Human Factors for Crash Imminent Safety in Intelligent Vehicles

University Transportation Centers Programs

Type of UTC: Tier 1 Center

U.S. DOT Strategic Goal as Primary Focus: Safety

Consortium Members:

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1. Applicant Information

Grantee University

- The Ohio State University
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Consortium Members

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2. Response to Evaluation Criteria

The vision of the proposed UTC is to **significantly improve ground transportation safety through interdisciplinary research and development in the interplay of autonomous and intelligent vehicle systems, human factors, and injury biomechanics.** We will do so by creating an innovative interdisciplinary program focused on research, leadership, education, technology transfer, and collaboration that brings together experts in intelligent vehicle design, human factors, and injury biomechanics. The focus of our UTC will be the few seconds directly preceding a vehicle near-collision or collision; we refer to this as the pre-crash interval. Specifically, our program will focus on improving the fundamental understanding and consequent technology design that improves human-machine interfaces with intelligent and autonomous or semi-autonomous vehicles, in order to reduce crashes and crash injury severity.

The vision of the proposed UTC—which we refer to as the Crash Imminent Safety UTC, or CrIS UTC—is directly aligned with the U.S. Department of Transportation's (US DOT's) top priority "to make the U.S. transportation system the safest in the world"[1]. Motor vehicle travel has the highest fatality and injury rates per capita of all modes, accounting for nearly 95 percent of transportation-related fatalities and draining more than $230 billion from the economy each year[2]. Reducing transportation-related fatalities and injuries in the nation's transportation system is paramount in achieving this goal. Even though considerable progress in reducing injuries and fatalities has been made over the past two decades, the United States still lags behind many other industrialized nations in minimizing fatality rates. CrIS directly addresses this priority

[1] U.S. Department of Transportation Strategic Plan 2012-2016, p. 6.
[2] National Highway Traffic Safety Administration (NHTSA) Fatality Analysis Reporting System (FARS) http://www.nhtsa.gov/FARS.

with a research and education agenda focused on improving human-vehicle interaction with semi-autonomous and autonomous vehicles in the critical moments leading up to a crash.

The CrIS vision and research activities directly address key MAP-21 research and technology objectives. In particular, MAP-21 safety objectives include the following[3]:

> "Reduce the number of fatalities and serious injuries on public roads"
>
> "Fill knowledge gaps that limit the effectiveness of research"
>
> "Advance improvements in, and use of, performance prediction analysis for decisionmaking"
>
> "Expand technology transfer to partners and stakeholders."

In addition, MAP-21 objectives for reducing traffic congestion include:

> "Acceleration of the implementation of Intelligent Transportation Systems technology."

2.a Research Activities and Capability

Technologies that warn drivers of impending collision risks are advancing rapidly, as are technologies for intelligent vehicle communications and ever more vehicle autonomy. These technologies and systems are being deployed so rapidly that there often has been little time to gain a comprehensive understanding of how drivers will interact with them. Such an understanding is critical to improving transportation safety, especially in crash imminent situations where actions taken in seconds, or even fractions of a second, can radically change the outcome. **The research objective of the CrIS UTC is to improve understanding of driver interaction with vehicle systems in crash imminent situations, with a goal of substantially improving safety.**

Although a number of research groups have begun to address the question of driver-vehicle interaction in a variety of autonomous system implementations, there has been little attention to the specific timeframe immediately prior to crash. In order for autonomous and warning systems to be effective, human-vehicle interaction in this crucial timeframe must be fully understood. This understanding is important not only for passenger vehicles, but also for other transportation modes (e.g., freight vehicles), as well as for first-responder emergency personnel (police, fire, ambulance). Further, the crash bioinjury studies can inform the design of improved autonomous and intelligent vehicle systems—an important topic that has not been well explored.

The CrIS research program differs from research underway elsewhere in several significant respects:

- CrIS aims to understand safety, perception of safety, and ensuing driver behavior before and leading to a crash[4] for humans operating intelligent, autonomous, or semi-autonomous vehicles.
- CrIS focuses on the pre-crash interval[5], rather than the entire driving experience.

