts to take the images and tags from the Android app and convert them to data that can be displayed in a Google Earth. Set up computer that will host the data and run the scripts Funding: UTC

Technologies or Techniques
We have developed an Android app that can take pictures of roads and tags it with GPS and other sensor information. These pictures can then be displayed in Google Earth in top-down view at the location they were taken. Eventually this app will be one-click procedure. The user points the smartphone camera to road damage, clicks it, and the image will appear on a web page that displays current and past road surface conditions. The app is still in the development phase and is not being shared.

Partner Organizations
Initial conversations with contacts at City of Pittsburgh and Takata Corporation. They have indicated interest in collaboration.

Impact on the Development of the Principal Discipline
Within the discipline of Robotics: Expand the field to include transportation research, expose students to transportation research.

Bridge Monitoring (DOT Goal: State of Good Repair; Topic: Infrastructure Monitoring)
Lead: Jim Garrett (CMU)
Publications
Environmental Engineering, University of Pittsburgh, PA 15261, USA.
Title: Indirect structural health monitoring of a simplified laboratory-scale bridge model Journal: Smart Structures and System http://technopress.kaist.ac.kr/?journal=ssss# Volume: Special Issue Year: 2012 Status of publication: submitted Acknowledgement: yes National Science Foundation (Award No. CMMI1130616)

Type of publication: conference paper Author(s): F. Cerda1, J. Garrett1, J. Bielak1, J. Barrera1, Z. Zhuang, S. Chen1, M. McCann1, J. Kovacevik & , P. Rizzo, Carnegie Mellon University, Pittsburgh, Pennsylvania, USA, University of Pittsburgh, Pittsburgh, Pennsylvania
Title: Indirect structural health monitoring in bridges: scale experiments Conference proceedings: IABMAS 2012 Year: 2012 Page numbers: - not public yet Status of publication accepted, awaiting publication Acknowledgement: National Science Foundation (Award No. CMMI1130616)

Technologies and Techniques
We have explored the feasibility of indirect structural health monitoring. By means of machine learning techniques, different damage scenarios can be identified on a laboratory scale bridge. The findings of this work (and the related NSF project) have been and will be shared through scientific journal articles and presentations on technical conferences.

Individuals Who Have Worked on this Project
- Name: James Garrett Project Role: PI Country(ies) of foreign collaborator: Colombia-Chile
- Name: Jacobo Bielak Project Role: co-PI Country(ies) of foreign collaborator: Japan
- Name: Jelena Kovacevik Project Role: co-PI
- Name: Piero Rizzo Project Role: co-PI
- Name: Fernando Cerda Project Role: Research Assistant Hours: 960 Country(ies) of foreign collaborator: Japan
- Name: Siheng Chen Project Role: Research Assistant Hours: 290 Funding: NSF
- Name: Eduard Romero Project Role: Research Assistant Hours: 640 Country(ies) of foreign collaborator: Colombia
- Name: Tim Pianka Project Role: Research Assistant Hours: 120 Contribution: Building of experiment model, running experiments Funding: Personal funding
- Name: Zhe Zhuang Project Role: Research Assistant Hours: 50 Contribution: Building of experiment model, running experiments. Country(ies) of foreign collaborator: Japan
- Name: Ranny Zhao Project Role: Research Assistant Hours: 80 Contribution: Building of experiment model, running experiments.
- Name: Madelyn Gioffre Project Role: Research Assistant Hours: 320 Contribution: Building of experiment model, running experiments. Funding: NSF
- Name: Chenhao Jin Project Role: Research Assistant Hours: 320 Contribution: Building of experiment model, running experiments. Funding: Self

Partnering Organizations
University of Pittsburgh (Pittsburgh, PA, USA) Personnel exchanges, co-PI affiliated Universidad de los Andes (Bogotá, Colombia) Personnel exchange, Exchange student working as Research Assistant, Universidad de Concepcion (Concepcion, Chile) Personnel exchanges, PhD Student, Research Assistant also affiliated to this University.

