SEMI-ANNUAL PERFORMANCE REPORT

APRIL 2020 TO SEPTEMBER 2020

SAPR #7

SAFE-D: Safety Through Disruption University Transportation Center

San Diego State University

Texas A&M Transportation Institute

VT | Virginia Tech Transportation Institute

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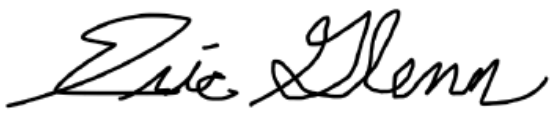
Signature of Submitting Official	

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Accomplishments

Major Goals of the Program

Fueled by the inevitable changes in our transportation system, the Safety through Disruption (Safe-D) National University Transportation Center (UTC) endeavors to maximize the potential safety benefits of disruptive technologies through targeted research that addresses the most pressing transportation safety questions. With the outstanding leadership of the Virginia Tech Transportation Institute (VTTI) and the Texas A&M Transportation Institute (TTI) in a mentoring collaboration with the new transportation research group at San Diego State University (SDSU), a Hispanic-Serving Institution known for educating the transportation workforce, our geographically balanced consortium encompasses the largest group of transportation safety researchers in the nation and provides unparalleled expertise, facilities, and resources to conduct impactful research toward our long-term vision. The Safe-D National UTC focuses its efforts in three key areas: (1) cutting-edge research conducted by leading transportation safety experts and their students; (2) education and workforce development (EWD) for programs of all levels, from grade school through college and extending to continuing education for professionals; and (3) fully supported technology transfer (T2), including practitioner training partnerships, social networking, commercialization, and intellectual property management. Furthermore, Safe-D met with the stakeholders to further strengthen our relationship with our industry partners and make suggested updates to our program. Our applications areas were updated to fit our goals and the growing change in transportation. Accessibility was added an application bubble and the driver factors and interface bubble was updated to occupant factors and interfaces.

Accomplishments During This Reporting Period

Project Awards and Activity

The fifth round of Call for Proposals commenced during this reporting period. Awards from this competitive cycle were issued in September 2020. Under this competition, 35 proposals (research statements) were received, including 2 that were collaborative across consortium university team members. Of the total proposals received, 16 of the 36 proposals received were selected for development of a full Work Plan, the next step in the Safe-D Proposal Process, with 15 projects awarded during this reporting period.

At the end of this reporting period, the Safe-D National UTC had a project portfolio of more than $23.8 million, with just over one-half of project funding sourced from non-federal matching funds. Safe-D projects are selected according to their focus on four Center theme areas: automated vehicles, connected vehicles, big data analytics, and transportation as a service. The coverage of Safe-D themes by project portfolio to-date is shown in Figure 1 (percentages are based on the number of projects reporting a focus in one or more Safe-D theme area(s), resulting in a total of over 100%).

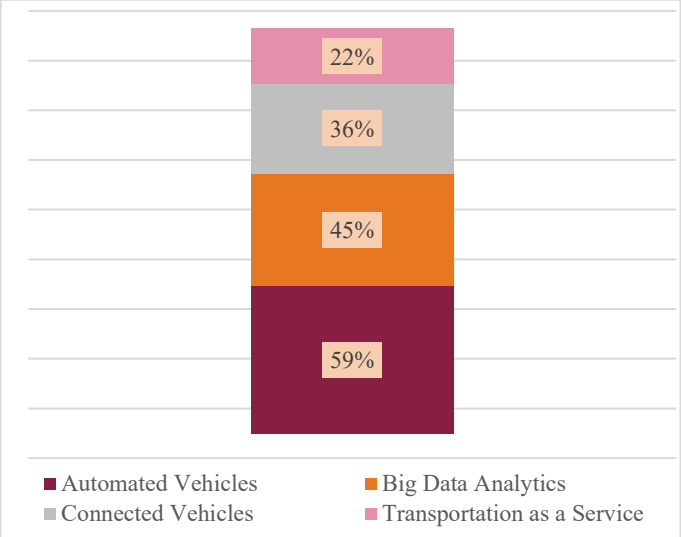

Figure 1. Portfolio of Safe-D Projects by Theme Area (total exceeds 100% due to projects covering multiple theme areas)

The Safe-D Leadership Team feels strongly that the projects awarded during this reporting period contribute to the overall Safe-D vision and mission. The Leadership Team is excited

about the potential of these projects to maximize the safety of disruptive technologies as they are integrated into our transportation system. Safe-D research projects awarded during this reporting period, their respective theme(s), and short descriptions are reported below. A (*) denotes the lead institution.

Newly Awarded

Project 05-008: Using Health Behavior Theory and Relative Risk Information to Increase and Inform Use of Alternative Transportation

Institution(s): VTTI and TTI; Award Round: Fall 2020; Theme Area(s): Transportation as a Service, Big Data Analytics*

This project develops an intervention and education program to encourage alternative transportation to, from, and around campus to reduce traffic on campus while still respecting COVID-19 precautionary measures. In addition, since there is currently no standardized approach for computing the injury rates for non-vehicle roadway users, this project will be done in collaboration with another project that will also refine and assess a methodology for estimating injury rates for pedestrians and bicyclists. The latter will be used to inform the developed intervention. This information will also aid in the development of an educational alternative transportation safety course.

Project TT-05-01: Connected Car Data Safety Applications

Institution(s): TTI; Award Round: Fall 2020; Theme Area(s): Connected Vehicles, Big Data Analytics

This project will evaluate the effectiveness of commercially available connected car data in roadway safety applications. Researchers will comprehensively explore the relationships between driving behaviors and different severity crash events. An innovative big data analytic framework will be developed to analyze this emerging safety data.

Project 05-082: Lane Change Hazard Analysis Using Radar Traces to Identify Conflicts and Time-To-Collision

Institution(s): VTTI; Award Round: Fall 2020; Theme Area(s): Automated Vehicles, Big Data Analytics*

This project will mine an existing set of radar data containing real-world lane change events executed by drivers relying on both conventional mirror and camera-based systems. The dataset provides valuable opportunities to develop computer-based algorithms for dealing with and managing radar traces to identify normative lane change signatures as well as conflict-based events (inappropriate lane changes, or lane changes executed with small-time gaps).

Project 05-084: Behavioral Indicators of Drowsy Driving: Active Search Mirror Checks

Institution(s): VTTI; Award Round: Fall 2020; Theme Area(s): Big Data Analytics, Automated Vehicles*

This project aims to mine an available dataset in order to examine driver search behavior, with the goal of identifying relationships between driver vigilance and drowsy driving. The hypothesis is that driver search behavior (e.g. mirror checks) degrades with increasing levels of drowsiness. If a reliable relationship is found between driver vigilance and state of drowsiness, the practical applications may be to incorporate this measure of driver search behavior into the "toolbox" of metrics for estimating driver drowsiness.

Project 05-086: A Data-Driven Approach to the Development and Evaluation of Acoustic Electric Vehicle Alerting Systems for Vision-Impaired Pedestrians

Institution(s): VTTI; Award Round: Fall 2020; Theme Area(s): Automated Vehicles, Connected Vehicles*

Based on previously collected data and new experiments, this project will continue to perfect the development of electric vehicles' acoustics-based safety measures for vision-impaired pedestrians. The project will establish data-driven safety performance measures, such as the probability of vehicle detection with respect to scientifically oriented additive sounds that meet existing standards, as well as techniques for uniform sound transmission around the vehicle.

Project 05-087: Autonomous Delivery Vehicle as a Disruptive Technology: How to Shape the Future with a Focus on Safety?

Institution(s): TTI and VTTI; Award Round: Fall 2020; Theme Area(s): Automated Vehicles, Connected Vehicles*

The goal of this project is to examine the safety-critical issues associated with autonomous delivery vehicles (ADVs). This research involves conducting a review of the literature; gathering and integrating several datasets, such as aggregated ADV trips and trajectories, ADV incidents, demographic data, crash, roadway, and traffic data, and crowdsourced data from multiple sources; performing rigorous analysis to determine the safety effects of ADVs; and developing a decision support tool to provide contexts of potential deployment zones for ADVs.

Project 05-089: **A Holistic Work Zone Safety Alert System through Automated Video and Smartphone Sensor Data Analysis**
Institution(s): SDSU; Award Round: Fall 2020; Theme Area(s): Big Data Analytics, Automated Vehicles, Connected Vehicles*
This project presents a hybrid approach in which visual- and wearable-sensor data are used for safety monitoring and alert generation to offer a practical mitigation strategy to both external and internal safety risks. It leverages smartphones as a pervasive and standalone resource for collecting data and communicating safety-related instructions to workers. The project also uses information systems and behavioral science theories (i.e., technology acceptance model and Diffusion of Innovation theory) to build end-users' trust toward scalable adoption of the developed systems.

