Semi-Annual Progress Report for University Transportation Centers

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Center Director:
Henry Liu
CCAT Director
University of Michigan Professor
Phone: (734) 647-4796
Mobile: (651) 260-5876
Email: henryliu@umich.edu

Submitted By:
Debby Bezzina
CCAT Managing Director
Phone: (734) 763-2498
Mobile: (734) 751-1778
Email: dbezzina@umich.edu

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Regents of the University of Michigan
3003 S. State Street
Ann Arbor, MI 48109

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1. Accomplishments

The University of Michigan at Ann Arbor (UM), in partnership with Purdue University, University of Illinois at Urbana-Champaign (UIUC), University of Akron (UA), Central State University (CSU), and Washtenaw Community College (WCC), established the USDOT Region 5 University Transportation Center: Center for Connected and Automated Transportation (CCAT). The FAST Act research priority area for CCAT is promoting safety and CCAT focuses its efforts in the field of comprehensive transportation safety and congestion management by taking advantage of connected vehicles, connected infrastructure, and autonomous vehicles. This report documents the progress for the reporting period April 1, 2021 through September 30, 2021.

1.A Current Research Status

During this reporting period, the CCAT technology advisory board (TAB) met to discuss the research focus for 2022 (year 6). Subsequently, a request for proposals was issued. Proposals are due November 29, 2021. The proposals will be reviewed by the CCAT TAB and the final project portfolio will be selected at the January 2022 TAB meeting. The TAB consists of member from industry, government, and academia including:

- American Center for Mobility
- Central State University
- Econolite
- Ford
- General Motors
- Illinois Department of Transportation
- Indiana Department of Transportation
- Michigan Department of Transportation
- Purdue
- Toyota
- University of Akron
- University of Illinois at Urbana-Champaign
- University of Michigan
- Washtenaw Community College
- WSP

Currently, CCAT researchers have 51 active projects and 9 completed projects. During this reporting period, work was performed on all active projects but due to page limitations only work completed on the 2021 projects are included in this report. Semi-annual status reports for all projects are available upon request. Additionally, for full project descriptions and final reports, visit the CCAT website.

A Data Driven Autonomous Driving System for Overtaking Bicyclists: University of Michigan, Dr. Shan Bao and Dr. Brian Lin. Many bicyclists share the roadway with motor vehicles that drive much faster. Once an accident occurs with bicyclists involved, the death rate of the bicyclist is extremely high. To date there is no mature or reliable technology that helps drivers overtake bicyclists safely and that has the potential to be well accepted by bicyclists. This study follows a systematic method to develop a prototype for an automated overtaking system, specifically for overtaking bicyclists. An experiment of human study will be conducted to evaluate the prototype from both the viewpoints of the driver and the bicyclist. In this period, overtaking scenarios were created and demonstrated in CarSim. The overtaking model was integrated into the driving simulator and the design of experiment was conducted. Lastly, the IRB exempt application was approved. Click here to view the UTC form.
Development of an Integrated Augmented Reality Testing Environment and Implementation at the American Center for Mobility (ACM): University of Michigan, Dr. Henry Liu. This project will develop an integrated solution for autonomous vehicle testing, in which the naturalistic adversarial driving environment (NADE) will be integrated with augmented reality (AR) testing system. The integrated solution will be implemented at American Center for Mobility (ACM). With the AR techniques, the real testing AVs can be tested at a test track and interact with the virtual background vehicles. With the NADE, the maneuvers of the virtual background vehicles will be generated purposely, in that most of the maneuvers are generated from naturalistic driving data, and only at selected moments, selected vehicles execute adversarial moves to challenge the AVs. This period, Dr. Henry Liu and his team implemented the Safe AI Framework for Trustworthy Edge Scenario Tests, or SAFE TEST, at the American Center for Mobility (ACM). This state-of-the-art toolbox increases the efficiency of AV performance testing, reduces operational costs, and accelerates product validation. Click here to view the UTC form.

Development of Situational Awareness Enhancing Systems for AV-Manual Handover and Other Tasks: Purdue, Dr. Samuel Labi and Dr. Sikai Chen. Partially and conditionally automated vehicle systems (AVS) can assist drivers with their driving tasks and have the potential to significantly reduce driving-related burden. Drivers still play a critical role such as monitoring the driving environment when the AVS is engaged and performing certain driving tasks when called upon by the system. However, there is ample evidence in the literature and real-world that drivers cannot maintain necessary situational awareness to safely take over the vehicle when needed. This study aims to design an in-vehicle situational awareness enhancing system (SAES) to facilitate AV-manual take-over in partially and conditionally automated vehicles. In this period, a preliminary study was completed, a comprehensive literature review is in progress, the experimental design was finalized, and some preliminary analysis was conducted. Click here to view the UTC form.

Exploring the Prospective Role of Connected Vehicles in Monitoring and Response to Pandemics and Disasters: Purdue, Dr. James Eric Dietz, and Dr. Samuel Labi. The first part of the proposed research will review/upgrade existing models for disease spread monitoring and evaluate the efficacy of pandemic-control policies and other interventions. Then the research will assess the two-way risks of infection. The second part of the research will explore how, in the near future, connected vehicles could potentially be used to assist in pandemic monitoring and control, either in a standalone manner or as part of a network of technology entities. Using these two outcomes, a spatiotemporal tool will be developed to assess the risks of pandemic propagation for use in the prospective era of CAVs. Connected vehicle technology can facilitate information exchange between the transport agency and road users during disruptive events. In this period, a comprehensive literature review was conducted and is currently being synthesized. Additionally, the study framework is being refined. Click here to view the UTC form.