Impact on the Development of the Principal Discipline
The progress so far represents initial work for detecting changes in bridge structures based on acceleration data from passing vehicles. We refer to this approach as indirect. We compare the results of the indirect approach with the traditional direct approach in which sensors are located on the bridge structure. A
detection procedure was developed to capture the shifts in the fundamental frequency of the bridge. The detection capability of the proposed signal processing approach is more stable across different speeds for acceleration data gathered in a direct fashion rather than in the indirect one. This project has been very attractive for various undergraduate students interested in gaining a research experience. We believe this is mainly because of the simplicity of the concept behind this research, the promising paradigm shifting impact for SHM, and the experimental nature of the project. What is the impact on the development of the principal discipline(s) of the program? Although our research is still on very early stages, we propose an alternative way to monitor the bridge infrastructure. Traditionally, the Structural Health Monitoring (SHM) community uses the data measured directly from a structural system for diagnostic purposes. In such an approach, a number of sensors are deployed on the structure. We refer to this as a direct SHM approach. In contrast, the use of data not recorded directly from a structure is referred to as an indirect SHM approach (Lin et al. 2005, Cerda et al. 2010). There are several practical reasons that drive our research on the indirect SHM approach. There is a need in most countries, and especially in the US, to monitor a large bridge stock in a reliable, objective and economically feasible way. The traditional direct SHM approach requires installation, power and maintenance of an expensive electronic infrastructure on the physical bridge infrastructure. The indirect approach can gain leverage by using the equipment already located on board newer models of vehicles, or on a fleet of vehicles, that can be equipped with sensors to collect the desired information as they undergo their daily routines. We have observed a high degree of consistency in the classification accuracies across the very different types and severity of damage and for different vehicle speeds. This gives us hope that our approach might be applicable to more general systems. Clearly, further research is needed to validate the robustness of these results for more realistic systems and conditions. The support provided by this UTC on this project will allow the researcher to explore a variety of machine learning approaches for enhancing the change detection accuracy and to further validate the approach. Funding from the National Science Foundation is also being used to support the researchers on this project.

Impact on Other Disciplines
Other disciplines are also considering the application of machine learning algorithms, as we did, to mine information embedded in the data. For example, research in pipe monitoring is showing promising results by applying machine learning techniques to identify and learn from combinations of features found in the signal. On the other hand, from the machine learning and signal processing community, the problems in civil engineering are becoming very attractive as a practical area of application.

Smart Camera Infrastructure (DOT Goal: Safety; Topic: Technology-Related)
Lead: C.J. Taylor (Penn)

Publications
Type of publication: Journal

Technologies and Techniques
Visual odometry algorithms: open source code implementations

Individuals Working on this Project
Name: Jordan Brindza Project Role: Graduate student Number Hours: 20/week Contribution: Visual odometry algorithm development

Other Organizations Involved as Partners
Intel has also partially supported students working on this project.
Impact on the Development of the Principal Discipline
Research may impact automobile navigation.

Impact on Other Disciplines
Important for low-cost robotics as well.

Automated Vehicle Type Recognition (DOT Goal: Safety; Topic: Technology-Related)
**Lead:** Kostas Daniilidis (Penn)

**Technologies and Techniques**
We worked on vehicle detection based on shape derived from 3D CAD models and we submitted our work to ECCV 2012.

**Individuals Working on this Project**
**Name:** Konstantin Derpanis **Project Role:** Postdoctoral Researcher **Hours:** 160 **Contribution:** Development of energy gradient filters for shape estimation **Funding:** UTC, ARL-RCTA

Impact on Other Disciplines
It will have broader impact on shape based object recognition in cluttered scenes.

**Thrust Area #3 Human-Vehicle Interactions for Safe Driving**

Understanding Driver Intentions (DOT Goal: Safety; Topic: Human Factors Research)
**Lead:** Jianbo Shi (Penn)

Project has not yet begun.