[3] H.R. 4348 (112th): MAP-21. 112th Congress, 2011–2013.
[4] Campbell, B. N., Smith, J. D. and Najm W. G. (2004), *Analysis of Fatal Crashes Due to Signal and Stop Sign Violations* (No. DOT-HS-809-779).

- CrIS develops a unique network of integrated driving simulators, coupled with outdoor field testing environments, for comprehensive performance evaluation using safety performance metrics that directly address US DOT safety goals.
- CrIS integrates bioinjury research and bioinjury data and understanding into the design of improved safety in autonomous vehicle systems.
- CrIS concurrently pursues policy research to accelerate adoption of safe technologies and protocols.

In order to achieve our objective, we will execute a coordinated research program that will significantly advance understanding in the following four strategies:

S1. Improve the interaction of the driver with an autonomous vehicle system to avert or minimize the impact of crashes

S2. Develop standard simulation/verification models to effectively understand human behavior and pre-crash safety over a wide range of autonomous vehicle properties and behaviors

S3. Use human behavior data across such variables as age, physical size, or alcohol intake, to inform the actions of the driver in pre-crash scenarios

S4. Include policy and regulation considerations early in the R&D process to accelerate the transition of promising research outcomes into widespread practice.

We will develop means to measure the impact of proposed innovations to improve pre-crash safety, including:

- Assess magnitude of safety improvement in mitigating crash effects in simulated scenarios
- Identify unintended consequences of autonomous and warning systems
- Measure driver/passenger responses to pre-crash interventions, such as warnings, transfers of control, engagement/distraction, allocation of tasks between driver/automation, and automated takeover
- Assess policy implications of the proposed innovation.

The CrIS UTC research plan will enhance our understanding of all aspects of the pre-crash environment, which, in the end, will produce measureable decreases in risk, collisions, injuries, and severity of injuries.

2.a.i. Proposed Research Activities

We will execute a research agenda along two parallel, but tightly interconnected, tracks in which both human behavior modeling and experimental pre-crash safety analysis play key and complementary roles, as shown in Figure 1. Safety goals pursued in this UTC lead to hypothesis statements and corresponding experimental scenarios and test plans. Concurrently, human factor modeling efforts are designed to understand, predict, and assess outcomes from the context of human behavior. Experimental outcomes lead to model refinement, experiment refinement, and quantitative metric assessment and tracking.

[5] Najm, W. G., Smith, J. D., & Yanagisawa, M. (2007). *Pre-crash scenario typology for crash avoidance research* (No. DOT-VNTSC-NHTSA-06-02).

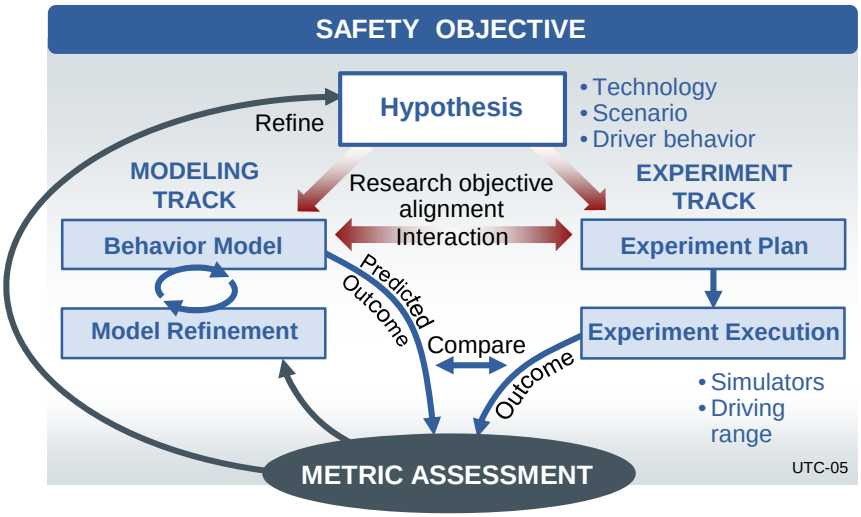


Figure 1. The UTC research comprises two tightly interconnected tracks to simultaneously build fundamental understanding and execute an experimental program that aims to improve safety.