Improving the Efficiency of Trucks via CV2X Connectivity on Highways (Year 2): University of Michigan, Dr. Gabor Orosz. This project aims to deploy a connected smart infrastructure (CSI) on a highway to collect and aggregate traffic information that can be used by heavy-duty trucks traveling the corridor to improve their efficiency. The system will consist of a set of roadside units which collect traffic
data via cellular vehicle-to-everything (CV2X) communication. The heavy-duty trucks will utilize the collected data when controlling their longitudinal motion to maximize their fuel economy without compromising their travel time. In this period, two RSUs along highway I-275 have been deployed; one at Telegraph road and one at Five Mile Road. The RSU communications have been tested by driving V2X equipped vehicles on the highway which were emitting basic safety messages (BSMs) and traffic history messages (THMs). The communication range of the RSUs was evaluated using the collected messages. Click here to view the UTC form.

Large Network Multi-Level Control for CAV and Smart Infrastructure: AI-based Fog-Cloud Collaboration: Purdue, Dr. Sikai Chen, Dr. Samuel Labi, and Dr. Kumares Sinha. The vast expanse of prospective CAV traffic networks is expected to exponentially increase the information availability and complexity of inter-agent interactions. In such an environment, a single system is inadequate to make decisions for all the agents individually, and therefore, multilevel system decomposition is needed. The research proposes a framework to decompose large transportation networks using a fog-cloud collaboration structure. That way, AI and optimization techniques can be scaled up to larger transportation networks with minimal compromises being made in real-time decision making. This research will address regional decision tasks (which require low latency) and network decision tasks (which require high computational capacity). By assigning regional decision tasks to the fog layer and network decision tasks to the cloud layer, we anticipate that systemic efficiency can be improved. A comprehensive literature review was conducted in this period. Furthermore, a preliminary study on designing an AI-based fog-cloud structure for CAV dynamic rerouting was completed, resulting in an IEEE International Smart Cities Conference paper. Click here to view the UTC form.

Leveraging CAVs for Participatory Traffic Control: University of Michigan, Dr. Yafeng Yin. This project aims to establish the theoretical foundation of proactive, participatory traffic control where connected and automated vehicles (CAVs) are used as mobile actuators to regulate traffic flow across a traffic network. We attempt to integrate traditional “anonymous” physical controllers (e.g., traffic signals) in the transportation system with personalized, targeted control of CAVs to improve traffic system efficiency. With the smart traffic corridor in Ann Arbor, it is also possible to test this framework in the real world. This period, the research team leveraged V2I communication capabilities to integrate strategic real-time traffic information perturbation into an online, in-vehicle coordinated routing mechanism for connected vehicles using a mixed strategy congestion game. The exercised proved that low information perturbation levels can lead to high system performance gains with correspondingly low individual user optimality losses. Click here to view the UTC form.

Motion Sickness Alleviation via Anticipatory Control of Active Seats in Autonomous Vehicles: University of Michigan, Dr. Shorya Awtar. The goal of this integrative research project is to develop and demonstrate a passenger motion sickness mitigation solution that employs preemptive or anticipatory control of Active Seats in autonomous vehicles. The resulting proof of concept will enable implementation and deployment of the proposed technology. During this period, the research team (1) acquired, registered, and insured a Dodge ProMaster Cargo Van for the vehicle testbed; (2) finalized the design of the vehicle testbed with several critical modifications and upgrades; (3) developed
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instrumentation to measure all the relevant motion states of the vehicle and the active seat; (4) developed wearable instrumentation packs (head-mounted and chest-mounted) to measure the passenger motion and physiological states; (5) developed several active passenger stimuli (audio and vibrotactile) that will integrated into the vehicle testbed environment; and (6) developed a test protocol/methodology for evaluating the occurrence and mitigation of motion sickness in Human Subjects, which was approved by the IRB (HUM00199425). Click here to view the UTC form.

Predicting Driver Takeover Performance in Conditional Automation (Level 3) through Physiological Sensing: University of Michigan, Dr. Carol Menassa, Dr. Vineet Kamat, Dr. Da Li, and Dr. Julian Brinkley. Being able to measure and predict the takeover performance (TOP) ahead of time and issue adequate warnings is critical to ensure driver comfort, trust, and safety in the system and ultimately acceptance of the technology by different stakeholders. The objective of this project is to perform fundamental research to understand drivers’ capabilities of taking over the vehicle safely and promptly at any time in level 3 automation. In this period, the driving simulation scenarios were coded into the simulator and the experimental protocol was established. In July, a pilot study was conducted to test the experimental protocol. Revisions were made to the experimental protocol based on results of pilot study. An IRB application was submitted and is pending approval. Lastly, the driver monitoring system from Aisin was received and the research team is working with them to connect to our simulator for additional data collection. Click here to view the UTC form.

Ridesharing with Advanced Air Mobility: Purdue, Dr. Daniel DeLaurentis, and Dr. Dengfeng Sun. In this project, we will design and evaluate ride-sharing schemes that can potentially reduce the time and economical cost on urban commuters, increase the revenue of the transportation service provider, and boost local economics. In this period, the research team investigated ride-sharing service using air and ground vehicles to improve efficiency and mobility in the transportation system of a metropolitan area. Consequently, the team developed a comprehensive mathematical model for the autonomous aerial ride-sharing service that capture the new characteristics in the futuristic ride-sharing system and the key components of related costs. A distributed computational framework to accommodate the large problem size for practical real-time ride-sharing recommendations was also developed. Click here to view the UTC form.