Modeling, Verification and Validation of Transportation Safety (DOT Goal: Safety; Topic: Technology-Related Research)
**Lead:** Andre Platzer (CMU)

**Publications**
**Type of publication:** Conference Paper and Presentation
**Author(s):** Stefan Mitsch, Sarah M. Loos, and Andre Platzer.
**Title:** Towards Formal Verification of Freeway Traffic Control. **Conference:** International Conference on Cyber-Physical Systems, ICCPS, Beijing, China **Year:** 2012 **Status:** published

**Acknowledgement of federal support (yes/no):** yes

**Type of publication:** Conference Paper and Presentation
**Author(s):** Nikos Aréchiga, Sarah M. Loos, Andre Platzer, and Bruce H. Krogh.
**Title:** Using theorem provers to guarantee closed-loop system properties. **Conference:** Dawn Tilbury, editor, American Control Conference, ACC, Montreal, Canada **Year:** 2012 **Status:** published

**Acknowledgement of federal support (yes/no):** yes

**Websites**
Academic homepage of Sarah Loos. Distributes publications and presentation slides, and provides links to related news articles, and research resources. [www.cs.cmu.edu/~sloos](http://www.cs.cmu.edu/~sloos)

**Technologies and Techniques**
The KeYmaera tool is freely available with a user friendly, web-start version. KeYmaera is a hybrid verification tool for hybrid systems that combines deductive, real algebraic, and computer algebraic
prover technologies. It is an automated and interactive theorem prover for a natural specification and verification logic for hybrid systems. KeYmaera is continually being improved with added functionality to keep up with growing research needs. We are also developing an intensive tutorial and course curricula for KeYmaera to keep up with growing demand for the tool. KeYmaera can be downloaded or launched from this website: http://symbolaris.com/info/KeYmaera.html

**Individuals Who Have Worked on this Project**

Name: Nikos Arechiga  
**Project Role:** Co-Author  
**Contribution:** Co-Author on Research paper

Name: Stefan Mitsch  
**Project Role:** Co-Author  
**Contribution:** Co-Author on Research paper

**Partner Organizations**

Carnegie Mellon University School of Engineering: Collaborative Research

**Impact on the Principal Discipline**

Safety-critical traffic and automotive systems are becoming increasingly dependent on complex interactions with computers. Safety systems such as adaptive cruise control, emergency braking and collision mitigation are becoming household terms, as family cars are equipped and sold with these devices. However, with this increased complexity, it is far more challenging to ensure the safe and accurate functioning of these devices, especially as an increasing number of them begin to interact on our roadways in a wide range of situations. Our research focuses on ensuring that these and other systems operate safely in all situations, even those that are not conceived by the designers of the systems. To tackle this issue, we apply formal verification techniques, which allow us to either produce a conclusive proof that the system is safe in all situations, or provide a counter example. However, these methods are only useful if they are powerful and robust enough to verify the computers which actually control our cars. To this end, we have developed several collaborations with people outside our field to ensure that the methods and tools we develop are increasingly applicable and useful. One such collaboration is with researchers in the Engineering department at Carnegie Mellon University. Together we are investigating how to create the right abstractions to translate systems which are currently too complex to prove directly into provably safe systems, without lessening the strength of our safety guarantees on the original system. This ongoing collaboration has already resulted in a publication in the 2012 American Controls Conference. We have also collaborated with visiting researcher Stefan Mitsch. In this work, we used formal methods to determine the minimum resolution required for an onboard camera to detect signs early enough to make appropriate control choices. This work is published in the 2012 International Conference on Cyber-Physical Systems.

**Impact on Other Discipline**

As described above, much of our research has resulted from cross-disciplinary collaborations. We have developed several collaborations with people outside our field to ensure that the methods and tools we develop are increasingly applicable and useful. One such collaboration is with researchers in the Engineering department at Carnegie Mellon University, which has resulted in a publication in the 2012 American Controls Conference. We have also collaborated with visiting researcher Stefan Mitsch. This work is published in the 2012 International Conference on Cyber-Physical Systems.