Project 05-091: **Improving Methods to Measure Attentiveness Through Driver Monitoring**
Institution(s): VTTI; Award Round: Fall 2020; Theme Area(s): Big Data Analytics, Automated Vehicles*
This project leverages previous research, naturalistic databases, and input from recent literature to develop robust algorithms for assessing when drivers are inattentive to the driving task, while also investigating limitations of different approaches and sources of information. Effectively detecting distraction and inattention can enable automakers to develop countermeasures against this behavior and thereby increase safety for all road users.

Project 05-093: **Automated Shuttles and Buses for All Users**
Institution(s): TTI; Award Round: Fall 2020; Theme Area(s): Connected Vehicles, Automated Vehicles*
The demonstrations of automated shuttles and buses have included little or no participation by the disabled community. This project will address that gap by introducing individuals with disabilities to an automated shuttle in Arlington and a Smart Intersection in College Station, assessing their safety perceptions before and after riding in the shuttle and navigating the intersection, and assessing information on their complete trip. The project will identify improvements in the vehicles, service operations, and the street system and built environment to ensure that individuals with disabilities have equal and safe access to automated shuttles and buses to improve their mobility.

Project 05-097: **Investigating and Developing Methods for Traditional Participant-based Data Collection with Remote Experimenters**
Institution(s): VTTI; Award Round: Fall 2020; Theme Area(s): Connected Vehicles, Automated Vehicles*
Remote experimentation is likely to increase along with rises in automated vehicle testing, when it might be desirable to remove traditional in-vehicle experimenters from the vehicle to create a more natural environment while still maintaining oversight and control of the experiment. This project will investigate and develop methods and technologies that would allow experimenters to conduct and monitor data collection from a remote location.

Project 05-101: **Evaluation of Transportation Safety Against Flooding in Disadvantaged Communities**
Institution(s): SDSU; Award Round: Fall 2020; Theme Area(s): Connected Vehicles, Big Data Analytics*
The goal of the proposed project is to systematically extract traffic safety information from multiple complex sources of flood monitoring, such as remote sensing technologies, flow gages, and weather stations, which can support informed planning for transportation safety against flooding in future smart cities.

Project 05-109: **ENDEAVRide**
Institution(s): TTI; Award Round: Fall 2020; Theme Area(s): Big Data Analytics, Transportation as a Service, Automated Vehicles*
A novel autonomous vehicle service named ENDEAVRide will start pilot testing in Nolanville, Texas, a typical rural town in central Texas. The autonomous vehicle will serve as a taxicab and a mobile telemedicine portal. This project marks the first attempt to conduct a real-world assessment of autonomous vehicles' potential safety impacts as a disruptive technology to offer older adults a pathway to continued independent mobility in underserved communities.

Project 05-113: **Evaluation Tools for Automated Shuttle Transit Readiness of the Area**
Institution(s): VTTI; Award Round: Fall 2020; Theme Area(s): Transportation as a Service, Automated Vehicles*
This project aims to develop a general evaluation protocol for transit readiness in the area for automated shuttle implementation. Using the data gathered from the EasyMile shuttle implemented in Fairfax County, Virginia, the research team will perform risk assessments and safety analysis for the automated shuttle to understand the risks associated with the interactions between the automated shuttle and other road users, roadway infrastructure, and traffic conditions.

Project 05-115: Cooperative Perception of Connected Vehicles for Safety
Institution(s): VTTI; Award Round: Fall 2020; Theme Area(s): Big Data Analytics, Transportation as a Service*
This project will develop vision-based cooperative perception and accident (crash) avoidance trajectory plans in dynamic environments for two connected vehicles in which the ego vehicle would face a potentially unseen hazard ahead but could receive safety-critical information from a vehicle in front and estimate/predict the trajectory of the potential hazard. The results will be tested in a traffic emulation environment with autonomous connected mobile robots. The methods and approaches will be equally applicable to real-life full vehicles upon further development and testing.

Project 05-116: Simulation-based Approach to Investigate the Electric Scooter Rider Protection During Traffic Accidents. *A Step Forward for Safer E-Scooters and for Standardized National Safety Policies*
Institution(s): VTTI; Award Round: Fall 2020; Theme Area(s): Transportation as a Service, Big Data Analytics*
This simulation-based study develops a better understanding of the injury mechanisms and injury risks for e-scooters during traffic accidents. A finite element model of a generic e-scooter is developed and then connected with a human finite element model in a rider posture in order to simulate the most common scooter accidents. Based on the injury data recorded in sensitivity studies performed using Design of Experiment, we expect to estimate possible reductions of rider injury risks in terms of maximum speed, use of various safety equipment, and using/avoiding sidewalks. Finally, recommendations for e-scooter design and standardized national policies for the protection of the rider and pedestrians will be provided.

Project VTTI-00-032: E-Scooter Design
Institutions: VTTI; Award Round: Directed: Theme Area(s): Transportation as a Service, Automated Vehicles, Big Data Analytics*
This project will result in an updated scooter design that will induce safer riding behavior.

Project VTTI-00-027: Impact of Automated Vehicle External Communication on Other Road User Behavior
Institutions: VTTI; Award Round: Directed: Theme Area(s): Automated Vehicles*
This project will evaluate HAV external communication design parameters in both static and dynamic settings and from a driver or pedestrian road user perspectives.

Project VTTI-00-031: Evaluation of Eyes Off Road During L2 Activation on Uncontrolled Access Roadways
Institutions: VTTI; Award Round: Directed: Theme Area(s): Automated Vehicles*
The goal of this research will be to evaluate the eye glance patterns of drivers operating L2 vehicles (ACC + lane centering) during normal, baseline driving while negotiating surface streets. Driver's eye glance patterns when L2 systems are active will be compared to driver's glance patterns when L2 systems are inactive while negotiating uncontrolled access roadways.

SDSU-01-01: Prediction of Vehicle Trajectories at Intersections Using Inverse Reinforcement Learning
Institutions: SDSU; Award Round: Directed: Theme Area(s): Automated Vehicles, Big Data Analytics*
This project presents a hybrid approach in which visual- and wearable-sensor data are used for safety monitoring and alert generation to offer a practical mitigation strategy to both external and internal safety risks. It leverages smartphones as a pervasive and standalone resource for collecting data and communicating safety-related instructions to workers. The project also uses information systems and behavioral science theories (i.e., technology acceptance model and Diffusion of Innovation theory) to build end-users trust toward scalable adoption of the developed systems.

Project TTI-05-04: Micromobility Safety Regulation: Municipal Best Practices Review
Institutions: TTI; Award Round: Directed: Theme Area(s): Transportation as a Service, Big Data Analytics*
This project explores what types of regulations municipalities and regions are imposing in an effort to address the safe deployment of these micromobility options.

Completed Projects

During this reporting period, research activities on the following projects were completed:[1]

- 03-036: Modeling Driver Behavior During Automated Vehicle Platooning Failures
- 03-072: Preventing Crashes in Mixed Traffic with Automated and Human-Drive
- 03-073: Autonomous Emergency Navigation to a Safe Roadside Location
- 04-101: Safety Impact Evaluation of a Narrow-Automated Vehicle-Exclusive Reversible Lane on an Existing Smart Freeway
- 04-103: Examining Senior Drivers' Adaptation to Mixed-Level Automated Vehicles: A Naturalistic Approach - Phase II Analysis of the Naturalistic Driving Data
- VTTI-00-029: Real-world Use of Automated Driving Systems and Their Consequences

As with the selection of Safe-D projects, Safe-D Final Research Reports undergo a rigorous, iterative peer-review process, including reviews by the Safe-D Leadership Team, Subject Matter Expert(s), and the Technical Editing team at VTTI. The following projects were finalized during this reporting period and/or final research reports were published to the Safe-D website and distributed to repositories, as per grant requirements:

- 01-003: Data Mining to Improve Planning for Pedestrian and Bicyclist Safety
- 01-006: Implications of Truck Platoons for Roadside Hardware and Vehicle Safety Hardware
- 02-008: Pavement Perspective on AV Safety through Optimizing Lateral Positioning Pattern
- 02-014: Formalizing Human-Machine Communication in the Context of Autonomous Vehicles
- 02-019: Identification of Railroad Requirements for the Future Automated and Connected Vehicle (AV/CV) Environment
- 03-051: Response of Autonomous Vehicles to Emergency Response Vehicles (RAVEV)
- 03-082: Assessing Alternative Approaches for Conveying Automated Vehicle 'Intentions'
- 03-087: Big Data Visualization and Spatiotemporal Modeling of Risky Driving
- TTI-01-03: Comparison of SHRP2 Naturalistic Driving Data to Geometric Design Speed Characteristics on Freeway Ramps
- TTI-Student-02: Development of Analytic Method to Determine Weaving Patterns for Safety Analysis near Freeway Interchanges with Access Management Treatments
- TTI-Student-05: Exploring Crowdsourced Monitoring Data for Safety
- TTI-01-01: Analysis of an Incentive-Based Smartphone App for Young Drivers

Safe-D Programming

As noted in the original proposal, Safe-D has commenced a number of programs targeting its Leadership, Education and Workforce Development, Technology Transfer, and Diversity initiatives. The following sections highlight major accomplishments under these directives.