Roadside-Based Cybersecurity in CAV Systems: University of Michigan, Dr. Neda Masoud. We aim to develop a holistic framework that integrates physics-based data-driven modeling and dynamic decision making under uncertainty and partial information to improve cybersecurity in CAVs. Major concerns remain as to whether an interconnected network of CAVs and infrastructure is vulnerable to malicious hackers or unintentional faults. In this proposed work, we aim to address open questions on cybersecurity of a network of connected CAVs. Our goal is to develop an integrated real-time, robust, and scalable context-aware framework to ensure safe navigation of CAVs and other road users. The proposed framework contributes to the literature of anomaly detection/identification, data fusion, non-linear control, physics-based learning, and decision making under uncertainty in novel and important ways. During this period, one PhD student was supported to develop methodology for the framework. Click here to view the UTC form.
The Impact of COVID-19 on User Perceptions of Public Transit, Share Mobility/Micro-Mobility Services, and Emerging Vehicle Types: Purdue, Dr. Konstantina Gkritza. The objective of this project is to investigate the impact of COVID-19 on user perceptions of public transit, shared mobility services, and emerging vehicle types (electric, connected, and autonomous vehicles). As transportation systems remain at the forefront of the COVID-19 pandemic, it is critical to examine the transportation trends and behaviors of shared modes’ and emerging vehicle types’ users to best plan for transportation policies in the long-run. This project will help transit operators, shared mobility and micro-mobility services operators gain a better understanding of the impacts of the pandemic on user perceptions for public transit, shared mobility, and micro-mobility services. In this period, a literature review of COVID-19 related articles along with a thorough review of user perception surveys in the context of COVID-19 was completed. Click here to view the UTC form.

Translation of Driver-pedestrian Behavioral Models at Semi-Controlled Crosswalks into Quantitative Framework for Practical Self-Driving Vehicle Applications: Purdue, Dr. John Fricker. There is a sufficient amount of interaction between pedestrians and vehicles at “semi-controlled” crosswalks to be concerned about the time when “negotiations” between pedestrians and human drivers are replaced by interactions between pedestrians and self-driving vehicles. In this period, object detection and tracking techniques (YOLO V3 and DeepSort algorithms) that speed up the conversion to video recordings of crossings to digital databases was applied. Also, an observing-tracking-learning framework was proposed to track road users’ movements and predict their future trajectories/behaviors. In addition, one paper has been published in the journal Accident Analysis & Prevention, a second paper has been presented at the conference IEEE Conference on Models and Technologies for Intelligent Transportation Systems, and a third paper has been drafted. Click here to view the UTC form.

Using Virtual Reality Techniques for Investigating Interactions between Fully Autonomous Vehicles and Vulnerable Road Users: Purdue, Dr. Samuel Labi, and Dr. Sikai Chen. Communication methods between vulnerable road users (pedestrians, bicyclists) and FAVs may lead to misunderstanding of intentions and cause more collisions. Road-crossing pedestrians and bicyclists generally rely on informal communication methods, eye contact, facial expression and gestures, to interpret intentions of other road users and make decisions based on the information. With FAVs, these informal communication approaches cannot be realized. Hence, it is necessary to design proper external features of FAV to establish efficient communication method. This project intends to expose participants to simulated testing environments with virtual reality headset and identify potential interface designs for FAV-pedestrian interaction. In this period, a comprehensive literature review was conducted. Additionally, the research team explored the simulation software option space (e.g., Carla simulator) and the corresponding VR equipment. Click here to view the UTC form.

1.B Tech Transfer Metrics for this Period
For this period, CCAT surpassed all technology transfer goals, most by a significant margin (reference Table 1). CCAT continues to put technology transfer on the forefront of all activities and is directly attributable to the success of the center. CCAT maintains a strong Technology Advisory Board (TAB) to
ensure that our research can be directly transferred to industry and government for implementation and deployment.

In addition to meeting with the TAB, CCAT researchers regularly meet with their industry and government project champions. This increases the amount of direct interaction with these organizations to enhance technology transfer opportunities. Examples include quarterly meetings with Intent Design to discuss the integration and testing of motion sickness vehicle testbed, and communications and webinars with the Indiana Department of Transportation regarding winter operation activities.

In this period, CCAT researcher Dr. Henry Liu executed the End-User License Agreement for “Testing Automated Driving Systems in a Naturalistic and Adversarial Driving Environment with Augmented Reality” with the American Center for Mobility (reference University of Michigan Office of Technology Transfer File #2021-0889, signed on May 26, 2021).

Table 1: CCAT Technology Transfer Goal Targets and Actual Performance for this Period

<table>
<thead>
<tr>
<th>PART II: CCAT UTC Specific Performance Indicators</th>
<th>CCAT October 1, 2020 - March 31, 2021</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Technology Transfer Goals</strong></td>
<td></td>
</tr>
<tr>
<td>1. OUTPUTS</td>
<td></td>
</tr>
<tr>
<td>1.A. Disseminate research results through publications, conference papers, and policy papers</td>
<td></td>
</tr>
<tr>
<td>Research Performance Measures</td>
<td>CCAT Annual Target</td>
</tr>
<tr>
<td>Technical reports</td>
<td>10</td>
</tr>
<tr>
<td>Papers at conferences, symposia, workshops, and meetings</td>
<td>3</td>
</tr>
<tr>
<td>Peer-reviewed journal articles</td>
<td>6</td>
</tr>
<tr>
<td>1.B. Develop inventions, new methodologies, or products</td>
<td>5</td>
</tr>
<tr>
<td>Annual number of research deployments</td>
<td>3</td>
</tr>
<tr>
<td>1.C. Research projects funded by sources other than UTC and matching fund sources</td>
<td></td>
</tr>
<tr>
<td>Number of projects</td>
<td>300,000</td>
</tr>
<tr>
<td>2. OUTCOMES</td>
<td></td>
</tr>
<tr>
<td>2.A. Incorporate new technologies, techniques or practices</td>
<td>Number of technology transfer activities that offer implementation or deployment guidance</td>
</tr>
<tr>
<td>2.B. Improve the processes, technologies, techniques in addressing transportation issues</td>
<td>Number of research deliverables disseminated from each research project</td>
</tr>
<tr>
<td>3. IMPACTS</td>
<td></td>
</tr>
<tr>
<td>3.A. Increase the body of knowledge and safety of the transportation system</td>
<td>Number of instances of technology adoption or commercialization</td>
</tr>
<tr>
<td>Number of conferences organized by the CCAT consortium members</td>
<td>2</td>
</tr>
<tr>
<td>3.B. Improve the operation and safety of the transportation system</td>
<td>Number of instances of research changing behavior, practices, decision making, policies (including regulatory policies), or social actions</td>
</tr>
</tbody>
</table>

1.C Dissemination of Research and Other Outreach, Education, Leadership and Workforce Development

CCAT members hosted or participated in 49 outreach engagements with industry, government, academia, media, and community organizations this reporting period. In total, CCAT research was
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shared with more than 6,100 people in the last six months. The University of Michigan CCAT outreach log is available upon request.

