Program Progress Performance Report for University Transportation Centers

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Research and Innovative Technology Administration
UTC Program

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

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Signature: [Signature]
Major Goals and Objectives of the Program

Research, Development, Deployment
The CMU-Penn T-SET UTC focuses on safety. Our research is specifically targeted at improving the safety of automotive drivers and passengers, bicyclists and pedestrians, and the safe usage of trucks and mass transit vehicles. 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.

Metrics:
- Faculty scientific leadership as reflected by the number of publications and citations of faculty work in transportation-related areas;
- The number of staff, faculty and students involved in leadership positions in academic, industry and government transportation organizations;
- New research collaborations in fields related to this work;
- Successful technology deployments and their impact; and
- Patents and start-ups.

Education and Workforce Development
Education and workforce development are important complements of the T-SET research program.

Metrics:
- Number of transportation-related courses,
- Students participating in transportation research projects,
- Advanced degree programs funding T-SET UTC students,
- T-SET UTC-funded graduate students,
- T-SET UTC-funded students who receive degrees,
- Institutional educational partnerships, and
- Participants in workforce and educational programs.

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

Metrics:
- Simple adoption of the innovation by a transportation operator, company or public, to more formalized outcomes such as licensing, patents, commercialization, and spin-off companies.
- Quantify numbers of meetings, attendance, publications, and social media and website activity.

Collaboration
Collaboration is the heart of the entire T-SET program. CMU and Penn seek to ensure our research and development program leads to deployment of technologies in the transportation systems serving our communities and state, providing pilot 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 and industry partners.

- Number and diversity of members of both the T-SET Consortium and Advisory Council, and by the
- Number and impact of deployments achieved through collaboration

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

Research, Development and Deployment
During this reporting period, T-SET was involved in supporting the City of Pittsburgh's application to the USDOT's Smart City Challenge

- T-SET faculty Sean Qian met with Bob Taylor, Manager of Traffic Operations at the Pennsylvania Turnpike Commission, to discuss research opportunities.
- Attended Smart City DOT Meeting
- Co-hosted Smart City Meeting with PennDOT
- Visit and events at CMU by Charlie Catlett, Un. Of Chicago
- Attended US DOT Visit to Pittsburgh
- Attended US DOT Smart City V2I Safety Applications Tour
- Attended CUTC and UTC Summer Meeting
- Participated in the Smart City Challenge Smart PGH Oral Presentation
- Attended Pitt Microgrid Tour of Pitt Ohio, Millvale and Sharpsburg
- Attended USDOT Opportunity Summit Connects Leaders and Communities
- Attended Future of Interstate Study Meeting recently launched the Transportation Research Board.
- Presented at the TRB Automated Vehicle Symposium

Education and Workforce Development

During this reporting period, we were the University lead for the Women’s Transportation Seminar (WTS) DC Youth Summit which brings 22 female students from across the nation for 5-day long conference; we sponsored a Women in Transportation Summer Scholars Fellowship for undergraduates in partnership with the Robotics Institute, focused efforts on expanding the programming of the Transportation Club.

Other Education and workforce development activities include:

- Heinz College Capstone Advisory Committee for School of the Blind
- Heinz College Capstone Advisory Committee for Chateau Street and URA
- Advisor to the following independent studies:
  - Developing a business plan for a transportation technology spin off,
  - Developing a deployment strategy for transportation technology spin off,
  - Analysis of Port Authority transit oriented development possibilities for existing rapid transit stops
  - Developing a deployment plan for SmartPGH without $40mil from USDOT
- Hosted 2 T-SET faculty meetings Hosted second event in series of Transportation Tech Nights: Crash Data Hack Night in partnership with the Western PA Regional Data Center, The Carnegie Library of Pittsburgh and Allegheny County
- Attended Committee Meetings for Transportation You
- Transportation Club Held 3 Meetings

Technology Transfer & Collaboration

On September 29th, together with PennDOT, T-SET conducted a driverless car demonstration in Harrisburg. The Governor, the Secretary of PennDOT, and state legislators rode in the Cadillac SRX driverless car in the new Harrisburg Connected and Automated Vehicle test bed. The third such test bed in Pennsylvania.

T-SET held the following Seminar Series:

1. **Automated Cars: Safety and Cost Savings**  Corey Harper
2. **What’s Next for Surtac: Impacts for Freight, Buses, Bicycles and Pedestrians**  Greg Barlow
3. Connected and Automated Vehicles in Pennsylvania: Demonstrations and Public Policy Challenges

Chris Hendrickson

- T-SET Director Raj Rajkumar was recently featured with CMU’s autonomous vehicle in Lo and Behold, Reveries of the Connected World, a film by Werner Herzog.
- On September 6-7th, key players including T21’s Chris Hendrickson gathered in our nation’s capital for the Future of Interstate Study Meeting recently launched the Transportation Research Board. Pursuant to the FAST Act of 2015, the 3-year, $5 million study is required to move forward on potential upgrades to the National System of Interstate and Defense Highways in order to meet the needs of the 21st century. Chris Hendrickson also serves on the Future Interstate Study Committee, an appointed board of 14 experts.
- On August 22nd, T-SET Director Raj Rajkumar hosted a workshop at the Autonomous Vehicles 2016 conference. His workshop, Protecting Citizens While Ensuring Cost Benefit of Implementation, was one of several workshops on Autonomous Cars track.
- CMU hosts the TRB Traffic Signal Systems Committee Mid-Year Meeting in Pittsburgh July 24th through 26th. Highlighted on the last day of the meeting was the UTC funded Surtrac, a connected vehicle technology with a real time adaptive signal system.
- PennDOT District 11’s Civil Engineer Council and Young Professionals in Transportation Pittsburgh chapter toured the Traffic21/T-SET Robotics labs at CMU on September 2nd. Here they are pictured in the Navlab with T-SET Director Raj Rajkumar and CMU’s driverless car.
- On August 4th, Stan Caldwell joined the USDOT and local leaders in Harrisburg for a roundtable discussion on the success of Pennsylvania’s State Transportation Innovation Councils (STIC) model. Deputy Secretary Mendez called Pennsylvania inspirational, showcasing the innovations by university transportation centers and STIC’s for highway projects.
- CMU hosted the TRB Traffic Signal Systems Committee Mid-Year Meeting in Pittsburgh July 24th through 26th. Highlighted on the last day of the meeting was the UTC funded Surtrac, a connected vehicle technology with a real time adaptive signal system.
- Stan Caldwell discussed the future of mobility through the impacts of connected and autonomous vehicles at the Future of Mobility Conference. The conference was hosted by the Regional Transportation Alliance of Southwestern Pennsylvania and held here in Pittsburgh on Monday, July 11th.
- The work of CMU professor Hae Young Noh was highlighted by Samsung’s CEO during his keynote lecture at the Internet of Things “Transforming the Future” event. Held in Washington D.C. on June 21st, CEO Kwon featured Noh’s work to demonstrate the potential for the Internet of Things to transform future cities.