Continuing Education/Professional Development

Safe-D continues to develop and implement many continuing education and professional development activities. All Safe-D researchers are encouraged to seek out opportunities in this area at the project level and to conduct these activities at the program level. Many of these activities are described in the Highlighted EWD & Other Outreach Activities and Outputs section; additional activities reported by research teams during this period are listed below:

- Safe-D project VTTI-00-028 was invited to present of their project at the Joint Statistical Meeting 2020 The Future of Transportation: The Predicting Power of Driver Behavior Data — Topic Contributed Papers Transportation Statistics Interest Group

[1] The outputs of these projects are currently under final review and are expected to be published during the next reporting period, per the Safe-D data management plan (DMP) and grant requirements.

- Safe-D Projects 04-098 and 03-036 (Data Mining Twitter to Improve Automated Vehicle Safety and Modeling Driver Responses during AV Platooning Failures) were presented at the Human Factors and Ergonomics Society's 2020 International Annual Meeting and US Department of Transportation's Getting to Know AI Webinar series.
- Safe-D Project 04-115 (Reference Machine Vision for ADAS Functions) researchers were invited and received federal support to present at the Understanding the Correlation between the Quality of Markings and Lane Detection/Following Systems, IEEE-ITS Symposium.

Professional Skills Training Series

None to Report

Due to COVID, no activities were conducted in this area during this reporting period.

Student Awards Program

Safe-D is proud of its students' accomplishments and continues to encourage students to seek opportunities, including the Eno Leadership Development Program, the Eisenhower Fellowship Program, and other student awards and leadership development opportunities that arise. The following is a selection of awards that our students have received during this reporting period.

Student Awards

During this reporting period many other Safe-D students also received awards for their exceptional efforts.

- Silvy Munira was granted the Keese-Wootan Transportation Fellowship
- Nicholas Britten was invited to join Alpha Pi Mu (Industrial Engineering Honors Society)
- Robert E. Brydia and Leonard G. Ruback received the 2020 Herbert H. Richardson Team Award
- Abhishek Nayak received a Mechanical Engineering Departmental Fellowship
- Vamsi Vegamoor received the Dwight Eisenhower Fellowship

Educational Courses Taught and Students Supported

Safe-D researchers are actively engaged in teaching efforts at each of the consortium universities and in supporting students through the conduct of research activities. While formal metrics are reported annually in the Program Performance Indicators, the following is a description of the metrics for this reporting period regarding courses taught and student support provided through the Safe-D program. During this reporting period, researchers involved in Safe-D research projects taught 21 graduate and 24 undergraduate courses, reaching 140 graduate and 1,357 undergraduate students. Safe-D research projects supported 44 undergraduate- and graduate-level students during this reporting period. The breakdown of the students supported during this period are presented in Table 1.

Table 1. Description of Students Supported under Safe-D Research Activities

Academic Level	Total Number of Students Supported	Number of Underrepresented Students Identified
Undergraduate	9	3
Masters	12	2
PhD	20	9

Highlighted EWD & Other Outreach Activities

COVID-Impact:

Due to the impact of COVID-19 the Safe-D consortium has not been able to engage in as many EWD and Outreach activities as in previous reporting periods. COVID-19 has led to the cancelation or rescheduling of various career fairs, research summits, and symposiums that had previously been scheduled for this reporting period.

High School Visit

The research team for Safe-D project 04-104: Development of a Connected Smart Vest for Improved Roadside Work Zone Safety presented the smart vest developed from the project to 45 female high school students from Buchanan County, VA interested in Engineering. The students learned about professional careers in the industry. They also were given the opportunity to try on the vest and shown scenarios of how the vest can keep workers safe. The team will continue these visits once COVID-19 regulations allow.

School of Biomedical Engineering and Sciences (SBES) Symposium

A graduate student who worked on project VTTI-00-032:E-Scooter Design, Adam Novotny, presented preliminary data from the E-Scooter Safety Assessment project (VTTI-00-023) as well as some of the medical record data collected in this study to an audience of 150. The presentation was part of a requirement for his PhD in biomedical engineering, for which students must present on their research at a School of Biomedical Engineering and Sciences (SBES) Symposium once a year. SBES is a joint program between the biomedical engineering departments at Virginia Tech and Wake Forest.

Safe-D Upcoming Webinar Series

Implications of Truck Platoons for Roadside and Vehicle Safety Hardware

Safe-D is currently working with this project 01-006 Implications of Truck Platoons for Roadside and Vehicle Safety Hardware to provide a webinar scheduled for early September. The webinar will be hosted my Dr. Chiara Silvestri Dobrovolny and Dr. Costin Unitariou. This projected investigated ways to identify and prioritize the critical MASH TL5 roadside safety device(s) for truck platooning impact assessment in order to understand the associated roadside and occupant risks and hazards.

Safe-D Researcher Honors and Awards

During this reporting period, many Safe-D Faculty received awards for their exceptional efforts and research:

- Sahar Ghanipoor Machiani was recognized by SDSU into the Student Research Symposium Mentors Hall of Fame. She also received the WTS San Diego Technology for Transportation Award
- Tony McDonald received the Stephanie Binder Young Professional Award from the HFES Surface Transportation Technical Group
- Reza Akhavian was recognized as one of ENR California's 2020 Top Young Professionals

Dissemination of Results

Research Project Results

Research results from Safe-D projects continued to be finalized during this reporting period. Safe-D researchers have been submitting and publishing results of their projects in peer-reviewed journals and presenting results at conferences nationwide. The publications, presentations, theses and dissertations, websites, and more avenues of dissemination reported thus far by researchers are listed in the Outputs section of this report. Project teams have also actively disseminated the results of their research projects through outreach, EWD, and T2 events, including those listed in the Highlighted EWD & Other Outreach Activities section.

Plans for Next Reporting Period

Safe-D programming for the next reporting period has continued to be significantly impacted by COVID-19 as it was in the previous reporting period. Many EWD outreach activities and T2 demonstrations that were planned for this reporting period have either been cancelled or postponed, making our goals in these areas difficult to achieve. The impacts of COVID-19 on Safe-D research are described in detail in the Impact of COVID-19 section of this report.

Safe-D has confirmed that some EWD and T2 activities will still be able to take place during the next reporting period, with some modifications. These activities are described in the following sections.

Safe-D Student and Faculty Interview Chain

In the next reporting period, students and researchers will continue a networking and interviewing chain in which Safe-D students and faculty interview their peers from separate universities within the consortium. This chain promotes further networking, collaboration, and research between the Safe-D universities. The interview chain gives students the opportunity to interact with peers and professionals outside of their immediate areas of research or professional study. This additional interaction provides a fantastic space for students to learn from their peers and develop professional relationships that could increase employment and partnership opportunities in the future.

2020 Undergraduate Research Internship Program

Safe-D will once again host a summer undergraduate research internship program at Texas A&M University in College Station, Texas. The program offers students the opportunity to participate in research in the areas of connected and automated vehicles, big data analytics, and transportation as a service. Each student will be paired with a research mentor and will work on an ongoing research project in areas of computing, electronic engineering systems, computer engineering, and industrial & system engineering. See Figure 2 for a picture of the participating students. Due to the impact of COVID-19 on student activities and human subjects research, TTI has altered the structure of the internship program so that internships can be completed remotely. The summer internships were still effective and successful with the modification to the program. The students involved were grateful for the opportunity to be able to continue their internship remotely. Because two of the selected students had been paired with research projects for which research activities could not be completed remotely, unfortunately, their internships were cancelled. Safe-D is extremely proud to announce that one student from these internships, Amarthya Annu, received a job offer from General Motors as a result of the internship.

Figure 2. TTI Summer Interns

Participants and Collaborating Organizations

Partner Organizations

In addition to inter-consortium collaborations on Safe-D research projects, the Safe-D T2 Plan requires each new project team to be matched with a project champion from industry who will provide a built-in "customer" for the research, further aligning the project with industry needs. The domestic and international collaborations listed below highlight some of the reported collaborations during this period.

Domestic Collaborators

- Project 04-101 (Safety Impact Evaluation of a Narrow-Automated Vehicle-Exclusive Reversible Lane) members collaborated with Linscott, Law & Greenspan, Engineers (LLGE) and LLGE and CALTRANS contributed in-kind.