Proposed Projects

We have developed a set of seven interconnected research projects, and laid out the Year 1 and Year 2 research objectives of each. Collectively, these projects address all four of CrIS's research strategies that define our research agenda, and they cover all of the elements of the research approach illustrated in Figure 1. Figure 2 summarizes these strategies and projects. Project 1 develops a networked simulation capability, and forms the basis of the Experimental Track. Projects 2 and 3 form the foundation of the Modeling Track. Projects 4, 5, and 7 include bioinjury implications, pedestrians/cyclists in the scene, and sensing technologies; all three have both Modeling Track and Experiment Track components and will be used to augment and extend the capabilities in Projects 1 and 2. Finally, Project 6 addresses policy implications, and primarily addresses the hypothesis formulation and metric assessment components of Figure 1. Taken together, these projects comprehensively address pre-crash modeling, experiment, human behavior, and physiology aspects of both multi-vehicle and vehicle to pedestrian/cyclist safety situations.

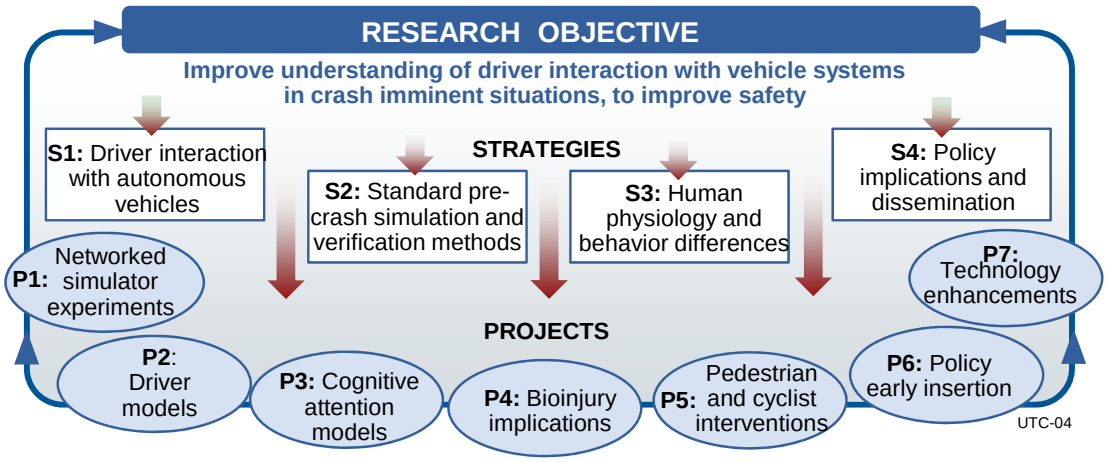


Figure 2. CrIS UTC research projects will address the four strategies supporting its overall research objective.

Project 1. Pre-crash Multi-vehicle Experimental Analysis Using a Networked Multiple Driving Simulator Facility

Investigators—Weisenberger (OSU), lead; Fisher (UMass); Homaifar (NCA&T)**;** Lee (UW); Ü. Özgüner (OSU); Redmill (OSU); Stredney (OSU)

Research Plan—Year 1: Create simulation network and evaluate safety of initial selections from the NHTSA Safety Pilot Model Deployment. **Year 2**: Design collaborative multi-vehicle experiments, and use the networked simulation environment to test hypotheses and collect/analyze data for multi-vehicle scenarios.

This project provides a multi-simulator evaluation testbed for conducting experiments that support the UTC's entire research agenda. It is the primary project in which we carry out the experiment execution activities shown in Figure 1.

To evaluate human performance and resulting crash safety, the UTC needs a robust simulation facility in which multiple vehicles interact; some of these vehicles will be driven by people, some will be autonomous, and some will be autonomous to varying levels, with people in the driver's seat but disengaged to various levels from the actual driving of the vehicle. Although a single simulator can be used to create scenarios that involve other programmed autonomous, semi-autonomous, and non-autonomous vehicles, it provides only an approximation of the level of unpredictability and uncertainty encountered when multiple human drivers are operating in the same environment—as is the case in real-world driving. The ability to create a virtual driving environment simultaneously accessed by three or more human drivers allows a much closer approximation of reality, with its attendant risks. Therefore, a key enabling first step will be to develop a network of driving simulators that can interoperate to conduct multi-driver tests.