Other Technology Transfer and Collaboration Activities include:

- Presented at Annual PennDOT Safety Symposium
- Presented City of Pittsburgh Inclusive Innovation Week
- Meeting with PA Secretary of Administration Minnich on Go Time
- Hosted ITSPA Tour of Pitt and CMU labs
- Attended WTS Northeastern Regional Council Meeting
- Attended ITSA Leadership Circle meeting
- Attended AIA Build Pittsburgh
- Hosted Singapore Land Transport Authority Visit
- Co-hosted Metro21 Speaker Series
- Participated in ITSPA Legislative Roundtable on Connected and Automated
- Attended Innovations in Urban Infrastructure Financing’, New Cities Foundation
- Presented at ASHE National Conference Pittsburgh
- Presented at Launch CMU Smart Cities SV
• Attended Multi State Corridor Meeting
• Attended PennDOT Automated Vehicle Working Group Visit to CMU
• Hosted USPS Meeting
• Presented at NE Regional AASHTO Meeting
• Hosted Senator Pat Toomey’s Chief of Staff, Christopher Gahan, tour of T-SET lab
• Attended ITS Annual Meeting
• Attended Smart Cities Innovation Summit
• Presented at ASCE Houston Event
• Hosted PPG Visit to CMU
• Attended Regional Transportation Alliance Forum
• Hosted US Attorney Visit
• Presented at ITSPA MASITE Annual Meeting
• Hosted State Farm Visit
• Spoke at Thrival Innovation Festival
• Presented at ITS Educators Workshop
• Presented at NACTO Conference
• Presented at Smart Cities Week

Diversity

T-SET continues to push initiatives that support women in the intelligent transportation domain including:
• Supporting the Women in Transportation Fellow to attend TRB Annual Meeting
• Member of the board of Pittsburgh Chapter of the Women’s Transportation Seminar
• Sat on panel with Leslie Richards WTS Lunch
• Member of the Northeast Regional Council of the Women’s Transportation Seminar
• Participated in WTS Scholarship Committee
• Sat on Women’s Forum Panel with Sec. Richards
• Held a meeting of the Women’s Graduates in Transportation Group
• Worked with WTS International on the Transportation YOU steering, leading the development of the challenge book for high school girls at the Transportation U event to be held in DC, summer 2016.

Products

General Program Products
• UTC website  www.uts.ices.cmu.edu
• 6224 blog posts
• Consistent weekly distribution of T-SET email newsletter, 1,684 subscribers
• Continue to use a webinar-based system of linking CMU and UPenn faculty and students for our bi-monthly T-SET meetings. Now a faculty member interactively presents their research at the beginning of each meeting.
• Promotion of various CMU and Penn research news articles in the T-SET blog and newsletter