- Project TTI-05-02 (Analysis of Advanced Driver-Assistance Systems in Police Vehicles) researchers partnered with Texas A&M Engineering Extension Services to assist in recruiting police office from state-wide police departments.
- Project VTTI-00-025 (Radar and LiDAR Fusion for Scaled Vehicle Sensing Test) researchers collaborated with Continental Automotive to receive research equipment and access to experts in the field.
- Project VTTI-00-021 (Signal Awareness Applications) researchers partnered with the Virginia Transportation Research Council (VTRC) for financial support.
- Project VTTI-00-022 (Automated Truck Mounted Attenuator) researchers collaborated with the Virginia Department of Transportation (VDOT), VTRC, and Transurban for cost-sharing. DBi Services provided the truck mounted attenuator truck and equipment for the project.
- Project VTTI-00-027 (An Evaluation of Road User Interactions with Automated Shuttles) researchers worked with State Farm for funding, guidance on research questions, and feedback on scenario development.
- Project 04-115 (Reference Machine Vision for ADAS Functions) researchers created a partnership with 3M to provide materials for testing and useful suggestions for the research.
- Project 04-117 (A Sensor Fusion and Localization System for Improving Vehicle Safety in Challenging Weather Conditions) researchers worked with TAMU Mays Innovation Center in College Station, Texas to provide financial support for Vamsi Vegamoor (graduate student).
- Project VTTI-00-023 (E-Scooter Safety Assessment and Campus Deployment Planning) researchers partnered with Spin and Ford to receive financial support and assistance in data collection.
- Project VTTI-00-032 (E-Scooter Design) researchers partnered with Spin and Ford to receive financial support and assistance in data collection.
- Project 04-114 (Behavior-based Predictive Safety Analytics Phase II) – SmartDrive contribute in-kind.
- Project 04-110 (Developing an Intelligent TMC with a Safety Evaluation Focus for Smart Cities) – the City of Chula Vista and CALTRANS contributed in kind.
- Project 04-115 (Reference Machine Vision for ADAS Functions) researchers collaborated with 3M to obtain materials for testing and assistance in data collection.
- Project 04-113 (Disruptive Technologies for Safety Analysis) researches collaborated with VDOT for safety performance function development.

International and Proprietary Collaborators

- Project 03-036 (Modeling Driver Responses during AV Platooning Failures) researchers collaborated with Leeds University UK on this project.
- Some Safe-D projects have collaborated with teams in the private industry sector who are unable to be named at the current time due to non-disclosure agreements.
- Project VTTI-00-027 (An Evaluation of Road User Interactions with Automated Shuttles) researchers received equipment, engineering, technical review from Daimler out of Germany.

Outputs

The following T2 Performance Goals and corresponding Metrics for Outputs are copied from the currently approved Safe-D T2 Plan. The Safe-D Leadership Team has tracked and will be reporting these metrics in the current and all following SAPRs (Table 2). The Safe-D Website Traffic Measures provide evidence that Safe-D products are being exposed to practitioners and potential users. The Safe-D website attracted 1,778 visitors during the 6-month reporting period. With the 2,729 visitors during the previous 6-month reporting period, Safe-D greatly exceeded our annual goal of 2,000 visitors per year, with a total of 4,507 visitors from October 1, 2019–September 30, 2020. Project Page visits averaged just over 39 visits per page for the 6-month reporting period. At the rate observed during this 6-month period, Project Page visits will fall short of our intended goal of more than 150 Project Page

visits per year. The numbers of Project Page visits for the prior two 6-month periods were 42.5 and 40, indicating a slight decline in the rate of visits but a relatively consistent level of traffic even though the number of overall website visits increased. One possible interpretation is that with the increased number of Project Pages, casual visitors have more pages to choose from and each individual page is receiving less traffic. The Safe-D team will continue to seek ways to raise awareness about the website Project Pages during the next reporting period.

Table 2. T2 Performance Goals and Corresponding Metrics for Outputs

T2 Performance Goal	Goal (Annual)	Measures for Current 6-Month Reporting Period
Website Traffic Measures	Website: ≥ 2,000 visitors/year	1,778; 4,507 visitors/previous 12 mo.
	Project Pages: Average ≥ 150 visitors/year	2,455 total visits/period; average 39 visitors/project page
Journal Articles/Conference Presentations	Project Teams: 1 article/year	12 articles; 0.32 average per reporting project
	Project Teams: 1 conference/year	5 presentations; 0.132 average per reporting project
Facility Tours	Displays viewed by ≥ 200/year	195 total visitor views; average of 5 views per reporting project
	Follow-up Interest: 5 visitors/year	1

Prior to this reporting period, a total of 26 projects had been completed, resulting in 42 journal articles and 87 conference presentations. Within this reporting period, six additional projects were completed and a total of 12 new journal articles with five new conference presentations were reported by project teams. These additions bring the average rate of publications per completed project to 2 journal articles per project and 3.5 conference presentations per completed project. These rates indicate that Safe-D is tracking ahead of its publication goals for projects through the current reporting period. Safe-D researchers also reported 195 views of Safe-D displays during outreach events during the 6-month reporting period; last period, researchers reported 5,886 views, bringing the yearly total to 6,931, which greatly exceeds with the annual goal of 200 views.

Publications, Conference Papers, and Presentations

The following are the publications, conference papers, and presentations that were submitted, accepted, or published during this reporting period.

Journal Publications/Conference Papers

Alambeigi, H., McDonald, A.D. (2020). A Bayesian regression analysis of the effects of alert presence and scenario criticality on automated vehicle takeover performance. Human Factors: The Journal of the Human Factors and Ergonomics Society. (Submitted)

Buehler, R., Broaddus, A., Sweeney, T., Zhang, W., White, E., Mollenhauer, M. (2020, July 31). Changes in Travel Behavior, Attitudes, and Preferences among E-Scooter Riders and Non-Riders: Results from Pre and Post E-Scooter System Launch Surveys at Virginia Tech. Transportation Research Board. (Under Review)

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Website(s) or Other Internet Sites

Safe-D Website

During this reporting period, the Safe-D National UTC website was regularly updated with developments from the Safe-D program, including links to project products (e.g., EWD and T2 outputs) and Safe-D outreach activity descriptions. As the website is Safe-D's primary method of external interfacing, the Center is committed to providing up-to-date information through this public website using a modern, minimalist approach to rapid information sharing. The Safe-D website averaged over 296 users per month, with 1,728 new users during this period. Users viewed pages 7,634 times during this period, visiting an average of 2.7 pages per session. These website traffic measures indicate a steady flow of activity, exceeding our T2 performance goals, and this trend is expected to continue as projects complete their activities, and as project products become available for download via the website.

Safe-D Researcher Portal

With 355 users at the end of this reporting period, the Safe-D Researcher Portal continues to successfully facilitate inter-consortium collaboration and access to Center-level resources across our geographically dispersed universities. During this reporting period, the Safe-D leadership team continued to use the portal to disseminate information to project teams and researchers interested in proposing projects to Safe-D. Information on the portal is continually updated so that research team members are aware of upcoming reporting deadlines, processes for the submission of deliverables, and other Safe-D project requirements.

Outcomes

The Safe-D projects described in the previous sections are continuing to create outcomes resulting in changes to the transportation system through increased understanding and awareness of transportation issues; focus and impact on future policy, regulation, rulemaking, and legislation; additions to the body of knowledge; training of the future transportation workforce; and improvements to transportation-related processes, technologies, techniques, and skills. Due in part to the strong Safe-D T2 Plan and industry involvement with each Safe-D project, we are starting to see Safe-D projects which are resulting in the adoption of new technologies, techniques, or practices, as outlined in the next sections.

The T2 Performance Goals and corresponding Metrics for Outcomes/Impacts, as written in the currently approved Safe-D T2 Plan, are listed below (Table 3). Safe-D project teams received multiple cancellations to events due to the COVID-19 pandemic. The Safe-D team participated in one outreach event to promote the program and projects to an audience totaling 100 practitioners, including DOT officials, industry partners, and graduate students. Within this reporting period, Safe-D researchers did not report any DOTs adopting technologies resulting from projects. However, we are optimistic that current and future projects will yield better results. To improve reporting, the Safe-D team met with industry champions directly to request implementation information prior to the next period and receive feedback on areas of interest and the overall program. As discussed earlier, changes were made to our applications area and projects were funded during the Fall 2020 call with the input of these industry experts.