A key CCAT goal is to be a national thought leader for connected and automated transportation. As the center evolves, more and more examples of our leadership come to light. When the FCC issued a Report and Order that gave away most of the 5.9 GHz safety spectrum and chose CV2X over DSRC, experts at CCAT were called upon to analyze the impacts of the decision. We provided content to ITS America on the costs to retrofit the Ann Arbor Connected Environment DSRC deployment area with CV2X devices, which they used in their letter to the FCC that opposed the Further Notice of Proposed Rulemaking (FNPRM). Additionally, the University of Michigan wrote a letter to the FCC that opposed the FNPRM, as we believe that the FCC’s decision will cause significant harm to transportation safety through its spectrum reallocation in the 5.9 GHz band and recommended that the FCC should take immediate steps to mitigate that harm. Our letter to the FCC is a matter of public record and our efforts have not gone unnoticed. U.S. Government Accountability Office (GAO) contacted us and requested a meeting to further discuss our letter and our knowledge from successfully operating connected vehicles the real world. Lastly, this period we wrote a case study on the cost of the FCC ruling on the Ann Arbor Connected Vehicle Environment as part of the Evaluation and Synthesis of Connected Vehicle Communication Technologies web-only document.

The largest event this period was the fourth annual CCAT Global Symposium on Connected Vehicles and Infrastructure held on April 12 and 13, 2021. Although the symposium was virtual due to COVID-19 restrictions, the event went back to the previous format of two-days and two-tracks. The event was free, and we had a record number of attendees – 850 attendees and 927 video-on-demand views after the symposium. The event attracted speakers and attendees from around the world.

CCAT hosted a Student Poster Competition in April in conjunction with the virtual 2021 CCAT Global Symposium. In total, 12 undergraduate and graduate submissions were received across four universities (University of Illinois at Urbana-Champaign, Purdue University, University of Michigan, and University of Washington). The audience was able to join the poster session via Zoom to speak with the students about their research. From there, they voted for their favorite poster via an online form. The graduate winner was Egemen Okte, and their poster was titled “A Framework to Determine Road Networks’ Platoonability.” The graduate runner-up was Sachindra Dahal, and their poster was titled “Passive Electromagnetic Signature of Roadway for Vehicle Lateral Positioning.” The undergraduate winner was Sion Pizzi, and their poster was titled “A Learning-based Trajectory Prediction Approach for Heterogeneous Traffic Agents.” All the posters and abstracts received for the 2021 Student Poster Competition can be found on the CCAT website.

We’ve already begun planning for next year’s fifth annual CCAT Global Symposium on Connected Vehicles and infrastructure that will be held on April 12 and 13, 2022. We are planning for a hybrid in-person and virtual event but will, in parallel, plan for a fully on-line event if required. We will use the ITSA Annual Meeting and 2022 TRB Annual Meeting as litmus tests of the viability of in-person events. For the 2022 CCAT Global Symposium, we envision three tracks: (1) keynote speakers and moderated panel sessions; (2) CCAT research reviews; and (3) student posters. Furthermore, we are expanding the
event with a pre-workshop focusing on education and a post-event HBCU-only “CAV Immersion.” HBCU members will be able to experience connected and automated vehicles and technologies firsthand through tours and live demonstrations.

This period, CCAT continued the bi-monthly research reviews and the Distinguished Lecture Series and had our first in-person event on September 15, 2021. All are available on CCAT’s YouTube channel (links below). The distinguished lecture series is intended to share important information to our stakeholders that is within the expertise of the CCAT consortium but is not necessarily from a specific research project from prominent experts in the field.

Table 2: Distinguished Lecture Series and Research Reviews for the Reporting Period 4/1/21 – 9/30/21

<table>
<thead>
<tr>
<th>Date</th>
<th>Title (Link)</th>
<th>Presenter(s)</th>
<th>Registrants</th>
<th>Attendees</th>
<th>Views</th>
</tr>
</thead>
<tbody>
<tr>
<td>5/13/21</td>
<td>Distinguished Lecture Series: <a href="#">Lagrangian Control at Large and Local Scales in Mixed Autonomy Traffic Flow</a></td>
<td>Dr. Alexandre Bayen, University of California Berkeley</td>
<td>239</td>
<td>113</td>
<td>393</td>
</tr>
<tr>
<td>6/9/2021</td>
<td>Research Review: <a href="#">Assessment of AVs with a Naturalistic and Adversarial Driving Environment</a></td>
<td>Dr. Henry Liu and Dr. Shuo Feng, University of Michigan</td>
<td>247</td>
<td>160</td>
<td>254</td>
</tr>
<tr>
<td>7/15/21</td>
<td>Distinguished Lecture Series: <a href="#">How Many CAVs Does it Take to Smooth Traffic?</a></td>
<td>Dr. Evangelos Simoudis, Synapse Partners</td>
<td>193</td>
<td>84</td>
<td>70</td>
</tr>
<tr>
<td>8/12/21</td>
<td>Research Review: <a href="#">Effect of Human Drivers’ Time Delay and Heterogeneity Stabilization on Capability of CAVs (Resolving Phantom Traffic Jams with CAV Controllers)</a></td>
<td>Dr. Samuel Labi and Dr. Yujie Li, Purdue University</td>
<td>130</td>
<td>68</td>
<td>35</td>
</tr>
<tr>
<td>9/15/21</td>
<td>Distinguished Lecture Series: <a href="#">The Future of Mobility &amp; Connected Transportation with Smart Infrastructure</a></td>
<td>Jaime Waydo, Cavnue (pictured above with Dr. Henry Liu, CCAT Director)</td>
<td>278</td>
<td>148</td>
<td>200</td>
</tr>
</tbody>
</table>