**Thrust Area #4: Large-Scale Mobility and Data Analytics**

Social Networks in Transportation (DOT Goal: Livable Communities; Topic: Land Use Planning and Multi Modal Transportation Research)  
**Lead:** Dr. Lavanya Marla and Dr. Ramayya Krishnan (CMU)

**Publications**

**Type of publication:** Conference paper and poster presentation
Author(s): Yisong Yue, Lavanya Marla and Ramayya Krishnan
Title: An Efficient Simulation-based Approach to Ambulance Fleet Allocation and Dynamic Redeployment Proceedings: National Conference on Artificial Intelligence (AAAI) Year: June 2012
Status: Accepted Acknowledgement of federal support (yes/no): No

Technologies and Techniques
Data-driven methodologies, simulation-embedded optimization

Individuals Working on this Project
Name: Lavanya Marla Project Role: Co-PI Hours: 40 hours per month Contribution: Research Funding: None from UTC Country(ies) of foreign collaborator: India

Name: Yisong Yue Project Role: Post-doctoral associate Hours: 40 hours per month Contribution: Research Funding: None from UTC Country(ies) of foreign collaborator

Other Collaborators
An emergency medical services provider in a large Asian economy provided the data for the paper "An Efficient Simulation-based Approach to Ambulance Fleet Allocation and Dynamic Redeployment"

Impact on the Development of the Principal Discipline
New techniques for emergency management decisions

Distributed Transit Rider Messaging (DOT Goal: Livable Communities; Topic: Land Use Planning and Multi Modal Transportation Research)
Lead: Dr. Aaron Steinfeld (CMU)

Technologies and Techniques
A technique for extracting tabular data from alert and transportation related websites, called SmartWrap, has been advanced from prototype stage. The team has successfully demonstrated example use cases including, but not limited to: PA state alert pages, home baseball schedules, local theater schedules, etc. We are trying to refine the system to better handle content from transit agency web pages (e.g., alerts, detours, etc). While some agencies provide such data in open formats (e.g., NYC), most do not and the only way to obtain the information is from their websites. Under other funding, the team is also in the process of updating the Tiramisu system architecture, data model, and user interfaces to support rider and transit agency messaging. This pipeline will be used to transmit information obtained from relevant websites.

Individuals Working on This Project
Name: Steve Gardiner Project Role: Graduate Student Number Hours: Since May Contribution: Primary researcher Funding: Full time since May Country(ies) of foreign collaborator: Japan (IBM)

Other Organizations Involved as Partners
Tiramisu Transit LLC, the team's spinout company for commercializing Tiramisu, received a Phase I SBIR from US DOT. The company side of the team has begun work on the project and will coordinate with university team members throughout the project. This SBIR is focused on commercialization and sustainability of the crowdsourced transit information system approach.

Collaborators Involved
SmartWrap and related technologies and methods were discussed with a visitor from IBM Research Japan. We have existing relationship, as two of our students have completed summer internships with the group.
Impact on the Development of the Principal Discipline
The SmartWrap approach was described and demonstrated to an industry visitor. While this has minimal impact, demonstrating a new method works has the potential to motivate the visitor and their organization to plan for the eventual deployment of such technologies. Knowing something is possible is different than guessing it is possible.

Real-Time Traffic Congestion Management (DOT Goal: Livable Communities; Topic: Land Use Planning and Multi Modal Transportation Research)
Lead: Prof. Rahul Mangharam (Penn)

Publications
Author(s): Yash Pant, Miroslav Pajic and Rahul Mangharam
Status: Under review Acknowledgement of federal support: Yes

Websites
AutoPlug - Automotive Architectures for Electronic Controller Unit Testing and Verification
http://www.autoplug.org
GrooveNet - Open-source simulator for Vehicle-to-Vehicle Networks
http://mlab.seas.upenn.edu/GrooveNet
AutoMatrix - A Large-scale Traffic Simulator for Real-Time Traffic Routing
http://mlab.seas.upenn.edu/AutoMatrix