Table 3. T2 Performance Goals and Corresponding Metrics for Outcomes/Impacts

T2 Performance Goal	Goal (Annual)	Measures for Current 6-Month Reporting Period
Practitioner Attendance at Events	Project Teams: average 1 event/team	1
	Each Event: average 15 practitioners	100
Vendors Using Technology Developed	Average 1/3 projects result in vendors using technology	0
	1 license in later stages of UTC operation	0
DOTs Using Technology Developed	3 DOTs using project technology	0
	Follow-on funding from 2 DOTs	0

Increased Understanding and Awareness of Transportation Issues

During this reporting period, Safe-D research projects enhanced the understanding and awareness of various transportation issues arising from the increasing implementation of vehicle connectivity, automation, big data analytics, and transportation as a service. Safe-D projects have improved our understanding of various issues surrounding the development and implementation of automated and connected vehicles. For example, Project 04-101 (Safety Impact Evaluation of a Narrow Automated Vehicle-Exclusive Reversible Lane) has shed light on the barriers and opportunities associated with AVs in our existing infrastructure. This project has established a baseline functional safety concept for the future development of automated vehicle-exclusive lanes and recommendations for adapting infrastructure for automated vehicle technology. The outcomes improve our understanding of the infrastructure requirements for the future design and implementation of automated vehicle-exclusive lanes. Project

VTTI-00-021 (Signal Awareness Applications) is working toward a demonstration of SPaT and MAP data transmission by connected intersections within the Virginia Connected Corridors (VCC). A successful demonstration will encourage VDOT and other stakeholders to further develop and expand mobility applications and eventually safety applications. This project is furthering the understanding and awareness of how vehicle and infrastructure connectivity can be leveraged to enhance mobility and safety in our transportation system.

Safe-D projects have also made significant contributions to the understanding and awareness of safety-related transportation issues affecting our transportation system. As an example, Project 03-087 (Big Data Visualization and Spatiotemporal Modeling of Aggressive Driving) developed an interactive web-based tool that can be used to identify when and where risky driving has occurred in the road network. This tool allows transportation agencies to identify potential risky locations and take appropriate action to curb risky driving behavior. In this way, this project has improved awareness of risky driving behaviors and where they are most likely to occur. Other projects have furthered our understanding of issues affecting advanced safety features. Project 04-115 (Reference Machine Vision for ADAS Functions) has shed light on the challenges involved in lane detection and the infrastructure needed to support lane detection technologies. Project 04-117 (A Sensor Fusion and Localization System for Improving Vehicle Safety) developed and implemented sensor fusion algorithms based on radar and thermal data in challenging weather conditions involving sun glare and night-time. The findings improve our awareness of weather-related challenges for sensor operation and ways to ensure safe sensor function in challenging conditions.

Safe-D research has also brought attention to issues related to pedestrians and bicyclists. Project 03-049 (Data Fusion for Non-Motorized Safety Analysis) developed multiple bike activity models from both traditional and emerging data sources. The direct demand model expanded on traditional approaches by incorporating a bike ability index and Strava data to understand model representativeness and the factors influencing bike activity. This project also adopted a new technique for combining multiple data sources to improve model accuracy. Finally, a state-of-the-art statistical approach, the Dempster Shafer method, was customized to accommodate the characteristics of the nonmotorized data. Overall, the developed models enhance our understanding of bike activity and its determinants. Project 04-110 (Developing an Intelligent TMC with a Safety Evaluation Focus for Smart Cities) has generated a publicly available Skateboarder and Pedestrian Dataset that can be used to train and test machine vision models to detect/classify skateboarders and pedestrians for use in vision-based safety monitoring systems. This dataset will improve the ability of vision-based systems to detect non-motorized actors, and the project outcomes highlights the need for specialized datasets to further pedestrian detection.

Passage of New Policies, Regulation, Rulemaking, or Legislation

The results of several Safe-D projects have contributed to new policies, regulations, rulemaking, or legislation during this reporting period or are currently being considered in regulations or legislation. Project 04-098 (Data Mining Twitter to Improve Automated Vehicle Safety) generated a conference proceedings paper that is forming the basis for a set of guidelines aimed at public information officers at law enforcement agencies and DOTs to improve the quality and information of their communications regarding automated vehicles. These guidelines will ensure that public safety officials and the general public have accurate expectations regarding the appropriate use of automated vehicles. The models developed under Project 03-036 (Modeling Driver Responses during AV Platooning Failures) will be made available to the government and stakeholders for use in the design of new automated vehicle technologies. The findings are thus expected to lead to the implementation of new policies for dealing with automated vehicle failures and driver responses to rear-end emergency scenarios. Project TTI-05-02 (Analysis of Advanced Driver-Assistance Systems [ADAS] in Police Vehicles) generated a list of ADAS features currently being used in police vehicles, identified the impacts of such technologies on officer driving safety, and provided a list of potential ADAS features to be implemented in police vehicles. This project also involved a survey with more than 70 police officers in Texas to understand their specific ADAS needs and requirements, and the collected data are currently being analyzed. The outcomes of this project will generate guidance and recommendations for vehicle manufacturers and police departments to update policy to ultimately improve the safety of police officers.

The results of Project 04-114 (Behavior-based Predictive Safety Analytics Phase II) may lead to the adjustment of selection or retention procedures used by organizations to maintain a safe driver workforce population. While drivers are typically evaluated for hire based on past violations and crashes, the industry may evolve to adopt other determinants of high risk, including scores from third-party driver monitoring systems. Due to the nature of driver monitoring systems, drivers may make notable self-improvements towards decreasing unsafe driving behaviors through feedback presented from either the monitoring system or management.

Increases in the Body of Knowledge

Safe-D projects have made meaningful contributions to the body of scientific knowledge during this reporting period. For example, Project 04-098's (Data Mining Twitter to Improve Automated Vehicle Safety) twitter search process and semi-supervised topic filtering method was a significant advancement in computer science and social media analysis. Finding relevant data on social media is a challenge and this method significantly improves on prior benchmark methods. Furthermore, while there have been multiple surveys of drivers' feelings regarding automated vehicles, this analysis is the first documented analysis of how these feelings translate to social media and how they change with significant events. The lessons learned from this analysis will inform subsequent experiments and analyses of automated vehicle safety and the lessons learned illustrate some significant limitations of prior social media analyses of automated vehicle crashes (e.g., sentiment dictionaries developed for general discourse are not effective for automated vehicle analyses). Project TTI-01-03 (Comparison of SHRP2 Naturalistic Driving Data to Geometric Design Speed Characteristics on Freeway Ramps) describes a previously unused source of data that could be used in a variety of design and operational studies; its use in studying freeway ramps is one example of many potential applications. The results provide a new way of estimating speed on freeway ramps based on many vehicles at many locations, yielding results from a much broader sample of drivers than is found in most previous studies of similar purpose.

Improved Processes, Technologies, Techniques, and Skills in Addressing Transportation Issues

The outcomes of numerous Safe-D projects have been processes and technologies that can be applied to improve transportation safety. Under Project 04-104 (Development of a Connected Smart Vest for Improved Roadside Work Zone Safety), the research team developed a technology that can be used in work zones to reduce associated injuries and fatalities. Similarly, Safe-D project VTTI-00-022 (Automated Truck Mounted Attenuator) generated an automated truck mounted attenuator (ATMA) system that removes drivers from the most vulnerable TMA position within dynamic and short-duration work zone operations. The key to developing an ATMA design that can be rapidly migrated into operational field trials is the design of a tight leader-follower configuration within the dynamic platoon configurations of work zone operations. By creating a system designed and customized for short following distances (50–400 feet), this project has reduced some of the complexity of the operational control, object detection, potential for the incursion, and potential for communications loss. The design also includes a robust user interface that allows the lead vehicle driver to monitor and maintain situational awareness regarding the following vehicle behavior. The developed ATMA can be tested in real work zone operations. Both of these developments will transform the processes and technologies applied in work zones to improve work zone safety.

Adoption of New Technologies, Techniques, or Practices

During this reporting period, numerous Safe-D projects have contributed to the adoption of new technologies, techniques, and practices. Examples of this include the following:

- Project 04-117 (A Sensor Fusion and Localization System for Improving Vehicle Safety) developed and implemented sensor fusion algorithms involving radar and thermal data for challenging weather conditions involving sun glare and night-time.

Impacts

Impact on Effectiveness of Transportation System

Safe-D research projects are designed to produce implementable results that have both near-term and long-term effects on the transportation system. Although the results of some Safe-D studies have only recently begun to be implemented and/or disseminated to practitioners, the outcomes of some projects are beginning to influence our transportation system. For example, the outcomes of Project TTI-05-02 (Analysis of Advanced Driver-Assistance Systems in Police Vehicles) will improve officer safety in police operations. By providing information regarding police ADAS needs and requirements and identifying the most effective ADAS features and types for police operations, the outcomes of this project will provide practical guidelines to automotive companies supplying police vehicles. The application developed in project VTTI-00-021 (Signal Awareness Applications) can improve mobility through the connected intersections of the Virginia Connected Corridors. Project 04-113 (Use of Disruptive Technologies to Support Safety Analysis and Meet New Federal Requirements) could potentially change the traffic monitoring industry. The Federal Highway Administration (FHWA) is currently examining whether traffic volume estimates developed from probe and other sources of data can replace traffic volumes measured by conventional traffic monitoring devices. This project aims to shed light into this examination.