We will leverage three existing simulator facilities at OSU, UW, and UMass, all of which are from the same vendor, Realtime Technologies, to design and execute common scenes and scenarios. In addition, we will purchase desktop simulator units from Realtime Technologies for IUPUI and NCA&T, so that all five institutions are able to contribute to the experiment designs and access experiment data. The sharing of scenes and scenarios is a complex activity[6]; however, our team has already demonstrated progress in this regard. UMass and UW have already made initial progress and are working with the simulator vendor to make software revisions that will facilitate sharing. The networked simulator capability provides a more realistic testbed for verifying and validating the computational models of attention and engagement proposed in Projects 2 and 3.

The initial selection of safety applications to be evaluated is based on results from NHTSA's Crash Imminent Test Scenarios[7] and Safety Pilot Model Deployment[8].

[6] Fisher, D. L., Caird, J.K., Rizzo, M. & Lee, J.D. (2011). Handbook of Driving Simulation for Engineering, Medicine and Psychology: An Overview. In Fisher, Caird, Rizzo and Lee (Eds), *Handbook of Driving Simulation for Engineering, Medicine and Psychology*. Boca Raton, FL: CRC Press.

[7] Development of Crash Imminent Test Scenarios for Integrated Vehicle-Based Safety Systems, W.G. Najm and J.D. Smith, Report DOT-VNTSC-NHTSA-07-01, NHTSA, April 2007.

[8] NHTSA (2011), *USDOT Connected Vehicle Research Program: Vehicle-to-Vehicle Safety Application Research Plan*, (Report No. DOT HS 811 373). Washington, DC: National Highway Traffic Safety Administration.

The safety applications will include Forward Collision Warning (FCW), Lane Change/Blind Spot Warning (LCW/BSW), Emergency Electric Brake Light Warning (EEBL), and Intersection Movement Assist (IMA).

This project will enable testing of drivers with autonomous vehicle systems with an unprecedented capability in multi-driver and multi-vehicle interaction studies. In addition, this project will generate "standard" scenarios that can be shared with the transportation research and education community.

Project 2. Driver Models for Both Human and Autonomous Vehicles with Different Sensing Technologies and Near-crash Activity

Investigators—Ü. Özgüner (OSU), lead; Fisher (UMass); Homaifar (NCA&T)**;** Lee (UW); Woods (OSU)

Research Plan—Year 1: Develop a multi-agent driver model for pre-crash human behavior understanding. **Year 2**: Conduct research, verification, and model refinement studies on human intent for pre-crash behavior estimation.

The goal of this project is to understand how multi-agent models of the driver and vehicle can inform design principles for optimized autonomous vehicle systems. In this project we will develop and refine a computational model for human behavior in pre-crash scenarios. The project is one of the primary modeling track projects charted in Figure 1, and it comprises model development and model refinement.

We will develop a multi-agent model with both human drivers and autonomous and semi-autonomous vehicles, using the framework shown in Figure 3. The model will build upon successful models used in our Defense Advanced Research Projects Agency (DARPA) Grand Challenge vehicles[9], and will also incorporate results from our experience in automotive industry projects[10,11]. This model takes dynamic inputs about the changing situation and behavior of others, and uses mathematical or symbolic processing to carry out the functions required to simulate the perception, attention,