Technologies or Techniques
Project I - AutoPlug: An Automotive Architecture for Remote Electronic Controller Unit Diagnostics and Testing In 2010, over 20.3 million vehicles were recalled. Software issues related to automotive controls such as cruise control, anti-lock braking system, traction control and stability control, account for an increasingly large percentage of the overall vehicles recalled. There is a need for new and scalable methods to evaluate automotive controls in a realistic and open setting. We have developed AutoPlug, an automotive Electronic Controller Unit (ECU) architecture between the vehicle and a Remote Diagnostics Center to diagnose, test, update and verify controls software. Within the vehicle, we evaluate observer-based runtime diagnostic schemes and introduce a framework for remote management of vehicle recalls. The diagnostics scheme deals with both real-time and non-real time faults, and we introduce a decision function to detect and isolate faults in a system with modeling uncertainties. We also evaluate the applicability of "Opportunistic Diagnostics", where the observer-based diagnostics are scheduled in the ECU's RTOS only when there is slack available in the system. This aperiodic diagnostics scheme performs similar to the standard, periodic diagnostics scheme under reasonable assumptions. This approach works on existing ECUs and does not interfere with current task sets. The overall framework integrates in-vehicle and remote diagnostics and serves to make vehicle recalls management a less reactive and cost-intensive procedure.

Project II - GrooveNet Hybrid-Network Simulator for Development of Vehicle-to-Vehicle Network Protocols GrooveNet is a hybrid simulator which enables communication between simulated vehicles, real vehicles and between real and simulated vehicles. By modeling inter-vehicular communication within a real street map-based topography it facilitates protocol design and also in-vehicle deployment. GrooveNet's modular architecture incorporates mobility, trip and message broadcast models over a variety of link and physical layer communication models. It is easy to run simulations of thousands of vehicles in any US city and to add new models for networking, security, applications and vehicle interaction. GrooveNet supports multiple network interfaces, GPS and events triggered from the vehicle's
on-board computer. Through simulation, we are able to study the message latency, and coverage under various traffic conditions. On-road tests over 400 miles lend insight to required market penetration.

Project III - AutoMatrix: A Large-scale Traffic Simulator for Real-Time Traffic Congestion Management
AutoMatrix is a vehicle traffic simulator that models cars driving through a street map, as well as the algorithms that can be used to route and direct these cars. It successfully simulates vehicle traffic congestion due to heavy usage or traffic incidents, and the effects on surrounding areas. Using NVIDIA CUDA parallel processing technology, the simulator can easily handle millions of cars driving across the map simultaneously. The goal for the project is to study real-time, dynamic routing algorithms for nodes in sparse graphs, such as street maps. The algorithm will consider current and known future conditions, and will also be able to react to unplanned incidents that occur. In terms of vehicles on the street, this translates to finding the fastest way to direct a large number of cars to get them from their starting points to their destinations.

**Individuals Working on this Project**
**Name:** Yash Pant  **Project Role:** UPENN Graduate Student  **Hours:** 40 hours per week  **Contribution:** Development of AutoPlug  **Funding:** UTC

**Name:** Paul Gurniak  **Project Role:** UPENN Graduate Student  **Hours:** 40 hours per week  **Contribution:** Development of AutoMatrix  **Funding:** UTC

**Name:** Lei Tao  **Project Role:** UPENN Graduate Student  **Hours:** 40 hours per week  **Contribution:** Development of GrooveNet  **Funding:** UTC

**Other Organizations Involved as Partners**
SEPTA Philadelphia - Project formulations for the remainder of the UTC award period. Identified projects to collaborate on related to train scheduling, predictive maintenance and development of transit apps. Facilities support in-kind to Penn.

Philadelphia Mayor's Office - Department of Streets and Traffic Defined collaborative project to help with the development of the Philadelphia Traffic Operations Center. The focus will be on scheduling and control of traffic signal lights and of acquisition of camera data across the city of Philadelphia. Facilities support in-kind to Penn.

Delaware Valley Regional Planning Commission Serve on Advisory Board for Evacuation Strategies from the tri-state region. Use of tools such as AutoMatrix will help in simulating and analyzing routes for evacuation during emergencies in the metropolitan area. Facilities support in-kind to Penn.

**Impact on the Development of the Principal Discipline**
**Project I - AutoPlug: An Automotive Architecture for Remote Electronic Controller Unit Diagnostics and Testing** Open-source hardware/software platform is used to further the development of methods to reduce the cost and damage due to potential automotive recalls. This project won the 8th World Embedded Programming Competition in Seoul, Korea.