Provision of tools/methodologies for practitioners

During this reporting period, Safe-D projects have provided or are expected to provide new tools and methodologies that can be applied by practitioners to enhance the effectiveness of the nation's transportation system. Some examples are provided as follows:

- Project TTI-01-03 (Comparison of SHRP2 Naturalistic Driving Data to Geometric Design Speed Characteristics on Freeway Ramps) has developed a new method for estimating speed on freeway ramps that should allow new ramps to be designed based on more accurate information about driver acceleration and merging behavior.
- Project VTTI-00-024 (Characterizing Level 2 Automation in a Naturalistic Driving Fleet) will improve the effectiveness of the transportation system by providing a better understanding of how drivers are using SAE L2-capable vehicles.
- The results of Project 03-087 (Big Data Visualization and Spatiotemporal Modeling of Aggressive Driving) demonstrates how kinematic data (from sources such as connected vehicles or smartphones) within large datasets can be utilized to identify risky driving behavior, thereby helping practitioners identify risky driving and develop appropriate countermeasures.
- Project SDSU-01-01 (Prediction of Vehicle Trajectories at Intersections Using Inverse Reinforcement Learning) will aid the transportation system in sending critical information to the users in potential danger to avoid or mitigate crashes by adopting of vehicle trajectory prediction models at intersections.
- Project VTTI-00-021 (E-Scooter Design) develops an e-scooter design that will improve the effectiveness of micromobility transportation options by reducing safety hazards and addressing concerns stemming from e-scooters.
- The findings of Project VTTI-00-023 (E-Scooter Safety Assessment and Campus Deployment Planning) will improve the effectiveness of commercial dockless e-scooter services.
- The results of Project 04-113 (Use of Disruptive Technologies to Support Safety Analysis and Meet New Federal Requirements) will be used by FHWA to determine whether probe-based volumes can replace traditional traffic volumes that transportation agencies collect in the field.

Provision of information for better decision making

Other Safe-D projects have generated valuable new data and information that can implemented by decision-makers to improve the effectiveness and safety of the transportation system. For example, Project 03-049 (Data Fusion for Non-Motorized Safety Analysis) impacts both research and practice. The bike activity models developed for this

project not only illustrate the use of different datasets of varying form, to bring into a homogeneous estimate at a micro level (intersection), it also sheds light on the characteristics and determinants of bike activity. Moreover, the proposed fusion framework, under the Dempster Shafer context, can handle both spatial variability and conflict of the data sources, which are common phenomena in nonmotorized data and models. The impact is extended to informed application, as the framework was applied for multiple scenarios of varying spatial coverage and a number of data sources. Hence, it educates and enables data informed decision making to adapt the fusion framework. which can provide more accurate bike activity estimates, which are most often needed in safety analysis and policy planning.

Impact on Adoption of New Practices or Initiation of Startups

Before research begins on each Safe-D project, a T2 plan is developed that details how the outcomes of the project will be translated for public use or commercialization. The development of the T2 plan and the eventual commercialization of the results are facilitated by the Safe-D T2 Coordinator, Dr. Mike Mollenhauer. While no start-up companies have been created at this point as a direct result of Safe-D projects, opportunities for commercialization have been identified and will be pursued as the research products are further developed. Beyond commercialization, Safe-D projects are expected to lead to the adoption of new practices in various transportation-related areas as the results and outcomes are disseminated. For example, project TTI-05-02 (Analysis of Advanced Driver-Assistance Systems in Police Vehicles) developed a list of ADAS guidelines and useful ADAS features that have the potential to improve police officers' safety while driving. The outcomes (detection and perception methods) of that project are now being applied as part of Safely Operating Automated Driving System in Dynamic Scenarios (SOADS) with OEMs represented by Crash Avoidance Metrics Partners. These methods will be used by a L4+ vehicle to detect first responders. The potential for commercialization and adoption of new practices resulting from several specific Safe-D projects are summarized below:

- The findings of Project 03-087 (Big Data Visualization and Spatiotemporal Modeling of Aggressive Driving) demonstrate how visualization tools can be used to identify risky driving in space and time. Agencies can adopt these tools to help identify locations with high frequency of risky driving and come up with strategies to reduce these risky events in a proactive manner. There is a potential to utilize the machine learning models and approaches from this project to initiate a start-up company that applies kinematic data to identify risky driving events, reports high-risk locations and times of day to interested agencies, and recommends countermeasures to reduce risky driving.
- The application developed in project VTTI-00-021 (Signal Awareness Applications) is planned for public deployment in the VCC through the Google Play Store and/or Apple store.
- The eventual deployment of the ATMA system developed under VTTI-00-022 (Automated Truck Mounted Attenuator) will affect the practices and procedures of infrastructure owner-operators, and results will be disseminated to both government (state DOTs) and industry partners with a vested interest in utilizing ATMAs in their operations.
- Project VTTI-00-025 (Radar and LiDAR Fusion for Scaled Vehicle Sensing Test) has successfully implemented radar and LiDAR fusion at a small scale and has enabled scaled vehicle testbeds to better model their full-sized autonomous vehicle counterparts. The findings provide commercially available small-scale vehicle testbeds that allow for the inclusion of radar in their sensor suite/architecture. Radar has largely been left out of such testbeds up to this point.
- The initial idea for Project 04-101 (Safety Impact Evaluation of a Narrow-Automated Vehicle-Exclusive Reversible Lane) was suggested by Caltrans district 11 in San Diego. The outcome of this research will directly feed the implementation considerations and design specifications of an automated vehicle-exclusive reversible lane on the I-15 smart corridor.
- The results of Project 04-114 (Behavior-based Predictive Safety Analytics Phase II) are expected to influence how fleet management, insurance agencies, in-vehicle monitoring system vendors, and other parties use previously collected data to improve driver safety in real time based on the self-regulation of driving

behaviors using active information garnered from vehicle data collection systems. The findings may also guide industry on the types of data that need to be collected to identify high-risk individuals. Finally, project findings may lead to an adjustment in the selection or retention procedures used by organizations to maintain a safe driver workforce.

- Project TTI-05-03 (Development of a Roadside LiDAR-Based Situational Awareness System for Work Zone Safety: Proof-of-Concept Study) will deploy emerging 360-degree 3D LiDAR sensors at the roadside and test their potential for providing work zone safety in terms of accuracy, efficiency, and ease of use. The outcomes will lead to the initiation of a start-up company focusing on smart work zone applications.
- Project 03-036 (Modeling Driver Responses during AV Platooning Failures) involved an analysis of the California DMV's automated vehicle crash database, leading to discussions with Caltrans and the California DMV. The findings are now contributing to the redesign of the crash reports in the database.
- The outcomes of Project 03-082 (Assessing Alternative Approaches for Conveying Automated Vehicle 'Intentions) are guiding the development of automated driving systems and have been used by Ford Motor Company as they refine their technology.
- The results from Project TTI-01-02 (Creating a Smart Connected Corridor to Support Research into Connected and Automated Vehicles) will promote the use of similar "big data" technologies in data collection efforts on future projects.

Impact on the Body of Scientific Knowledge

Through basic and applied research focused on four key disruptive technologies (connected vehicles, automated vehicles, transportation as a service, and big data analytics), Safe-D projects are expected to make meaningful contributions to the body of scientific knowledge within the broad area of transportation. For example, Project TTI-05-02 (Analysis of Advanced Driver-Assistance Systems in Police Vehicles) used a combination of user-centered design approaches and usability evaluation methods (e.g., surveys, observations, and user testing) to understand the ADAS needs of police and develop corresponding guidelines. The findings of the systematic literature review focused on the use of ADAS features in police vehicles was submitted as a conference paper. This paper is expected to further the body of knowledge regarding current ADAS features in police vehicles, the impact of automation and ADAS features on officer safety, and potential ADAS features that can be implemented in police vehicles.

As another example, Safe-D Project VTTI-00-024 (Characterizing Level 2 Automation in a Naturalistic Driving Fleet) has addressed a critical gap in knowledge regarding our understanding of automated driving features. To date, only a few studies have been conducted that observed how drivers use commercially available ADAS technology, which enables the vehicle to provide longitudinal and lateral control naturally during real-world driving. The analysis in these studies is largely focused on Tesla's Autopilot technology and, due to the availability of ADAS technology when the data was collected, is restricted to high-end models of luxury vehicles such as Audi, Mercedes, Infiniti, Land Rover, and Volvo. In the years since these studies were conducted, this technology has become increasingly common and is now more widely available to consumers. The findings of this project will greatly increase the knowledge of how drivers' use ADAS technology by analyzing different makes and models (i.e., different ADAS).

Project TTI-05-01 (Connected Car Data Safety Applications) is expected to have significant and practical impacts on the body of scientific knowledge. The outcomes of this project will benefit state and local transportation entities by informing roadway improvement planning processes through locating areas of concern before crashes occur. This research will also help auto manufacturers and data vendors better understanding what connected vehicle sensors and data are useful in developing leading indicators to traffic risk. The findings have the potential to improve the current state of traffic safety analysis tools or services based on connected vehicle data. Currently, these tools and services used hotspot detection as the means of locating potential traffic safety concerns. This method runs counter to the recent progress made by traffic safety experts, who have turned to systemic and network screening techniques to find and target safety issues. Factors derived from connected vehicle data have the potential to better inform these

techniques by incorporating behavioral aspects of road users to help predict crashes before they occur. Finally, the findings will assist the research team's industry partner in quickly assessing the traffic safety impact of infrastructure technology products in a real-world context.