CCAT has leveraged Twitter to promote its events, research, and reports. In the past six months, the Twitter profile has earned over 50,000 impressions and 73 followers for a total of 351. The LinkedIn profile is used to similarly promote upcoming events, research updates, and promote awards that researchers have received. This provides CCAT with the opportunity to have those researchers share the posts and grow the audience. LinkedIn analytics include receiving 28,583 impressions (nearly double from the six months prior), over 1,100 profile visits, and 218 new followers for a total of 666. CCAT is

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1 Presentations and videos are not listed in the output section to save space and omit redundant reporting.

Date: October 28, 2021
also the most subscribed University Transportation Center (UTC) channel. CCAT uploads all its events to the channel via live stream, edited VOD, and edited clips pulled from full webinars. CCAT’s YouTube analytics since April include over 3,400 upload views (1,200 more than the previous six months), 448 live views (4 times the growth from the past six months), 100 new subscribers (265 total; the most of any UTC YouTube channel and more than double the growth from the past six months), and a watch time of 33,960 minutes (3 times higher than the previous six months).

The CCAT website provides a wide array of information for those that work within and outside the CCAT umbrella. All research projects and their UTC and Final Report forms are available along with Semi-Annual Progress Reports. Updates since the last SAPR includes improved search functionality, dedicated Global Symposium event page, and dedicated research profile pages. Over the last six months, the website has received over 10,000 unique sessions.

**Awards**

- Dr. Mohammad Miralnigahi, a post-doctoral researcher at Purdue and researcher at the Center for Connected and Automated Transportation (CCAT) has been recognized with the 2020 Matthew G. Karlaftis Best Paper Award.
- CCAT Researcher and graduate student Bortiorkor "Naa" Alabi has been named a recipient of the 2021-2022 Edward J. Cox Memorial Transportation Scholarship Award.
- CCAT PhD Student Ali Ghahari has received the Spring 2021 Graduate Student Engagement Award by the Lyles School of Civil Engineering at Purdue University.
- CCAT PhD student Abdullah J. Nafakh was part of a 3-person team that received a Professional Development Scholarship for their performance in teaching a high school summer course titled Resiliency and Sustainability in Civil Engineering.
- Professor Kumares C. Sinha, Olson Distinguished Professor of Civil Engineering at Purdue University, published an article titled “Reflections on the History of the ASCE Journal of Transportation Engineering,” which was selected as the Editor’s Choice by the ASCE Journal of Transportation Systems.

Since the COVID-19 Pandemic policies of 2020 began, very limited numbers of interpersonal activities have been authorized. This has limited and restricted some CCAT activities and collaborations with organizations, including K-12 school systems. Despite the pandemic, WCC as our educational outreach partner accomplished the following:

**Workforce Development Training**

- Completed development of Data Management EXCEL and XML and launched a WorldEducation.net Product entitled “What do the Numbers Mean?”, consisting of 14 course modules. A total of 32 enrollments occurred in five (5) modules, four (4) in Microsoft Excel, and one (1) in Applied Machine Learning Basics. In addition, sixteen (16) enrollments occurred in a module entitled “Continuous Quality Improvement”.
- Added monitoring capabilities for instructor and student usage of the IEEE eLearning Library installed within the WCC Blackboard resource center to enhance WCC Online Learning Capabilities.
in CAV/SMART City Technologies. These IEEE courses are available to academic and workforce instructors for professional development.

- Continued development of certification training for Microsoft Power BI for Data Analysts.
- Continued development of visualization series based on the Edward Tufte method.
- Continued development of visualization series that teaches XML code with installation in WCC’s Blackboard resource center for review.

**Credit Education Certificate and Degree Programs**

- Continued development of the Automotive Cybersecurity Lab testing facility with the installation of seven Umlaut-designed Cybersecurity Workbenches and the GRIMM-designed Automotive Cybersecurity Educator Workbench. This is a joint cross-functional learning environment between the Computer Science & IT Department and the Transportation Technologies [Automotive] Department. Continuing development of the Automotive Cybersecurity Lab will allow students to interact with the vehicle CAN-BUS Systems in an engineering and cybersecurity capacity, identical to workbenches used by manufacturers, suppliers and product development engineering organizations.

- Instructors advanced the Transportation Technologies Curriculum development on object detection Sensors. 3-D LiDAR Sensors were integrated into the curricula demonstration of functional characteristics, inputs and outputs. MathWorks software was integrated into the curricula to aid in identifying and labeling objects from various Cameras and LiDAR sensors.

- A 2021 Ford Mustang Mach-E was procured using State of Michigan Perkins Award Funding to integrate a full Battery Electric Vehicle into the Transportation Technologies & CSIT Cybersecurity curricula to aid students in learning functional characteristics of BEV’s and measure performance characteristics.

**K-12 STEM Technology Awareness and Insight**

- Hosted a Cybersecurity Workshop for youth in collaboration with Square One Education Network for nine participants. Training was offered virtually due to COVID-19.

- Delivered programming in collaboration with Square One Education Network for four scholarship students; “Masters of Mobility: Robots on the Road”, which was offered virtually due to COVID-19. Students were sent kits ahead of time which were used in the camp. Note- this was a no-charge awareness event for disadvantaged youth in the Ypsilanti/Eastern Washtenaw County area.