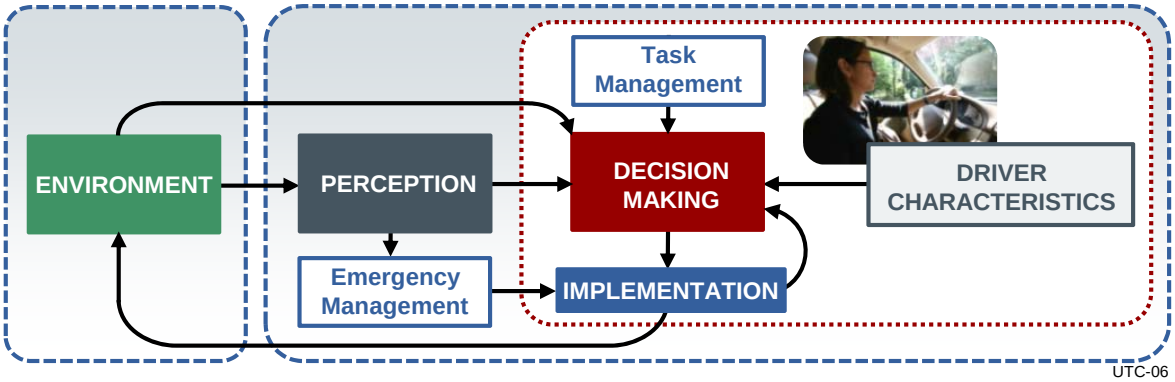


Figure 3. A multi-agent framework will be used for modeling and understanding behavior of both humans and autonomous vehicles.

[9] Özgüner, Ü., Acarman, T., & Redmill, K. (2011). *Autonomous ground vehicles*. Artech House Publishers.
[10] Kurt, A., & Özgüner, Ü. (2011, October). A probabilistic model of a set of driving decisions. In *Intelligent Transportation Systems (ITSC), 2011 14th International IEEE Conference on* (pp. 570-575).
[11] Song, B., & Delorme, D. (2000). Human driver model for smartAHS based on cognitive and control approaches. In ITS America. Meeting (10th: 2000: Washington, DC.). ITS 2000: conference proceedings.

cognition, and control behavior of interest. We will integrate different component models, including control theory models, decision and judgment models, learning classifier systems, joint human-automation system models, and attention models, to build a comprehensive model needed to make predictions in pre-crash situations, and needed to make quantitative estimates of hypothesized safety improvements.

These models will be cross-validated and verified using both the driver simulation experiments in Project 1 and data obtained from driving simulator and field driving experiments.

Project 3. Cognitive Attention Models for Driver Engagement in Intelligent and Semi-autonomous Vehicles

Investigators—Lee (UW), lead; Fisher (UMass); Homaifar (NCA&T)**;** Woods (OSU)

Research Plan—Year 1: Develop cognitive attention models that address pre-crash environments. **Year 2:** Refine the model of driver-automation interaction and assess performance in response to critical pre-crash safety events.

The focus of this project is to improve the state-of-the-art in human cognitive modeling in order to more accurately describe the human-machine interfaces that take place in the pre-crash scenarios. This project develops a cognitive attention model that provides a fundamental understanding and analysis capability for driver attention. In particular, the model will be used to understand how drivers respond to vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) information cues in pre-crash scenarios. It also addresses how to re-engage a driver who may be partially or completely disengaged from key attention elements while operating a semi-autonomous vehicle. We seek to understand driver engagement over a range of human physiological and behavioral factors, including age and drowsiness.

As vehicle systems become more autonomous, human drivers engage in other activities and tasks—in other words, drivers disengage from the driving situation. This is especially true of look-ahead functions that support early responses to defuse risky situations, such as taking back vehicle control when entering an area with a high density of pedestrians. It will be especially important to monitor for these situations as vehicle systems become more autonomous. Re-engagement can take many forms, such as alerting/warning, redirecting driver attention to look ahead to developing risk, directing the driver to take charge of some control functions while automation handles others, or reconfiguring automated subsystems.

The primary approach we will pursue is the development and use of a computational model of attention. Computational simulations of attention now exist that can be applied to the re-engagement challenge for driving and added to driving simulators as a new resource. We have been developing one that is specifically designed to handle situations where multiple sensors and algorithms assess anomalies and risk at multiple temporal and spatial scales. This simulation of attention can be used for design of warnings and automation to facilitate re-engagement. It can also be used as a critical measuring tool to assess the effectiveness of re-engagement under different conditions and with different types of response to pre-crash risk assessment. While the model is general, our focus in the CrIS UTC is to develop the model as it applies to the pre-crash

time interval; this interval will be longer than the immediate pre-crash interval, because of the importance of modeling attention state before the immediate event, and because we hypothesize that early attention-engagement strategies will significantly improve pre-crash safety.

Project 4. Bioinjury Implications of Pre-crash Safety Modeling and Intervention

Investigators—Bolte (OSU), lead; Weisenberger (OSU)

Research Plan—Year 1: Analyze NASS CDS and CIREN data for proposed pre-crash scenarios and quantify bioinjury outcomes for these scenarios. **Year 2:** Generate and test scenario changes or autonomous vehicle behavior changes that are likely to lead to improved safety.