Impact on Transportation Workforce Development

Each Safe-D project includes an individually created EWD plan guided by the EWD Coordinator, Dr. Miguel Perez. The EWD plans ensure that Safe-D projects generate significant impacts on the future transportation workforce by providing opportunities for teaching and education; building experience and skill among underrepresented groups in the transportation profession; and exposing practitioners, teachers, and members of the public to science and technology as they relate to Safe-D research. During this reporting period, Safe-D projects have (1) generated valuable educational opportunities for students of varying age groups, including students in underrepresented groups and (2) led to the development of curriculum materials for educators. Specific examples of how Safe-D projects have contributed to EWD are provided below.

Learning experiences and building the future for the next generation

Safe-D projects have contributed to the development of the transportation workforce through direct engagement with both K-12 students and older students at the undergraduate and post-graduate levels. For example, Project TTI-05-02 (Analysis of Advanced Driver-Assistance Systems in Police Vehicles) provided training opportunities for two undergraduate students (one female) and one female PhD student. The students were trained to conduct a systematic literature review, design structured surveys, design observational studies, and conduct data analysis using correlation analysis, inferential statistics, and non-parametric analysis. The project will continue carrying out its workforce development plan by providing lab tours for K-12 students, who will learn about the applications of driving simulations and physiological measures in human factors research. This project is also training undergraduate students through small projects and lab tours to familiarize them with qualitative usability analysis methods and simulation-based driver behavior assessment. Finally, this project involves the organization of webinars for law enforcement officers to improve training on police ADAS use and in-vehicle technologies.

Project TTI-05-01 (Connected Car Data Safety Applications) is contributing to the education of undergraduate and graduate students through the development of course material on CV data. Course materials derived through this project will offer graduate students and high-level undergraduates the opportunity to learn methods for working with very large datasets for traffic safety applications. This project is also contributing to the training of safety researchers. Workshop material on CV data derived from this project will provide researchers with the opportunity to learn methods for working with very large datasets for traffic safety applications. One goal of this project is to help other researchers become better equipped to incorporate large, complex spatial data into their research efforts. This will be accomplished through hands-on training via a workshop focused on cloud computing services, costs of operation, statistical methods, spatial processing, database management, and data visualization techniques.

Many other Safe-D projects have also provided valuable hands-on experiences for undergraduate and graduate students, including the following:

- During this reporting period, the two graduate research assistants working on Project 04-101 (Safety Impact Evaluation of a Narrow-Automated Vehicle-Exclusive Reversible Lane) helped prepare and submit two journal articles and the project's final report. These students gained valuable experience in the academic publication process and improved their technical writing skills.
- Student Lexi Basantis, who made significant contributions to Project 03-082 (Assessing Alternative Approaches for Conveying Automated Vehicle 'Intentions'), has graduated and is now contributing to the transportation research field.
- Project VTTI-00-024 (Characterizing Level 2 Automation in a Naturalistic Driving Fleet During) will involve an undergraduate research assistant during the data analysis stage of the project. This student will assist with data reduction and analysis while also learning about naturalistic driving research methods.

- One graduate student has been working on Project VTTI-00-023 (E-Scooter Safety Assessment and Campus Deployment Planning) and has gained first-hand knowledge of naturalistic data collection studies and experience working with industry sponsors. This dataset developed under this project will also be used by other researchers in the future to answer additional research questions, thereby providing additional opportunities for workforce development in the future.
- Project VTTI-00-032 (E-Scooter Design) has provided educational opportunities for one graduate research assistant as well as the senior design team, who is assisting with the literature review and design modification throughout this project.
- Project 04-110 (Developing an Intelligent TMC with a Safety Evaluation Focus for Smart Cities) will build a test bed that can be used by students, faculty, and practitioners to test different technologies, methodologies, and practices for use in safety evaluations. The project outcomes will also be developed into materials for use in courses offered by the Civil, Construction, and Environmental Engineering (CCEE) and Electrical and Computer Engineering (ECE) departments at SDSU.
- Masters and PhD students are involved in Project TTI-05-03 (Development of a Roadside LiDAR-Based Situational Awareness System for Work Zone Safety: Proof-of-Concept). Specifically, these students are developing the algorithms needed for processing the collected roadside LiDAR data based on machine learning or deep learning algorithms. Two undergraduate students from TAMU or UT Arlington are also assisting in the testing and implementation tasks.
- Project 03-036 (Modeling Driver Responses during AV Platooning Failures) has provided research opportunities for two PhD students and nine undergraduate students, who have received training in transportation research and data analysis. The project also led to the development of an educational module that has been used in two courses in the Industrial and Systems Engineering Department at Texas A&M as well as a guest lecture at Virginia Tech. Finally, the results were presented to the USDOT during the "Getting to Know AI" webinar series.
- One PhD student is working with fundamental vision processing algorithms under Project 04-115 (Reference Machine Vision for ADAS Functions). This student is also gaining valuable real-world experience through working closely with industry partners for system testing.
- Two PhD students are being trained under Project 04-117 (A Sensor Fusion and Localization System for Improving Vehicle Safety).
- One female PhD student's work centers around Project 04-103 (Examining Senior Drivers' Adaptation to Mixed-Level Automated Vehicles: Phase II).
- Project 03-087 (Big Data Visualization and Spatiotemporal Modeling of Aggressive Driving) allowed four students (two PhD and two master's) to develop models to identify risky driving events from kinematic data.
- Project 04-098 (Data Mining Twitter to Improve Automated Vehicle Safety) included three students from underrepresented backgrounds (of five total students). These students were trained in social media data analysis and machine learning as applied to transportation data.
- The students involved in Project 04-121 Development of an Infrastructure Based Data Acquisition System (iDAS) to Naturalistically Collect the Roadway Environment are learning the use of modern computer vision and machine learning techniques in transportation research while gaining experience in transportation research.

Development of Educational Tools and Courses

In addition to the students working directly on Safe-D projects, center research has reached a broader spectrum of students through the development of educational materials and content for college courses. These outputs range from teaching modules to classroom exercises based on real-world problems to web-based presentations. Specific examples of educational content produced by Safe-D projects in this reporting period are summarized below:

- Based on Project SDSU-01-01 (Prediction of Vehicle Trajectories at Intersections Using Inverse Reinforcement Learning), Safe-D researchers are developing materials for use in courses offered in the Civil, Construction, and Environmental Engineering (CCEE) department at SDSU. These materials focus on the

roles of cutting-edge technologies (e.g., machine learning and vehicle trajectory prediction) in advanced safety monitoring systems.

- Project 03-087 (Big Data Visualization and Spatiotemporal Modeling of Aggressive Driving) provided big data case studies for incorporation into courses related to Big Data Science and Analytics Platforms (GEOG-594 and GEOG-580).
- The findings of Project 05-084 (Behavioral Indicators of Drowsy Driving: Active Search Mirror Checks) will be incorporated into a learning module focused on the role of driver monitoring systems and PERCLOS.
- The results of Project 04-104 (Development of a Connected Smart Vest for Improved Roadside Work Zone Safety) were included in the Principal Investigators' undergraduate course lectures.
- The dataset and other outputs of Project 04-098 (Data Mining Twitter to Improve Automated Vehicle Safety) will be used in courses at Texas A&M to teach students the importance of social media data and analysis for transportation safety. This type of analysis is often overlooked but is being increasingly recognized as important by stakeholders.
- Researchers on Project 04-113 (Use of Disruptive Technologies to Support Safety Analysis and Meet New Federal Requirements) will incorporate the findings of this study into one graduate course titled CVEN 626 - Highway Safety at TAMU. Also, students involved in this project are learning how to assemble data, apply statistical techniques related to the validation of data, and develop safety performance factors.

Workforce Development Activities

Beyond engagement with students, Safe-D projects have contributed to the education of the existing transportation workforce as well as the development of the future workforce. For example, researchers from TTI and VTTI will uses the findings from Project 04-113 (Use of Disruptive Technologies to Support Safety Analysis and Meet New Federal Requirements) to organize short presentations and pop-up classes open to the Texas A&M University students and faculty as well as researchers from TTI and VTTI. These lectures will provide the opportunity to discuss the findings of this study with interested individuals and can result in attracting students from all engineering disciplines to work on this subject.

Project TTI-01-02 (Creating a Smart Connected Corridor to Support Research into Connected and Automated Vehicles) provides opportunities to describe features and applications of the SHRP 2 NDS dataset for future use.

Changes/Problems

Changes in Approach

Nothing to report.