T-SET In the MEDIA

September 30, 2016 - PennDOT Secretary: PA has quickly become a national leader in autonomous vehicles
September 30, 2016 - Udacity’s Self-Driving Car Engineering Degree Lures Over 11,000 Hopefuls
September 29, 2016 - ‘Absolutely amazing!’: CMU Driverless Cadillac laps Capitol Complex in Harrisburg
September 29, 2016 - Take a self-driving ride in CMU’s ride with News 8’s Brian Roche
September 29, 2016 - VIDEO: CMU Driverless car cruises Harrisburg searching for support
September 29, 2016 - A look at CMU’s role in the creation of self-driving cars
September 29, 2016 - Pitt joins Carnegie Mellon, city in White House Metrolab network
September 29, 2016 - Paul Mackie, Mobility Lab to speak at Traffic21, October 6th, Smart Transportation: Small Changes for Big Impact
September 26, 2016 - Self-Driving Hype Doesn’t Reflect Reality
September 22, 2016 - Self-driving Uber vehicles spotted on the streets of San Francisco
September 22, 2016 - Get Ready for Freeways That Ban Human Drivers
September 22, 2016 - CMU's Jon Peha Solving the Money Gap of Connected Vehicle Infrastructure Deployment
September 22, 2016 - Traffic21 Director Chris Hendrickson on CAV Policy and Implications; 9/29 LIVESTREAM
September 22, 2016 - Fed guidelines for self-driving cars won’t get in Pa.’s way
September 22, 2016 - The New Yorker Commentary: Pittsburgh “a perfect proving ground” for Uber tests
September 16, 2016 - Meet the startup that two of Google’s top self-driving engineers left to create
September 16, 2016 - Automakers may be beating Silicon Valley with robot cars, violating the laws of disruption
September 15, 2016 - CMU PRESIDENT SURESH TAKES RIDE IN UBER DRIVERLESS CAR w/ MAYOR PEDUTO
September 15, 2016 - Driverless Car Valley: The Pittsburgh Model for Innovation
September 15, 2016 - Uber riders in Pittsburgh can hail self-driving Ford Fusions in test program
September 13, 2016 - Uber’s Pittsburgh Project Is a Crucial Test for Self-Driving Cars
September 12, 2016 - This is why senior citizens get into accidents — and here’s what we can do about it
September 12, 2016 - No Driver? Bring It On. How Pittsburgh Became Uber’s Testing Ground
September 8, 2016 - Traffic21’s Women in Transportation Fellow, Ngani Ndimbie, awarded Pittsburgh 40 under 40
September 6, 2016 - The Road Ahead: Driverless Vehicles, Cities, and Architecture
September 6, 2016 - Self driving cars in more chaotic driving patterns
September 1, 2016 - President Obama to visit Pittsburgh for Innovation Conference
September 1, 2016 - The Looming Threat To Uber's Plan for World Domination
September 1, 2016 - Obama to Guest-Edit Wired Magazine
August 25, 2016 - Martial Herbert, Director of Carnegie Mellon's Robotics Institute Talks with 'To the Point' re: UBER
August 25, 2016 - Pittsburgh Public Meeting August 31: Forbes Avenue Near CMU Redesign Project
August 25, 2016 - Self-driving cars reach a fork in the road, and automakers take different routes
August 23, 2016 - Delphi, Mobileye team up for Level 4 self-driving tech
August 23, 2016 - Pittsburgh public meeting Aug. 31: Your voice needed on a Forbes Ave. near CMU redesign project
August 22, 2016 - Martial Herbert, Director of Carnegie Mellon's Robotics Institute Talks with 'To the Point' re: UBER
August 21, 2016 - How Tesla Autopilot drove a man with a blood clot to the hospital, and expanded the autonomous car debate
August 19, 2016 - Pittsburgh Is Going Driverless
August 19, 2016 - Uber's First Self-Driving Fleet Arrives in Pittsburgh This Month
August 19, 2016 - The Benefits of Semi-Automated Vehicles
August 17, 2016 - Tesla isn't alone with cars that can nearly drive themselves
August 16, 2016 - Advancing the Smart City movement through big data
August 16, 2016 - Pennsylvania Creates Task Force to Prep for Arrival of Self-Driving Cars
August 16, 2016 - How Many of Our Vehicles Could Be Electric? How Does 87% Strike You?
August 15, 2016 - Pennsylvania steers research into driverless technology
August 15, 2016 - She wants to make an autonomous wheelchair
August 15, 2016 - Carnegie Robotics, MVS Partner to Deliver Smart Mining Solutions
August 11, 2016 - Andrew Moore: Nobody 'poaches' talent from CMU
August 11, 2016 - Uber back in Austin to map streets
August 10, 2016 - Lo and Behold: Reveries of the Connected World; Werner Herzog explores online gaming, self-driving cars and soccer-playing robots
August 5, 2016 - Pittsburgh's PGH Lab 2016 Cohort Brings Startups into City Operations
August 1, 2016 - Tesla's Ambitions Run Into The Realities Of Making Cars
August 1, 2016 - PBS: Can Autonomous Cars Learn to be Moral?
August 1, 2016 - Uber Starts Mapping Roads in Mexico
August 1, 2016 - Elon Musk's push for autopilot unnerves some Tesla employees
July 26, 2016 - CMU: How $600 In Auto Safety Features Could Save Up To $202 Billion In Crash Costs
July 26, 2016 - Automakers Need to Work Together for a Truly Autonomous Future
July 22, 2016 - Uber is partnering with a satellite imaging company to help drivers find you
July 19, 2016 - CMU study: Semi-automated cars would boost safety
July 19, 2016 - CMU data science grad takes on bus bunching
July 18, 2016 - The Road to Driverless Cars: 1925 - 2025
July 18, 2016 - GM Earnings This Week to Shed Light on Big Investments
July 18, 2016 - Tesla Working on Autopilot Radar Changes After Crash
July 12, 2016 - CMU robotics researchers develop flying robots to find weaknesses in large structures such as bridges
July 5, 2016 - 'Socially-cooperative' cars are part of the future of driverless vehicles, says CMU professor
July 5, 2016 - PA Policymakers race to address self-driving vehicles
July 5, 2016 - LED Streetlights Are Great For The Planet — But Horrible For Your Health
July 5, 2016 - Tesla and Google Take Different Roads to Self-Driving Car
June 28, 2016 - Driverless Cars Will Face Moral Dilemmas
June 28, 2016 - Uber Reportedly Shopping Hyundai For Self-Driving Fleet
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June 28, 2016 - When self-driving cars arrive, drivers may not let go of wheel
June 28, 2016 - Why the US government should take Tesla up on its offer to share Autopilot data
June 28, 2016 - Once thought of as a just a dream — is the Hyperloop a real possibility?
June 17, 2016 - Skeptics of Self-Driving Cars Span Generations
June 16, 2016 - The Potential of Self-Driving Vehicles | CMU's Raj Rajkumar | TEDxPittsburgh
June 14, 2016 - How Future Tesla Owners Will Escape Range Anxiety
June 9, 2016 - 10 years of Bicycle Crash data released in PGH, HACK WITH US TONIGHT
June 9, 2016 - Pittsburgh's Smart City proposal combines data, energy and transportation
June 9, 2016 - Emergence as Regional Tech Hub Reflected in Pittsburgh's Smart City Challenge Bid
June 9, 2016 - Werner Herzog spotlights CMU innovations in new trailer for "Lo and Behold"
June 9, 2016 - Uber, Fiat Discuss a Self-Driving Car Partnership
June 8, 2016 - Industry rides along as Pennsylvania develops self-driving laws
June 2, 2016 - Wolf: What Self-Driving Cars Could Do For Pennsylvania
June 2, 2016 - June 9th, Bicycle Crash Data Workshop and Hack Night
June 1, 2016 - CMU self-driving car demoed with Sec. Richards as state bill presses on
June 1, 2016 - PA unveils task force to guide driverless car technology
May 31, 2016 - Autonomous-Car Startup Zoox Seeks Up to $252 Million in Funding
May 27, 2016 - Pittsburgh roads wired with 'talking' traffic signals
May 26, 2016 - Pittsburgh files for $50M transportation grant in Smart City Challenge
May 19, 2016 - Pittsburgh pitches comprehensive proposal for $50 million transportation grant
May 19, 2016 - Pittsburgh offers ultimate test for Uber's self-driving Fusions
May 17, 2016 - Top 10 Transportation Thought Leaders in Academia
May 13, 2016 - Secretary Foxx to Visit Seven Smart City Challenge Finalist Cities
May 11, 2016 - Buying an electric car can increase fuel use allowed by CAFE rules
May 9, 2016 - Bicycle count to analyze impact, pattern of added lanes in Pittsburgh
May 5, 2016 - Can Tesla Build Enough Electric Cars?
May 5, 2016 - Pat Hassett from City of Pgh will talk about Greenfield Bridge Demo at MASITE lunch
May 4, 2016 - U.S. EPA Provides $30 Million to Create Research Centers at Three Universities
May 4, 2016 - Engineering students designed this mobile playground that fits in a semi-truck trailer
April 29, 2016 - Ready for self-driving technology? PennDOT already looking at the challenges
April 29, 2016 - "Smokin Robot in 1939" - Pittsburgh has always been a leader in the robotics revolution
April 29, 2016 - DARPA’s Latest Concept Video Looks Like a Bad 90s Movie in an Awesome Way
April 28, 2016 - It isn’t just Uber: Carnegie Mellon’s computer science dean on its poaching problem
April 19, 2016 - Adelaide primed for driverless car research by Carnegie Mellon University
April 14, 2016 - Regarding Tesla sales to regular people: CMU Prof says it will take a lot
April 14, 2016 - WTS PGH Hosts Women's Forum with PennDOT Sec. Leslie Richards
April 14, 2016 - CMU in final round of SpaceX Hyperloop competition: 30 minutes from here to NYC
April 12, 2016 - Autonomous Parking Garages May Come Before the Cars
April 8, 2016 - CMU Prof on Tesla Delivery Snag
Appendix A - Research Projects Accomplishments, Products and Participants


**Website:** Mac.heinz.cmu.edu/traffic **Impact:** In the past two years, we have started building the data engine and a prototype web application to demonstrate the feasibility of Mobility Data Analytics Center. We started from the Pittsburgh region where we have close partnerships with many local entities, and have successfully applied our data analytics tools in several case studies. **Impact on Technology Transfer:** The web application for bike score has great potential to be commercialized and serve the mobility sustainability.

**Sharing Costs of Vehicle-to-Infrastructure Deployment for Safety, PI: Jon Peha, CMU Students: Alexandre Ligo Deployment Partner(s):** The vehicular network trial we use in our research is operating in the City of Porto. The University of Porto has shared data with us. The Ph.D. student working on this project has spent time in Porto, and the University of Porto has provided him office space when he is there. **Journal Publication(s):** Alexandre Ligo, Jon M. Peha and Joao Barros, "Throughput and Cost-Effectiveness of Vehicular Mesh Networks for Internet Access,": Proceedings of IEEE 84th Vehicular Technology Conference (VTC), Montreal, Canada, September 2016. Acknowledged federal support. **Other publications, conference papers and presentations:** Alexandre Ligo and Jon M. Peha, "Cost-Effectiveness of Using Connected Vehicle Infrastructure for Internet Access," 2016 MASITE-ITSPA Annual Conference, State College, PA, August 2016. Acknowledged federal support. **Other dissemination activities:** Made a presentation to leadership at the U.S. Federal Communications Commission (FCC) on this research, and its implications for FCC regulations on spectrum for ITS. **Website:** https://users.ece.cmu.edu/~peha/vehicular.html **Impact:** This program has contributed to transportation research by showing that DSRC-based connected vehicle mesh networks can be cost-effective as dual-use technology, i.e., they can support both safety applications and provide Internet access in a way that is more cost-effective than cellular networks. In particular, our results show that these vehicular networks will be more cost-effective than cellular networks just a few years after deployment in densely populated cities like Chicago, Boston, New York and San Francisco. **Impact in other disciplines:** The impact on telecommunications is both technical and economic. First, as described above, our results show that connected vehicles offer a new way to provide mobile Internet access, and that this approach will soon be more cost-effective than today’s approach in urban areas. Second, our results show that connected vehicles scale well, which has been an open research question. In particular, even when the number of DSRC-equipped vehicles per square mile and the data rate per vehicle are greatly increase, the mechanisms that deal with congestion and interference are sufficiently effective that throughput remains stable. **Impact on Technology Transfer:** We have presented results to the U.S. Federal Communications Commission (FCC), and offered advice to them on connected vehicles. The FCC has important decisions to make regarding spectrum used for
Intelligent Transportation Services, and technical standards for devices that operate in this spectrum band.