**General Outreach**

- WCC continued active collaboration and leadership roles on key mobility [CAV/CAT/Infrastructure] organizations, including Center for Automotive Research [CAR], MI Office of Future Mobility & Electrification, ITS Michigan, American Center for Mobility (ACM), MICHauto, USDOT ITS PCB, IEEE, MI CAV Working Group, MI Alliance for Greater Mobility Advancement [MAGMA], NOCoE & TSMO, SAE and others.

- 2021 CAR Management Briefing Seminars: WCC staff, instructors and students participated in industry seminars, presented a mobility exhibit, and networked with industry representatives in this multiple industry event, Aug. 3-5.
• 2021 Motor Bella Automobili-D Exhibit: WCC presented a mobility exhibit at the M-1 Concourse in Pontiac, MI, Sept. 21 consisting of Automotive Cybersecurity and a 2021 Ford Mustang Mach-E BEV and networked with industry representatives.

• 2021 EyesOn Automotive Design: WCC presented a mobility exhibit at the EyesOn Automotive Design Event at the Ford House in Grosse Pointe Shores, MI, Sept. 21, consisting of Automotive Cybersecurity and a 2021 Ford Mustang Mach-E BEV, and networked with the public and industry representatives.

• 2021 ITS PCB Community College Workgroup #2 Meetings: Seven meetings held with WCC participation in “Strengthening the ITS Workforce”, and “Defining the ITS Technician Job Market, April to September, 2021.

• Several WCC and commercial news articles were written about WCC advances in curricula and learning experiences in the technologies of CAV/CAT. Also reported were activities and personnel surrounding WCC’s new Automotive Cybersecurity Certificate programs and the 2021 Ford Mustang Mach-E full Battery Electric Vehicle. See 2021 Semi/Annual Performance Metrics Reports.

Lastly, CCAT events have been picked up by Event Browse, an event discovery platform for the best business conferences and events for 200+ metro areas across the globe.

2. Participants and Other Collaborating Organizations

One of the CCAT goals is to collaborate with other organizations within the CCAT consortium, within Region 5, and nationally. The following table summarize the collaborations that occurred during this reporting period.

<table>
<thead>
<tr>
<th>CCAT Member</th>
<th>Collaborating Organization</th>
<th>Location</th>
<th>Contribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Akron</td>
<td>ODOT District 4</td>
<td>Akron, OH</td>
<td>Data sources and project support.</td>
</tr>
<tr>
<td>Akron</td>
<td>PathMaster, Inc.</td>
<td>Twinsburg, OH</td>
<td>Personnel and technical support on algorithm testing, and data sources.</td>
</tr>
<tr>
<td>Akron</td>
<td>City of Akron</td>
<td>Akron, OH</td>
<td>Personnel and technical support.</td>
</tr>
<tr>
<td>Akron</td>
<td>City of Twinsburg</td>
<td>Twinsburg, OH</td>
<td>Personnel and technical support.</td>
</tr>
<tr>
<td>Akron</td>
<td>City of Copley</td>
<td>Copley, OH</td>
<td>Project support with older driver selection.</td>
</tr>
<tr>
<td>Purdue</td>
<td>McGavic Outdoor Power</td>
<td>Noblesville, IN</td>
<td>Development of electric vehicle de-icing prototype.</td>
</tr>
<tr>
<td>Purdue</td>
<td>Purdue University</td>
<td>West Lafayette, IN</td>
<td>Facilities and collaborative research.</td>
</tr>
<tr>
<td>Purdue</td>
<td>Area Planning Commission of Tippecanoe County</td>
<td>Lafayette, Indiana</td>
<td>Mutual assistance in counting vehicles, pedestrians, and other users of selected locations on city streets.</td>
</tr>
<tr>
<td>Purdue</td>
<td>Indiana Department of Transportation</td>
<td>Indianapolis, IN</td>
<td>Collaborative research (in-kind) and cost sharing (cash).</td>
</tr>
<tr>
<td>Purdue</td>
<td>NYU Shanghai</td>
<td>Shanghai, China</td>
<td>Collaborative research.</td>
</tr>
<tr>
<td>Purdue</td>
<td>Georgia Institute of Technology</td>
<td>Atlanta, GA</td>
<td>Collaborative research.</td>
</tr>
</tbody>
</table>
3. Outputs

In this reporting period, the CCAT consortium produced the following products and other outputs:

**University of Michigan**

- End-User License Agreement for “Testing Automated Driving Systems in a Naturalistic and Adversarial Driving Environment with Augmented Reality” with the American Center for Mobility (reference University of Michigan Office of Technology Transfer File #2021-0889).
- Computational overtaking-bicyclist models demonstrated in a virtual environment.
- Closed track testing platform for automated weaving feature.
- Institutional Review Board (IRB) approval (HUM00199425) for motion sickness response in vehicles when using preemptive interventions via active systems.
- Developed the experimental protocol that combines data from the driving simulator, physiological sensing, and driver monitoring system for the project “Predicting Driver Takeover Performance in Conditional Automation (Level 3) through Physiological Sensing.”
- Experimental protocol submitted to the UM IRB for above project.
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• Wang, X., Jerome, Z., Zhang, C., Shen, S., Kumar, V., and Liu, H., Trajectory Data Processing and Mobility Performance Evaluation for Urban Traffic Networks, to be presented at 2022 Annual Meeting of Transportation Research Board, Washington DC.
• A video was produced “Improving the Efficiency of Trucks Via C-V2X Connectivity on Highways – A case study from Detroit, Michigan.”