Actual/Anticipated Problems/Delays

Impact of COVID-19

During this reporting period, 21 Safe-D projects reported that research activities had been impacted by COVID-19 in some way. Among these projects, nine reported minor impacts, nine reported moderate impacts, and three reported significant impacts from COVID-19. Projects that were impacted by COVID-19 reported the biggest effects from April to June. Although some states have begun to relax COVID-19 restrictions, many of these impacts can still be attributed to the social distancing measures and travel restrictions put in place in response to COVID-19. Specific examples of how COVID-19 has affected Safe-D projects are given below.

Safe-D Projects Reporting Minor Impacts

- Project VTTI-00-025 (Radar and LiDAR Fusion for Scaled Vehicle Sensing Test). The COVID-19 outbreak continues to slow collaboration and testing capabilities among the members of the team, including making it impossible for students to collaborate on site with the corporate sponsor. This has delayed the

project, and the current completion date is now December 2020. Virtual meetings continue to be conducted between team members and the corporate sponsor as needed.

- Project SDSU-01-01 (Prediction of Vehicle Trajectories at Intersections Using Inverse Reinforcement Learning). Due to COVID-19, work cannot be completed on campus. However, the team is able to work remotely on project tasks according to the original project timeline. However, productivity and managing team members may not be as effective as before. Remote access to campus computers poses some challenges (computer shutdowns, interruptions, etc.). While the impact appears minor at this point, a project extension might be required.
- Project VTTI-00-021 (Signal Awareness Applications). An extension to this project was granted in April to accommodate for travel restrictions and delays in testing and demonstration activities in Northern Virginia.
- Project 04-114 (Behavior-based Predictive Safety Analytics Phase II). The VTTI students involved in the project are finding it more difficult to work remotely on VTTI project servers and VTTI clusters. A no-cost time extension for the draft final report and subsequent final report have been submitted.
- Project 04-115 (Reference Machine Vision for ADAS Functions). Data collection and processing have been delayed a bit because student workers could not be hired over the summer. A no-cost extension has been submitted and approved. Thus, no major impacts to the project are expected.
- Project TTI-01-02 (Creating a Smart Connected Corridor to Support Research into Connected and Automated Vehicles). At this point in time, no immediate adjustments due to COVID-19 are necessary. However, an extension may be requested if the COVID-19 regulations tighten in the future.

Safe-D Projects Reporting Moderate Impacts

- Project TTI-05-02 (Analysis of Advanced Driver-Assistance Systems in Police Vehicles). COVID-19 and the recent events involving police departments across the country and state have resulted in some delays and modifications to the Phase 1 study. The ride-along format had to be changed to online observations. Furthermore, the planned focus group could not be conducted with officers; data had to be collected using an online survey instead. The project team is trying to compensate for these changes/delays and is currently analyzing the survey data. The team has also made connections with a local police department to collect observation data. The first project webinar with police officers has been delayed until Phase 1 is completed so that the findings of Phase 1 can be shared with officers and police chiefs during the webinar (now planned for the end of October instead of August).
- Project VTTI-00-022 (Automated Truck Mounted Attenuator). An extension had to be requested due to the COVID-19 pandemic regulations.
- Project VTTI-00-023 (E-Scooter Safety Assessment and Campus Deployment Planning). The scooter deployment on the VT campus was cancelled at the onset of COVID-19 when the students were sent home in March. The project team is working with stakeholders to determine if/when the scooters can be redeployed on the VT campus and/or in another location to complete data collection, which was cut short by 5 months.
- Project 04-104 (Development of a Connected Smart Vest for Improved Roadside Work Zone Safety). The final stakeholder feedback collection and demonstration had to be stopped due to COVID-19 restrictions. The project team is working with the VT Institutional Review Board to conduct the final demonstration and collect feedback in accordance with the restrictions.
  Project TTI-05-03 (Development of a Roadside LiDAR-Based Situational Awareness System for Work Zone Safety: Proof-of-Concept Study). The starting date for this project has been postponed by 1 month, and an extension of 2 months has been requested to minimize the impacts of COVID-19 on the scheduled field experiments and the related travel activities.
- Project 04-098 (Data Mining Twitter to Improve Automated Vehicle Safety). A portion of the EWD activities that involved teaching high school students about social media analysis had to be cancelled due to restrictions on outside visitors at local schools. The team is also unsure of the ability to obtain additional

feedback from the Public Information Officers initially involved in the project; however, this feedback will be sought when the guidelines are developed. The project team has asked for an extension.

- Project 04-117 (A Sensor Fusion and Localization System for Improving Vehicle Safety). Data collection has been delayed for approximately 1 month due to the COVID-19 restrictions enacted during the spring semester.
- Project 01-002 (Countermeasures to Detect and Combat Driver Inattention Final). Data analysis was being conducted by a single supported PhD student. COVID-19 shut down access to the simulation computer that held some of the data, delaying the finalization of data analysis for months. The student has since completed the analysis and submitted a draft final report that is currently under review by the Principal Investigator. The submission of the final project report is expected by December 2020.
- Project 04-103 (Examining Senior Drivers' Adaptation to Mixed-Level Automated Vehicles: Phase II). COVID-19 has hampered the dissemination of research findings via presentations by the graduate student.
- Project VTTI-00-027 received some setbacks to their original protocol due to COVID-19 regulations. The team will submit a COVID-19 plan as part of their IRB application.

Safe-D with Significant Impact

- Project VTTI-00-024 (Characterizing Level 2 Automation in a Naturalistic Driving Fleet). The challenges resulting from COVID-19 have suspended data collection for the Northern Virginia Fleet project, which was to provide the dataset for this project. Alternatively, the research team plans to use data captured from another ongoing naturalistic driving study being conducted by VTTI: the Advanced Driver Assistance Systems Naturalistic Driving Study (ADAS study), which will include up to 250 participants in Northern Virginia, Blacksburg (Virginia), Eastern Washington State, and San Antonio (Texas) driving a 2016 or newer L2-capable vehicle. The DAS being used for the ADAS study is different from the once used in the Northern Virginia Fleet study; the DAS in the ADAS study lacks the foot well and over-the-shoulder camera views (i.e., cameras that record driver interaction with the brake/accelerator pedals and steering wheel/center console respectively) that were included in the Northern Virginia Fleet study. However, the ADAS study will collect CAN data for certain makes and models, thereby providing equivalent data. Overall, the research team is confident that the similarities between the ADAS and Northern Virginia Fleet studies will allow the research team to meet the project's existing objectives using the new dataset. There are currently 40 participants/vehicles enrolled in Northern Virginia for the ADAS study. Despite this progress, the data collection and analysis are behind the initial schedule. While the project remains on-track to produce the final deliverables on schedule, the project timeline may need to be adjusted to reflect the delay in data collection resulting from COVID-19.
- Project TTI-04-02 (Delving into Safety Considerations of E Scooters: A Case Study of Austin, Texas). Due to COVID-19, the research team was not able to reach to their contacts at the medical center to access the needed for the analysis. Based on a meeting between the Principal Investigator met the project contact at the medical center in late summer, and the medical center remains interested in this project. However, since all resources are currently reallocated to COVID-19 cases, project-related activities at the medical center are pending. The study is thus currently on hold with research expected to be resumed in early 2021.
- Project 04-110 (Developing an Intelligent TMC with a Safety Evaluation Focus for Smart Cities). Equipment installation for the new transportation lab had to be stopped due to COVID-19 restrictions on access to campus buildings. The project team anticipates a fully functional lab in the next reporting period. Progress on the Memorandum of Understanding (MOU) between SDSU and the City of Chula Vista/Caltrans has been slower than expected as both institutions are adjusting to changes imposed by COVID-19. The project team is continuing to work with the City, Caltrans, and SDSU to finalize this agreement and anticipates that an agreement will be signed in the next reporting period. The delay in the MOU has delayed the installation of several video cameras at intersections in the city of Chula Vista. In the interim, the project team installed a video camera on the SDSU campus and collected some data. However, these data may not yet provide meaningful results since there is currently little activity on campus.

Overall, the main outcome of the above effects of COVID-19 is the expected delay of some Safe-D research projects. The Safe-D administration is working individually with each project team to determine how to best adjust project activities to minimize delays and ensure continued research progress. Where possible, meetings and other project activities will be shifted from in person to virtual. In some cases, project tasks may be able to be restructured to avoid significant delays. However, more time has been given for certain projects that rely on the collection of participant data or other in-person interactions, and certain project tasks reliant on human subject data. Human subject research has been approved by the Institutional Review Board to run again with strict guidelines. These guidelines include temperature checks, glass/plastic partitions in vehicles, and sanitation between vehicles, all of which add more times to the overall studies.

Changes Affecting Expenditures

Nothing to report.

Changes in Study Protocols

Nothing to report.

Changes in Performance Site Location

Nothing to report.

Special Reporting Requirements

N/A