Multimodal Distraction Detection, PI: Maxine Eskenazi, CMU, Co-PI: LP Morency, Students: Yulun Du (formerly Shrimai Prabhumoye) Other publications, conference papers and presentations: UTC Summit Showcase, March 30, 2016 Washington DC Other dissemination activities: The database that we are in the process of creating is being structured in a way that will allow for easy dissemination to anyone who requests it. We have also crafted our consent form so that the data can be used by others and can be annotated. Website: http://utc.ices.cmu.edu/utc/projectitem.asp?ID=192 Technologies / Techniques: We are in the process of creating a database of subjects using a driving simulator and being distracted by emails, texts and phone calls while doing so. We will have 50 subjects by the end of 2016. There is a back-facing camera that captures both the subject, their head movements, gaze, etc and the audio of the session. We will use this data to have a fuller picture of the conditions that cause distraction and of different degrees of distraction. We will use machine learning on this dataset to automatically determine when a driver was distracted. Other Products associated: The abovementioned dataset. Please explain: The dataset, when finished, will be advertised at major conferences and through mailing lists to colleagues who can request a copy for their own research. Impact: This dataset should dramatically change the way we look at distraction. So far, researchers have taken it to be very straightforward to detect distraction - whenever there is a change in some constant user behavior, there is distraction. This leads to many false positives and to the user abandoning any warning system based on this approach. We depart from that view by standing on solid psychology research that shows that distraction is a more complex event, changing from one individual to another and changing according to the type of cognitive load and task that the individual is confronting. Impact in other disciplines: Results of our work (when implemented and tested) should reinforce the theories put forward in psychology.

Non-intrusive Driver Fatigue and Stress Monitoring Using Ambient Vibration Sensing, PI: Hae Young Noh, CMU, Co-PI: Pei Zhang, Students: Susu Xu, Frank Mokaya, Amelie Bonde Deployment Partner(s): Renault Innovation Silicon Valley, 1215 Bordeaux Dr, Sunnyvale, CA 94089 Together with Renault, we evaluated our system in a realistic situation during driving scenarios. We used their driving simulation facility to test driving stress, noise model and noise separation algorithms efficiency in a controlled and safe environment. In addition, we utilized the research Nissan Leaf vehicle at the lab to test our algorithm with the subject in the passenger seat on isolated roads in the NASA research center where CMU SV campus is located. Journal Publication(s): Mokaya, F., Lucas, R., Noh, H., & Zhang, P. (2016). Burnout: A Wearable System for Unobtrusive Skeletal Muscle Fatigue Estimation. The 15th ACM/IEEE International Conference on Information Processing in Sensor Networks (IPSN ’16). Published. Partially supported by NSF, Renault, Google. Other dissemination activities: 1. We presented our work at Intel, February 2016. 2. We gave a seminar on this project at Lehigh University, Bethlehem, PA, April 2016. 3. We presented our work at Microsoft Research, May 2016. 4. We presented our work at IWCP workshop, August 2016. Website: https://www.cmu.edu/cee/people/faculty/noh.html, https://www.cmu.edu/silicon-valley/faculty-staff/zhang-pei.html Technologies / Techniques: We have been developing a driver fatigue and stress monitoring system using embedded accelerometers in car seats. These sensors can sense physiological states of the driver, such as movement, heart rate, and breathing, and then infer high level driver status, such as attention level and stress. Our algorithm combines analytical human model with data-driven approaches to reduce modeling uncertainties and noise in the signal. The developed technologies are and will be shared through publications and PI’s research lab website. Other Products associated: We created a demo based on this project. A car seat cushion with embedded accelerometers measure and display heartbeat signals from a person sitting on it. This demo has been presented during our other dissemination activities described above. Impact: By monitoring the fatigue and stress level of the driver through the physiological variables, we enable the autonomous cars to
understand the capability of the driver to take the control back in dangerous and/or unexpected situations. This will further improve the safety of the autonomous vehicles in dangerous situations. The PIs also plan to use the developed demo for outreach and education activities at CMU. **Impact in other disciplines:** Our research has impacts in many other disciplines. First, the development of our sensing system can be applied to other fields for non-intrusive indirect monitoring through vibration, such as wearable suits for muscle monitoring in sports activities, smart furniture to sense human activities, etc.

interruptibility and dialog-based HCI demands in cars (Note: for now, the actual contract between HMC and CMU has been ceased in the middle of contract process since both CMU and HMC have realized that HMC’s demand was closer to work-for-hire type project, rather than an academic research, and then both parties decided to postpone related discussion up to the next year.

Do Vehicle Safety Inspection Programs Result In Younger, Safer Fleets Or Do Younger, Safer Fleets Lead To Significantly Safer Vehicles?: The national effects and underlying benefits of the vehicle safety inspection program on the vehicle fleet or vice versa, PI: H. Scott Matthews, CMU, Co-PI: Paul Fischbeck and Chris Hendrickson, Students: Dana Peck, Michelle Liu Deployment Partner(s): CompuSpecifications, LLC, 1177 Pittsburgh Rd, Valenica, PA 16059. In-kind support: provided significant amount of data related to vehicle inspection characteristics and other details. They also provided many hours of in-kind technical support and background information related to transportation safety issues. Collaborative research and personnel exchange - we had various meetings at CMU and their headquarters, used their office space when needed to manage data transfers, etc. Journal Publication(s): Manuscript was submitted (not yet published): VEHICLE SAFETY INSPECTIONS AFFECT ON URBAN/RURAL FATALITY RATES, Peck, Fischbeck, Hendrickson, and Matthews, Accident Analysis and Prevention, 2016. Other publications, conference papers and presentations: During this time period, time was spent on preparing a poster presentation (by Dana Peck) for the annual TRB conference in early January in DC. Other dissemination activities: We held a meeting in November 2015 at PennDOT to discuss the results of this research (as well as other related work). Website: gdi.ce.cmu.edu Technologies / Techniques: We developed methods to assess fatality rates from reported data in conjunction with other sources. Please explain: We had to end the project early (March 2016) when the student leading the research accepted a post-doctoral fellow position at US DOT, and since there were no other students able to continue the proposed work. Impact: While the project had a premature ending due to personnel constraints, in addition to modifying regression analyses for modeling motor vehicle fatalities across the U.S. and comparing States with more stringent safety inspection programs to those with less stringent programs to conclude whether having the annual vehicle safety inspection program is associated with fewer vehicle fatalities. We also reported on another research topic on vehicle travel trends was in progress. This research used PA emission inspection data which contained odometer readings for vehicles at the time of the annual inspection (along with inspection dates, registration zip code location, and vehicle characteristics) and allows for travel trends to be analyzed at the zip code level. In addition to vehicle travel trends, this data also allows for household travel trends and household vehicle preference by using a household identifier. The results of this work are useful in the transportation domain because they perform detailed comparisons of publicly available data sources to generate fatality rates useful for intrastate comparisons against the existence of safety inspection programs. Impact in other disciplines: There are potential impacts to the field of data science as well as in vehicle design.