Purdue University

• Winter Operations Resources from related INDOT Projects are posted at this website: https://doi.org/10.4231/HB7W-S331.
• The following training videos were developed/refined during this reporting period:
  o Automated Precision Brine Application on Interstate 465: https://doi.org/10.4231/1MFV-RD45;
  o Automated Precision Brine Application: https://doi.org/10.4231/X34H-9221; and
  o Importance of Brine Application: https://doi.org/10.4231/MECJ-AN70.
• Computational model for ridesharing with advanced air mobility.
• Yunchang Zhang and Jon Fricker, "Incorporating Conflict Risks in Pedestrian-Motorist Interactions: A Game Theoretical Approach”, published in Accident Analysis & Prevention.
• A database of more than 2000 interactions between pedestrians and motorists has been created. Pedestrian and vehicle trajectory data is available for subsequent safety and efficiency analysis.
• Yunchang Zhang and Jon Fricker, "Incorporating Conflict Risks in Pedestrian-Motorist Interactions: A Game Theoretical Approach", accepted 6/10/2021 for publication in Accident Analysis & Prevention.


• A spatial-temporal graph-based model is proposed to predict future movements as well as the behavior of road users, given their historical trajectories and interactions with other road users. The state of art machine learning models in motion prediction (Social-LSTM, Convolutional Social Pooling, etc.) have been replicated/applied in our experiment to demonstrate the performance of the proposed spatial-temporal graph-based model for the project “Translation of Driver-Pedestrian Behavioral Models at Semi-Controlled Crosswalks into a Quantitative Framework for Practical Self-Driving Vehicle Applications.” Also, a trajectory dataset consisting of complicated traffic flows mixed with vehicles, cyclists, and pedestrians was developed. The large-scale trajectory dataset contains 4-hour video recordings that can be used for planning, trajectory prediction, and simulation tasks.


• Methodology to identify market segments and assess transportation disadvantaged areas.

• Survey data for Indianapolis and Chicago.

• Database for transportation health-related factors in both Chicago, IL and Indianapolis, IN.


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- A new methodology for roundabout control strategy for connected and autonomous vehicles (CAVs) developed and posted to YouTube.
- Zhu Qing, Viswa Sri Rupa Anne, Srinivas Peeta, "Driving simulator-based study of the impacts of various roadway design modifications on the curiosity lab test track," presented in ATCR Final Presentations meeting, Atlanta, May, 2021.

University of Akron

- Added to dataset at minor intersection entrance when vehicles select proper gaps to enter the roadway.
- Additional data collected to set up the "before" baseline for simulation for model setup and parameter calibrations. The simulation study will help answer the “what if” questions.

University of Illinois at Urbana Champaign

- A novel FEM model for characterizing air drag resistance of multiple platoon bodies was developed.
- A "deep Galerkin" method utilizing neural network and random sampling is being developed to solve the proposed PDE.
A simplified approach (equivalent number of cycles) was developed to incorporate the effect of rest period on permanent deformation. It can be used to translate the experimental data to the rutting calculation of AASHTOWare PMED framework without changing transfer functions.

Tested sensor array mounted on vehicle to detect the EM signature made on the pavement.

Developed a side mirror mounted camera-based system to find the location of vehicle within the lane (ground truth) to compare the results of EM signature.

Central State University
- Undergraduate research assistants Ms. Lundy and Mr. Smith submitted abstracts to a NTA research symposium on "Broadening Participation in STEM: Valuing HBCUs.” The topic is "Comparison of On-Road Vehicle Emissions at Four Highway Intersections in Ohio" and "Impact of COVID on On-Road Emissions in Montgomery County, Ohio" respectively.
- Dr. Nedunuri was an Invited Panel Member at USDOT Center for Connected Multimodal Mobility’s (C2M2) 5th Annual Fall Conference on October 15, 2021, in Clemson, South Carolina where he discussed the University of Michigan and the Central State University model in “Developing Meaningful HBCU – UTC Partnerships for the Future.”
- Continued collection of ground level emissions concentrations.

4. Outcomes
The application of outputs has produced the following outcomes during this reporting period:

University of Michigan
- Acquired, registered, and insured a Dodge ProMaster Cargo Van for the motion sickness vehicle testbed.
- Finalized the design of the motion sickness vehicle testbed.
- Developed instrumentation to measure all the relevant motion states of the vehicle and the active seat and instrumentation packs (head-mounted and chest-mounted) to measure the passenger motion and physiological states.
- Developed several active passenger stimuli (audio and vibrotactile).
- Developed a test protocol and methodology for evaluating the occurrence and mitigation of motion sickness in Human Subjects, approved by IRB (HUM00199425).
- Established the concept of V2X-basic traffic prediction.

Purdue University
- Dissemination and training to various agencies (including academia, state DOT and local agencies) on brine vehicles developed for CCAT.
- Multi-State Semi-Markov Modeling was applied to the Recurrent Events inherent with the gap acceptance phenomena at crossing locations.
- Advanced pedestrian detection and tracking techniques (YOLO V5 and DeepSort algorithms) were applied to speed up the conversion to video recordings of crossings to digital databases and identify events with conflict risks.
- A game-theoretic model has been developed to quantify probabilities of conflict and confusion under alternative scenarios.
Reinforcement learning techniques have been integrated into the traffic simulation software (SUMO) to investigate the optimal control strategies at crosswalks.

Increased understanding of behavior of pedestrians and motorists in a variety of situations at the same site. This forms the basis of an analysis of the performance of similar crossing facilities when new technologies are employed for vehicles and pedestrians. Additionally, pedestrian and vehicle trajectory data are available for subsequent safety and efficiency analysis.

Identification of infrastructure changes needed in the CAV era.

Increased awareness of current deficiency of road infrastructure to accommodate CAVs.