**Project II - GrooveNet Hybrid-Network Simulator for Development of Vehicle-to-Vehicle Network Protocols** Open-source software that has been downloaded by over 45 institutions for development of protocols for vehicular networks that will make transportation safer and more efficient. The platform works both in real vehicles and with simulated vehicles on any US street map and is able to evaluate the potential benefit as more vehicles have communication capabilities.

**Project III - AutoMatrix: A Large-scale Traffic Simulator for Real-Time Traffic Congestion Management** This project allows us to simulate very large traffic congestion scenarios (involving over 16
MILLION vehicles) and has furthered the research in real-time traffic routing. With this open-source tool, planners will be able to evaluate the potential impact of different route planning decisions, where congestion will form in the next few years and how different road topologies will result in different congestion scenarios.

Impact on Other Disciplines
We are interfacing with the Penn Transit Policy program to understand how these technologies may be integrated within the regulatory environment.

Travel Behavior Data Analysis and Synthesis to Promote Transportation System Safety and Reliability (DOT Goal: Livable Communities; Topic: Land Use Planning and Multi Modal Transportation Research)
Lead: John Landis (Penn)

This progress report describes the status of four Transportation Safety and Reliability Data Analysis (TSRDA) projects to be undertaken under the auspices of the CMU/Penn Center for Transportation Safety and Reliability (T-SET) by Crossways Professor and City Planning Chair John Landis and four masters students.

Understanding Sources of Congestion Resilience
Current Status: Will formally begin September 1, 2012; preliminary data collection currently underway.

Bayesian Modeling of Transit Vehicle Breakdowns
Current Status: Will formally begin September 1, 2012; preliminary contacts with SEPTA have already been made.

Statistical Modeling of Traffic Accidents

How Real People Respond in Real Time to Real Congestion

Thrust Area 5: Policy & Guidance

Assessment of Information & Communication Technologies in Transportation (DOT Goal: Livable Communities; Topic: Development of Livability Performance Measures)
Lead: Chris Hendrickson (CMU)

Individuals Working on this Project
Name: Yeganeh Mashayekh Project Role: Doctoral Student Hours: 40 hours/week Contribution: Research Funding: UTC

Quantitative Trust Management for V2V/V2I Networks (DOT Goal: Safety; Topic: Technology-Related Research)
Lead: Insup Lee (Penn)

Publications
Type of publication: Presentation Author(s): Jian Chang, Krishna K. Venkatasubramanian, Insup Lee Title: Quantitative Trust Management (QTM) and Vehicle-to-Vehicle Networks (V2V)
Journal: The 1st ACM International Conference on High Confidence Networked Systems (HiCoNS) Poster and Demonstration Session Volume: Year: 2012 Status: accepted
Acknowledgement of federal support: yes
Technologies or Techniques
We have proposed a novel trust management framework for ensuring trustworthy traffic accident report using Vehicle-to-Vehicle (V2V) networks. Accident report messages being received can be evaluated regarding their trustworthiness through explicit feedback mechanism or auto-correlation with authoritative dataset, with the benefit of hindsight. Such historical behavior information of message sender will be used to compute a trust value for trust decision making by the receivers of the message in real-time. Further, static information about the message sender such as vehicle maker, vehicle model, and spatial and temporal context information is also considered to reason about trust and to achieve trust decisions.

Individuals Working on this Project
Name: Insup Lee Project Role: Project leader (Cecilia Fitler Moore Professor at the University of Pennsylvania) Contribution: Leading the research team.

Name: Krishna K. Venkatasubramanian Project Role: Project member (Postdoctoral Researcher at the UPenn) Contribution: Designing the system framework and workflow under the collaboration with other project members.

Name: Jian Chang Project Role: Project member (Doctoral Student at the UPenn) Contribution: Designing the system framework and workflow under the collaboration with other project members.

Name: Cong Liao Project Role: Project member (Master Student at the UPenn Contribution: Conducting experiment and programming under the collaboration with other project members.

Impact on the Development of the Principal Discipline
(1) Improve the state-of-the-art of trust management in vehicular networks, poster presentation at international conferences. (2) Support and train graduate students and postdoctoral researcher.