Stereoscopic Programmable Automotive Headlights for Improved Safety on the Road, PI: Srinivasa Narasimhan, Robert Tamburo, CMU, Students: Srihari Sankar Other Collaborators: James Hoe, ECE professor, CMU has been involved with the project for some time to lend his expertise. Marie Nguyen, ECE PhD student, is working on FPGA development as part of her thesis work. Anthony Rowe, ECE, professor, CMU has been involved with the project for some time to lend his expertise. Deployment Partner(s): Financial support: NSF grant awarded to supplement funding towards the project. NSF (CNS-1446601). CPS: Synergy: TTP Option: Anytime Visual Scene Understanding for Heterogeneous and Distributed Cyber-Physical Systems. Closely working with the
National Robotics Engineering Center (NREC) to further develop project. They assist with facilities, staff, and equipment. We are currently in talks with General Motors, Ford, and Honda for partnership (financial support, resource support, and/or domain support) Journal Publication(s): "Performance Characterization of Reactive Visual Systems," Subhagato Dutta, Abhishek Chugh, Robert Tamburo, Anthony Rowe, Takeo Kanade and Srinivasa G. Narasimhan. IEEE International Conference on Computational Photography (ICCP), 2015. Houston, TX. Federal support acknowledged Website: http://www.cs.cmu.edu/~ilim/projects/IL/smartHeadlight/ Technologies / Techniques: We have developed headlights that can perform 3D reconstruction while driving. Distance estimations are used to improve classification algorithms. Our two programmable adaptive automotive headlights can also react to detected objects based on their measured shape. In order to accomplish the above, custom hardware, software, and algorithms were developed. Other Products associated: FPGA accelerated algorithm for stereo matching and computing disparity maps. Architecture for transmitting and receiving data between headlight prototypes. A unique data set will be acquired in the coming months-- images from two cameras while driving on various roads in different weather conditions. Impact: Our technology has numerous benefits towards improving safety on the road. As a programmable, stereoscopic headlight, we have available a platform available for developing never-before-seen safety features for automotive headlights. Developments are underway to create an easy to use API for developing algorithms for our headlight systems. We plan to engage with students through workshops and courses to teach them the API, and possibly, hold contests for best features developed. We have engaged with multiple entities in industry to move towards partnerships and commercialization in order to see our safety device on the road as soon as possible. Impact in other disciplines: We have demonstrated utility of our methods in the field of computational photography. We have also expect our work to benefit the area of cyberphysical systems.

Optimizing Snow Plowing Operations in Urban Road Networks, PI: Stephen F. Smith, CMU, Co-PI: Joris Kinable, Students: Suryansh Saxena Other Collaborators: Prof. Willem van Hoeve, Assoc. Prof. of Business, has participated in the design of the snow plow routing algorithms we have developed Deployment Partner(s): Organization: City of Pittsburgh, Public Works Department Location: City-County Building, Grant Street, Pittsburgh PA Partners Contribution: In-Kind Support Facilities: Knowledge acquisition visits at both PWD office and Division 3 Snow Plow facilities Collaborative research: PWD staff have shared expertise and data from their current "Route Smart" snow plow routing software; Plowing personnel have provided knowledge on their operations and snow plow planning constraints. Personnel Exchanges: Project not yet at the stage where this step is useful. Other publications, conference papers and presentations: 1. J. Kinable, W.-J. van Hoeve, and S. Smith, "Optimization models for a real-world snow plow routing problem," in Proceedings of CPAIOR , ser. LNCS , vol. 9676. Springer, May 2016, pp. 229–245 2. J. Kinable, W.-J. van Hoeve, and S. Smith, "Optimization models for a real-world snow plow routing problem," Nov. 2015, INFORMS, Philadelphia, USA 3. J. Kinable, W.-J. van Hoeve, and S. Smith, "Plowing the streets of pittsburgh - a dynamic route planning system," 2016, TRB, International Conference & Workshop on Winter Maintenance and Surface Transportation Weather, Fort Collins, USA Other dissemination activities: 1. J. Kinable and L. Haller, "Where does the snow go? Urban snow clearing challenges," Feb. 2016, Seminar series, Traffic21, Pittsburgh, USA Website: under construction Technologies / Techniques: Thus far, the project has developed the following technologies: (1) A prototype plowing route planner that generates snow plow routes that considers such objective criteria as minimizing completion or deadheading times, subject to roadway characteristics (e.g., number of lanes, directionality, segment distances) and vehicle constraints (fuel, salt capacity, travel speed). The planner accepts map data for
a given plowing area from Open Street Maps and returns a set of feasible vehicle routes for clearing it. The planner generates routes incrementally, which makes it ideally suitable for also reactively revising a set of routes in response to an unexpected problem (e.g., an abandoned vehicle blocking a road segment). (2) A mobile app that runs on a tablet that is intended to reside in each snow plow vehicle and provide the vehicle with turn-by-turn instructions. The mobile app receives as input a generated snow plowing route, and converts this route into turn-by-turn instructions as the route is executed. Impact: This project has made fundamental contributions to the snow plow routing research, contributing new search techniques for generating routes under realistic snow plowing constraints. We also expect the project to positively impact snow plowing operations in Pittsburgh. Our goal is to transition the capabilities we are developing into operations. Just the ability to communicate turn-by-turn instructions to drivers, a capability that we plan to pilot test this winter, will provide a significant advance over the current practice of reading routes printed on paper in the vehicles and reporting status by hand on these same sheets. The ability to better optimize routes, which we intend to deliver in the longer term, will result in better service and more efficient use of snow plowing resources. Impact in other disciplines: There are a range of municipal transportation services for which the technologies being developed could be applicable including trash pickup, street cleaning and local freight delivery. Impact on Technology Transfer: As indicated above, we expect to transition both in-vehicle technology for generating turn-by-turn instructions to drivers, and backend route generation and revision capabilities for managing overall operations.