**University of Illinois at Urbana Champaign**

- A surrogate model that can predict the air drag coefficient for 5 truck bodies.
- Shift factors were obtained as a function of stress level and temperature using the experimental data. Equivalent number of cycles approach was found to be effective in including the rest period influence on permanent deformation.
- Successfully tested sensor array mounted on vehicle.
- Created EM signature on the pavement using the materials identified from laboratory testing.
- Developed a method to find ground truth location of vehicle within the lane using camera mounted on side mirror of the car.

5. Impacts

In addition to the impacts that CCAT outreach has on the body of knowledge and technology, these additional impacts were derived from CCAT research this reporting period.

**University of Michigan**

- Reduced travel delay in Oakland County, MI by 10-20% in the pilot area of the traffic signal optimization system, OSaaS (Optimizing Signals as a Service).
- Deployed a test methodology at the American Center for Mobility, Safe AI Framework for Trustworthy Edge Scenario Tests (SAFE-TEST), for any OEM or Tier 1 to use while testing the commercial viability of their products. SAFE-TEST has the potential to save manufacturers millions of dollars per platform, improve the safety of their testing staff, and improve customer satisfaction and safety.

**Purdue University**

- Knowledge gained in the research and initial deployment of the automated brine application system has developed capabilities in the connected and automated space for small campus vehicles and will provide information needed to scale precision application of de-icing chemicals to highways and airports.
- Improvements to the operation and safety of semi-controlled crosswalks by developing a database and identifying factors that affect pedestrian and motorist behavior. This information will be used to test the impact of new technologies on crosswalk safety and performance.
Semi-Annual Progress Report for University Transportation Centers

- Improves the safety of semi-controlled crosswalks by developing a method to quantify the conflict risk in pedestrian-motorist interaction (event). This information will be used to test the impact of new technologies on crosswalk safety and performance.
- The observing-tracking-learning framework can be generally used in the design of intelligent tracking systems at “smart” crosswalks and collision-avoidance systems for self-driving vehicles.

University of Illinois at Urbana Champaign

- An accurate FE model was developed that optimizes truck air drag and demonstrates that truck platooning can save 5-15% fuel.
- The integrated truck-drone delivery system is a promising implementation which simultaneously optimizes routing and scheduling for line-haul and last-mile trips. The proposed model provides steady-state routing suggestions to improve fuel-time efficiency, sustainability, and accessibility of the delivery service.
- Shift factors obtained using shifting can be used to obtain the permanent deformation for any new rest period, stress levels, and temperature without conducting further experiments. For any new rest period, rutting accumulation can be calculated using the proposed approach. Therefore, it can be used to check the adequacy of a pavement section to rutting for different truck platooning scenarios (rest periods).
- Materials and sensor combination that was tested in lab to locate EM signature in normal and adverse conditions was successfully tested in field. The method developed has promising results and can assist vehicles with ADAS system or AVs to stay within the lane accurately both in normal and adverse condition. Moreover, the proposed method if adopted by infrastructure owners and operators, could bring a paradigm shift in pavement design by having future roads meet not just physical properties standard but also electromagnetic properties standard to enable vehicle to pavement interaction.

6. Changes/Problems:

In this period, CCAT continued to struggle with the impacts of COVID-19.

Below is a summary of changes and problems for each of our consortium members, including issues stemming from COVID-19.

University of Michigan

- The project “Development of Machine-Learning Models for Autonomous Vehicle Decisions on Weaving Sections of freeway Ramps” had some delays due to the upgrade of Mcity’s communication technology. After initial testing, it was found that modifications to the communications platform between Mcity AV and UMTRI instrumented vehicle for successful testing are required. A solution has been developed and will be tested in the next reporting period.
- A key challenge during this period was acquiring a vehicle to develop the experimental vehicle testbed for the project “Motion Sickness Alleviation via Anticipatory Control of Active Seats in Autonomous Vehicles.” There have been significant shortages in the supply of cargo vans (along with any new or used vehicle) in the last six months. It took longer than expected, and cost more than planned, to acquire a suitable vehicle. Also, the modifications to the van have taken much
longer because of external resource limitations. Overall, this has resulted in the schedule slipping by several months and higher expenses than initially planned.

**Akron**

- Progress on data collection has been largely delayed due to at-home work operations by employees of tire companies and state DOTs, affecting the project “Impact Analysis of Roadway Surface and Vehicle Conditions on Fleet Formation for Connected and Automated Vehicles.” Faster progress is expected after summer 2021 with loosening restrictions from the pandemic.
- Lack of travel demand in the first part of the reporting year due to prolonged pandemic, affecting the ability to collect field data for the project “Access Control at Major-Minor Intersection through CAV in Mixed Traffic.” The situation improved in the second part of the year benefiting from the vaccine rollout program.
- Work was slowed down with continued restrictions on face-to-face meetings, delaying research on the project “Development of a Prototype Safety Advisory System to Older Drivers in Gap Selection,” including interactions with the older drivers as research subjects.

**WCC**

- Instead of supporting students to attend conferences, WCC has redirected their efforts to buy supplies for students, deliver them to their houses, for the students to participate remotely.

**Purdue University**

- Experimental work on human subject related driving simulation slowed considerably during the reporting period due to the COVID pandemic, affecting the timing of the project “Investigation of AV Operational Issues using Driving Simulator Equipment.”
- While developing the map of Midtown Atlanta, file size limitations were encountered while importing to the simulator software. The challenge has been overcome and an advanced stage in the map development was achieved.

7. Special Reporting Requirements: Final Reports

This period, the final report below was completed, edited to meet 508 compliance, and posted to the [CCAT website](http://www.ccat.org). Additionally, all outputs, outcomes, and impacts from the project were documented and submitted.


**URL:** [https://deepblue.lib.umich.edu/handle/2027.42/156048](https://deepblue.lib.umich.edu/handle/2027.42/156048)

Additionally, there are currently 13 CCAT final reports in the final stages of editing that will be submitted next period.