**Route 51 Corridor Transformation: Phase II, PI:** Donald K. Carter, CMU, **Students:** Yuan Zi, Marantha Dawkins **Other Collaborators:** - Economic Development South (EDS): in kind contributions to organize and outreach activities. - Deliberative Democracy Program (Dietrich College): to conduct outreach activities **Deployment Partner(s):** Heinz Endowments, PennDOT, **Other dissemination activities:** - The Final Research Study Report or Phase II was submitted to PennDOT for dissemination within the agency. - Copies will also be distributed to SPC, the nine communities along the Route 51 corridor, PWSA, and ALCOSAN **Website:** http://www.cmu.edu/roi/ **Technologies / Techniques:** - the SURTRAC micro-traffic simulation model of the Robotics Institute was used in Phase I and Phase II of the research study - The Deliberative Democracy technique of community engagement was used in Phase I and Phase II of the research study - GIS technology was used extensively in study, including land use, environmental systems, transportation systems, and economic development scenarios. **Impact:** KEY TAKEAWAYS 1. Transportation Corridors are a new category of roadway classification, not just a new type of roadway. 2. Multimodal design will require changes in standards of design speed, level of service, and traffic calming. 3. Climate Change will alter how corridors will be designed in the future. 4. Federal and Pennsylvania transportation policies and standards are not fully reconciled with multimodal corridor planning. **Impact on Technology Transfer:** The SURTRAC technology has been patented and spun off as a start up company

**Unsafe Transit Connections, PI:** Aaron Steinfeld, CMU, **Co-PI:** Anthony Tomasic, John Zimmerman, **Students:** Sunny Zheng (undergrad) **Other Collaborators:** Elizabeth Traut, a post doc in the Robotics Institute, has been partially funded under this project. **Deployment Partner(s):** Tiramisu Transit LLC, Port Authority of Allegheny County **Other publications, conference papers and presentations:** 1. "Identifying Commonly Used and Potentially Unsafe Transit Connections With Crowdsourcing" has been accepted for presentation at TRB 2017. This will form the basis for a journal article under preparation. 2. "Tiramisu: A Large-Scale Participatory Public Transit Information System" poster at the 2016 Japan-America Frontiers of Engineering Symposium (JAFOE), National Academy of Engineering (NAE), one
of 60 invited engineers. Other dissemination activities: Work from this project, and Tiramisu as a whole, is regularly discussed with reporters, stakeholders, and other interested parties. Website: http://utic.ices.cmu.edu/utc/projectitem.asp?ID=203 Technologies / Techniques: Methods for extracting transit connections from the Tiramisu app logs have been developed. The algorithm for this process will be detailed in an upcoming journal article. Impact: We have created new methods for identifying transit connections from smartphone based participatory sensing systems. These methods include generation of new metrics on connection safety and efficiency, including techniques for registering connections with external data (e.g., crime, weather, etc). These methods and metrics have the potential for use by transportation engineers in other regions. Impact in other disciplines: When further along in our work, we will provide new knowledge on where unsafe and inefficient transit connections are occurring in the Pittsburgh region. These findings will have value to transit and infrastructure planners.

Supporting Bicycle Rider Safety, PI: Aaron Steinfeld, CMU, Students: Sarah Amick Other Collaborators: An RERC-APT staff programmer will assist with aspects of this work in the Fall of 2016. Deployment Partner(s): BikePGH Other dissemination activities: Material from this project is discussed with relevant stakeholders. Technologies / Techniques: Not applicable - this project focuses on gathering stakeholder input and assessing available technologies. Please explain: The team has collected survey responses from over 800 bicyclists in the local region. We are in the process of cleaning and reviewing this data. Impact: Results from the survey and software review will help inform associated technology development efforts at Carnegie Mellon. Impact in other disciplines: Some of the survey findings are likely to be relevant to transportation and infrastructure planners within the local region. Some generalizable information might be useful to other regions. Impact on Technology Transfer: Findings from the survey and software scan may lead to functional specifications for future bicycle safety systems.

Enhanced pedestrian and vehicle detection using surround-view camera systems, PI: Vijayakumar Bhagavatula, CMU, Co-PI: Nothing to report, Students: Zhiding Yu Deployment Partner(s): General Motors (GM) has been working with us in this research effort. GM has enabled the acquisition of a surround-view camera which was used to collect the videos used for developing computer vision algorithms and evaluating them. Technologies / Techniques: Computer vision algorithms for detection of road features such as road shoulders, concrete barriers, lane markers and guard rail. Other Products associated: Software and video data base Please explain: We have setup a surround-view camera system on a vehicle and collected videos as the vehicle is being driven on highway. We have labeled relevant regions in many these videos to indicate the locations of these road features in these videos. Impact: By using synchronized videos of surroundings on all four sides (i.e., front, right-side, rear and left-side) of a vehicle provided by the surround-view camera, we can more accurately identify the road features such as guard rails, lane markers, concrete barriers, other vehicles and pedestrians. More accurate identification of road features and objects should enable self-driving vehicles to better estimate safely-drivable regions and to maneuver into highway road shoulders in emergency situations. Impact in other disciplines: The computer vision algorithms, currently being developed for road feature detection, should be useful for other computer vision problems such as scene analysis. Airport Parking, PI: Alex Hauptmann, CMU, Students: Poyao Huang Deployment Partner(s): Pittsburgh Airport, Grant Oliver Parking Other dissemination activities: Presentation to Airport participants Invention / Patent applications / Licenses: Invention disclosure preparation in progress Other Products associated: Collected a multi-camera parking lot video data set spanning several months, Developed an app to guide cars to available spots, Created several presentations of component technologies, Create a video of the mobile phone app that guides drivers to available spots Please explain: The video dataset will be made available to interested researchers after ground truth annotations of have been completed. Impact: This project will improve the customer parking experience and utilization of available parking spaces. Impact in other disciplines: Computer vision research will be impacted through techniques developed for robust tracking and object detection. Impact on Technology Transfer: Discussions with 2 companies are in progress.
Journal Publication(s): 1) Harper, Corey D., Chris T. Hendrickson, and Constantine Samaras. Cost and benefit estimates of partially-automated vehicle collision avoidance technologies. Accident Analysis & Prevention 95 (2016): 104-115. 2) Harper, Corey D., Chris T. Hendrickson, Sonia Mangones, and Constantine Samaras. Estimating Potential Increases in Travel with Autonomous Vehicles for the Non-Driving, Elderly and People with Travel-Restrictive Medical Conditions. Transportation Research Part C 75 (2016):1-9. Other publications, conference papers and presentations: Harper, Corey D., Chris T. Hendrickson, and Constantine Samaras. Cost and benefit estimates of partially-automated vehicle collision avoidance technologies. Presented at the 2016 ITSPA, 28-30 August 2016, State College, PA. Impact: The results from this analysis can be used to determine if it is economically feasible to equip the entire light-duty vehicle with crash avoidance technologies due to benefits from prevented and less severe crashes, given current system limitations. Sensitivity analyses are conducted to examine how a change in crash cost and frequency and technology cost impact the annual net-benefit. The economic impact that these technologies will have on private insurers, households, third-parties (charities, etc.), and congestion are reported. Impact in other disciplines: An important research goal for transportation professionals is to investigate the economic impact of partial vehicle automation, in order to aid policymakers in identifying effective policies to help stimulate automated vehicle deployment and provide a smooth transition to a fully automated light-duty vehicle fleet. Determining the annual net-benefit of equipping all light-duty vehicles with blind spot monitoring, lane-departure warning, and forward collision warning crash avoidance technologies should provide a basis for policy makers to begin to consider when and if any regulations regarding these technologies should be put in place which would have an impact on market penetration and insurance rates and vehicle cost. Impact on Technology Transfer: NHTSA should also find this research useful when developing regulations and guidelines for automakers, as the results state that it is feasible from an economic perspective to equip all vehicles with level 1 crash avoidance technologies.

Monitoring and Predicting Pedestrian Behavior at Traffic Intersections, PI: Luis E. Navarro-Serment, CMU, Co-PI: Martial Hebert, Students: Meghana Reddy Guduru Deployment Partner(s): Rapid Flow Technologies, LLC, 124 South Highland Ave Suite 206, Pittsburgh PA 15206, Provides: access to video data from traffic intersections, expertise on practical issues. Other publications, conference papers and presentations: Presentation at the 2016 MASITE/ITSPA Annual Conference, “Calibration of traffic cameras using low-cost 3D scanners”, State College, PA, Aug. 29, 2016. Technologies / Techniques: We have developed a video processing pipeline to detect people from images, which is customized for operation with the type of cameras currently used to monitor vehicular traffic. We have also developed an approach to calibrate traffic cameras on-site, which is inexpensive in terms of time and logistics; does not require expensive instruments or software packages; uses a low-cost custom-made laser scanner; and can be performed by personnel with minimal training. Finally, building upon the calibration approach, we have developed a methodology to determine the location of a person in an image with respect to the geometry of the traffic intersection, and considering all the cameras covering the intersection. Invention / Patent applications / Licenses: Nothing to report Other Products associated: Low-cost 3D scanner for traffic camera calibration. Please explain: To support the calibration approach and the methodology for person location within the intersection, we designed and constructed a low-cost 3D scanner. This scanner, built around a low-cost 2D laser range finder, allows us to obtain three-dimensional models of traffic intersections quickly and accurately, but at a fraction of the cost of more expensive scanners
commercially available. We plan to make our design (i.e. mechanical design and accompanying software) freely available to other researchers in the near future. This will facilitate the adoption of our camera calibration methodology by other agencies. **Impact:** The cost analysis project evaluates the economic feasibility of large-scale deployment of current Blind Spot Monitoring (BSM), Lane Departure Warning (LDW), and Forward Collision Warning (FCW) crash avoidance systems within the light-duty vehicle fleet by conducting a cost and benefit analysis. This is done by updating any existing estimates of the maximum number of crashes that potentially could be avoided or made less severe by the three technologies (given system limitations) and examining changes in insurance collision claim frequency and severity in motor vehicles with these technologies to assess costs and benefits. The primary sources of data for this project are the 2012 GES which provides information on crashes of all severities and the 2012 FARS which provides information on fatal crashes. **Impact in other disciplines:** We anticipate that our research will have an impact on adaptive traffic light control systems, which currently operate entirely based on information pertaining vehicular traffic.

**Pedestrian Detection for the SurTrac Adaptive Traffic System, PI:** Bernardo Pires, Steve Smith, CMU, Co-PI: Mehmet Kocamaz, Greg Barlow, **Students:** Christopher Kaffine, Luyao Hou **Deployment Partner(s):** City of Pittsburgh; Axis Communications AB **Other publications, conference papers and presentations:** Mehmet Kocamaz, Jian Gong, Bernardo Pires, “Vision-based Counting of Pedestrians and Cyclists”, IEEE Winter Conference on Applications of Computer Vision WACV'16, March 7-9, 2016, Lake Placid, NY, USA. Acknowledged Federal Support. **Website:** http://www.contrib.andrew.cmu.edu/~bpires/pedssurtrac.html **Technologies / Techniques:** Computer vision automatic detection of pedestrians and pedestrian intent to cross intersection. Visual data collection and processing. Tools for fast and assisted labeling of videos. **Other Products associated:** Data & Research Material, Instruments or equipment, Software / Netware **Please explain:** This project entails equipping one Surtrac intersection with cameras that will collect pedestrian activity and intent to cross intersection. For this purpose, we will collect and label public video data. We will also further develop data labeling software. **Impact:** The objective of this project is to make Surtrac, the real-time adaptive traffic signal control system, aware of pedestrian traffic. Phase 1 of this one-year project will analyze pedestrian traffic at multiple Surtrac deployments. Phase 2 will focus on an intersection already equipped with Surtrac system in the Oakland / East Liberty region and will add additional sensing and processing capabilities to determine the presence of pedestrians waiting to cross the intersection. **Impact in other disciplines:** In addition to the primary impact on transportation planning, this project will push forward the state of the art on the Computer Vision and Machine Learning Fields, by creating new classifiers tailored specifically to the bike and pedestrian detection problem, as well as a large body of classified visual data. **Impact on Technology Transfer:** As more intersections are instrumented with smart traffic control systems, there is a growing need for pedestrian detection as an input for such control systems. We expect that the current project, and its associated deployment, will mature our detection technology to the point where it is ready for commercialization.

**Measuring Pedestrian Wait Times at Intersections, PI:** Bernardo Pires, CMU, Co-PI: Mehmet Kocamaz, **Students:** Christopher Kaffine, Jian Gong **Deployment Partner(s):** City of Pittsburgh; Bike Pittsburgh **Books or other non-periodicals:** Measuring Pedestrian Wait Times at Intersections - Results for Data Collection Run on December 2015. Bernardo Pires, Chris Kaffine. CMU Technical Report. **Other dissemination activities:** Presentation to key Bike Pittsburgh Stakeholders, 04.22.2015 **Website:** http://www.contrib.andrew.cmu.edu/~bpires/pedwaittime.html **Technologies / Techniques:** Image processing methods for automatic pedestrian detection on top-down camera
views. **Other Products associated:** Data & Research Material, Instruments or equipment, Software / Netware Please explain: During December of 2015, this project used custom assembled hardware to collected a dataset of top-down views showing pedestrians waiting at one Pittsburgh intersection. Purpose-built software was created to process this dataset and determine the average length of time that pedestrians were waiting to cross the intersection. **Impact:** The objective of this project is to bring insight into the impact that smart traffic light systems have on the pedestrian flow. As more and more intelligent traffic control systems are deployed it is paramount to determine what effect they have on pedestrian flow, both for planning and safety purposes. **Impact in other disciplines:** In addition to the primary impact on the field of transportation, this project develops novel image processing methods for detection of humans in videos. **Impact on Technology Transfer:** The algorithms developed in this project further augment the domain knowledge at CMU for the optimal construction of pedestrian detection systems. As the field matures, we expect that commercial applications will become viable.


**Technologies / Techniques:** Visual data collection devices. Computer vision automatic detection, classification, and counting of bikes and pedestrians. Tools for fast and assisted labeling of videos. **Invention / Patent applications / Licenses:** Nothing to report **Other Products associated:** Data & Research Material, Instruments or equipment, Software / Netware Please explain: This project entails created a data collection device, the collection of public video data (more than 75 hours have been collected), and the creation of data labeling software as well as automatic counting software. **Impact:** The primary impact of this project is to provide actionable data for government officials and advocates that promote bicycling and walking. In particular, the partnership with the City of Pittsburgh intends to collect data that is relevant for city planning. As part of this effort, a full week of rush hour data has been collected and analyzed for the City of Pittsburgh. This data will inform the usage of the newly created bike lane at the intersection of Craig St and Bayard St. **Impact in other disciplines:** In addition to the primary impact on transportation planning, this project will push forward the state of the art on the Computer Vision and Machine Learning Fields, by creating new classifiers tailored specifically to the bike and pedestrian detection problem, as well as a large body of classified visual data.

**In-Car Cell Phone Detection, PI:** Bernardo Pires, CMU, **Students:** Christopher Kaffine Jian Gong **Books or other non-periodicals:** In-Vehicle Vision-Based Cell Phone Detection. Anirudh Viswanathan and Bernardo Pires. CMU Technical Report. January 2016. **Other publications, conference papers and presentations:** Testimony on "Enhancing the Safety of Highway Workers, Drivers and Pedestrians" at the Joint Hearing before the Senate Transportation Committee and the House Transportation
Committee Other dissemination activities: Participation at the ITS America Annual Meeting, May 31st, 2015 to June 3rd, 2015. Participation on T-SET Consortium, 11.11.2015 Website: http://www.contrib.andrew.cmu.edu/~bpires/phonodetect.html Technologies / Techniques: Visual data collection devices. Computer vision automatic detection and classification. Tools for fast and assisted labeling of videos. Other Products associated: Data & Research Material, Software / Netware Please explain: This project created a dataset of users handling cell phones inside vehicles as well automatic phone detection software. Impact: The primary impact of this project is a contribution to in-car safety and crash prevention by creating cost-effective methods for distraction detection due to use of electronic devices. Impact in other disciplines: In addition to the primary impact on in-car safety and distraction detection due to use of electronic devices, this project will push forward the state of the art on the Computer Vision and Machine Learning Fields, by creating new classifiers tailored specifically to the detection of electronic displays inside the car, as well as a body of classified visual data.

Accident Investigation with 3D Models from Images, PI: Christoph Mertz, CMU, Students: Abhinav Girish Deployment Partner(s): Pittsburgh Police Department: provide us with crashed cars for testing our algorithms, give feedback on our technology Other publications, conference papers and presentations: Invited presentation at WREX 2016 World Reconstruction Exposition Other dissemination activities: Website with description of system, downloads and documentation of software, downloads of 3D models. Presentation of technology to industry, government, and academic visitors. Website: http://www.cs.cmu.edu/~reconstruction/ Technologies / Techniques: We have developed technologies that can reconstruct 3D accident scenes. In particular we have refined the method to reconstruct inside and outside of the crashed vehicle in one model and modeling intricate and difficult-to-reach parts of the vehicle. We have also done data collection to produce 3D movies of accidents. All our code and description of technology is available for free on our website. Other Products associated: Database of 3D models of crashed vehicles, software and documentation of the technology Please explain: Models, software and documentation are available for download from our website Impact: The developed technology and its free availability on a website can significantly reduce the cost of 3D accident reconstruction for investigators. Impact in other disciplines: The technology can also be used in related fields like crime scene investigation, inspection of buildings, etc. Impact on Technology Transfer: Several accident investigators have downloaded our code and testing its applicability to their work.

City Road Inspection, PI: Christoph Mertz, CMU, Co-PI: Nothing to report, Students: Abhinav Girish, Peter Wei, Luyao Hou Deployment Partner(s): City of Pittsburgh, Cranberry Township, North Huntington Township - these government entities collect road data that we analyze, they provide us insight into their work practices and give us feedback. Other dissemination activities: The project was presented to many industry, government, and academic visitors. Website: http://www.cs.cmu.edu/~road/ Technologies / Techniques: We have developed road surface assessment, traffic sign detection and assessment, and we are still developing sign retroreflectivity measurements with smartphones. Invention / Patent applications / Licenses: We have filed following invention disclosures: CMU Invention Disclosure 2017-033 entitled “Road infrastructure data pipeline,” CMU Invention Disclosure 2017-008 entitled “Visual texture detection for road inspection.” CMU Invention Disclosure 2017-029 “Stop sign detection and assessment” CMU Invention Disclosure "Data collection app for android cameras and mobile devices". CMU is in negotiation with a startup to license these inventions Other Products associated: Databases: maps of road damage, traffic signs, and damaged traffic signs. These are shared with City of Pittsburgh,
Cranberry Township and North Huntington Township. Please explain: The city and townships collect the raw data, we analyze the data and return the inventory and assessment maps back to them. They give us feedback on them. Impact: We have spun out a startup that will commercialize this technology. Invention disclosures have been filed and the license agreements are being negotiated. The product will significantly reduce the cost of infrastructure inventory and assessment. Impact in other disciplines: The data collected and maps that have been created can be used in other computer vision projects. Impact on Technology Transfer: A start-up has been created to commercialize the technology.

Low-Cost Vehicle Localization for Driving and Mapping, PI: John M. Dolan, CMU, Students: Adam Werries Deployment Partner(s): GM R&D, Warren, MI; In-kind support via use of test vehicle Other publications, conference papers and presentations: Werries, A. and Dolan, J.M., Adaptive Kalman Filtering Methods for Low-Cost GPS/INS Localization for Autonomous Vehicles, Technical Report CMU-RI-TR-16-18, Robotics Institute, Carnegie Mellon University, May, 2016 Website: http://www.ri.cmu.edu/research_project_detail.html?project_id=775&menu_id=261 Technologies / Techniques: Our current work is on reducing computation through focused sampling and minimal replanning; and generation of smooth trajectories across the range of highway, urban, and evasive maneuver scenarios. The motion planner requires high-accuracy localization. For autonomous vehicles, navigation systems must be accurate enough to provide lane-level localization. High-accuracy sensors are available but not cost-effective for production use. Although prone to significant error in poor circumstances, even low-cost GPS systems are able to correct Inertial Navigation Systems to limit the effects of dead reckoning error over short periods between sufficiently accurate GPS updates. Kalman filters are a standard approach for GPS/INS integration, but require careful tuning in order to achieve quality results. This creates a motivation for a Kalman filter which is able to adapt to different sensors and circumstances on its own. Typically for adaptive filters, either the process (Q) or measurement (R) noise covariance matrix of Kalman filters is adapted, and the other is fixed to values estimated a priori. We show that intelligently adapting both matrices in an intelligent manner can provide a more accurate navigation solution. Other Products associated: Software Please explain: The described techniques for low-cost localization have been coded in C++ and tested in both closed-course and real-world scenarios in the Pittsburgh area, including the Oakland university neighborhood of Pittsburgh, which is a fairly dense urban environment. Impact: The developed localization techniques are not yet sufficiently accurate to provide lane-level localization. However, in conjunction with odometry and map-matching, they have the potential to make it more cost-effective to provide localization for autonomous and semi-autonomous vehicles at an affordable price. Impact in other disciplines: High-accuracy, low-cost localization for outdoor robots is a valuable technology that can be used for many other types of field robots besides autonomous cars.

Marcellus Shale Traffic, PI: Robert P Strauss, CMU, Students: Nauman Afridi Deployment Partner(s): PA. State Police and Administrator of the PA Courts Journal Technologies / Techniques: A relational and spatial database has been generated which shows all road improvements in PA due to activities of the natural gas industry. Other Products associated: A research report and journal articles are contemplated once we receive the over weight citation data. Impact: Coincidental with this project has been the establishment and deployment of 15 mobile weight monitoring units throughout the Commonwealth. Our project could well have prompted transportation policy makes to upgrade the number of weight monitoring stations in the Commonwealth.