Project 4 will directly address the UTC's human physiology strategy, S3. The goal will be to include bioinjury expertise in scenario generation, data collection, and human behavioral models so that research outcome metrics are closely aligned with the goal of improving safety.

In particular, we will investigate whether bioinjury data from a particular crash scenario can suggest particular evasive actions by the driver or the autonomous vehicle to minimize injury. We hypothesize that bioinjury data from a particular crash scenario can suggest situations in which the driver should not re-engage and assume control of the vehicle but rather leave the autonomous system in control, because human motor skill or reaction time would be insufficient to mitigate injury. Coupled with human behavioral models developed in Projects 2 and 3, we will be able to extrapolate situations beyond those for which data currently exist, and to test these extrapolated situations under Project 1.

We will also investigate how bioinjury data can inform the user community—both vehicle designers and vehicle safety policy makers—about the optimum position of the driver and the timing of passive restraints for given crash scenarios. As an example, recent data from airbag injury studies have suggested that the position of the driver's hands on the wheel should be modified to avert arm and wrist fractures when airbags are deployed. This information is expected to inform policy and safety procedures as well. As a second example, increasing vehicle autonomy for crash prevention increases the likelihood that the vehicle is braking hard at the time of impact, placing the driver and passengers in very different positions than those currently being employed in crash testing. The research on both driver behavior and autonomous vehicle behavior is expected to suggest alternative—and more relevant—safety testing procedures.

A primary resource for this research will be the crash data available from two national sources. The National Automotive Sampling System (NASS) Crashworthiness Data System (CDS) provides a broad range of data from crashes that occur in the United States. These data, largely based on police reports, focus on passenger vehicle crashes and are used to investigate injury mechanisms. The database may be queried across several relevant variables, including primary direction of impact, object impacted, age and sex of occupants, safety restraints, and resulting injuries. The Crash Injury Research Engineering Network (CIREN) consists of detailed analyses of motor vehicle crashes, including both accident reconstruction and medical injury profiles. CIREN is

more focused on specific crashes in which the occupant received a serious injury. The CIREN network brings together the first responders to the crash, the treating physicians, and a panel of bioinjury experts to examine each injury in detail and to document corresponding injury mechanisms. Similar to NASS CDS, CIREN cases may be searched across several relevant variables. The CIREN database is ideal for comparing bioinjury data across variations in a given crash scenario, such as different passive restraints or different occupant positions.

We will use the NASS CDS to define the most critical injury mechanisms related to each scenario to be considered in the UTC. We will also examine CIREN to document specific injury outcomes based on variations related to the automobile safety systems and to the driver's position and reaction. These analyses will be used to understand which variations lead to fewer or less severe injuries, providing valuable input to both human behavior influencing strategies and autonomous vehicle control strategies considered in other projects, with the goal of improving pre-crash safety. Information leading to improvements in passive restraint systems and more effective crash test protocols are also expected.

Project 5. Pre-Crash Interactions between Pedestrians and Cyclists and Intelligent Vehicles

Investigators—Chen (IUPUI), lead; Fisher (UMass); Ü. Özgüner (OSU)

Research Plan— Year 1: Develop simulation models for vehicle to pedestrian/cyclist pre-crash interval. **Year 2:** Validate and refine models using driver simulation tests.

This project investigates how autonomous and semi-autonomous vehicle systems can be configured and improved to accommodate pedestrian and bicycle safety. This project directly addresses Strategy S1, and comprises both the modeling track and experimental track components in Figure 1, with a specific focus on pre-crash scenarios involving pedestrians and cyclists.

We propose to develop a simulation model for the vehicle pedestrian/cyclist crash testing scenarios building upon the Pre-Scan model developed at IUPUI. We will validate and modify the simulation models using the UTC's driving simulator network and vehicle field tests. We will first consider single vehicles, but extend to scenarios involving two or more vehicles engaging pedestrians and cyclists. One of the most dangerous scenarios for pedestrians is the multiple-threat scenario[12] in which a vehicle approaching a crosswalk cannot see a pedestrian crossing the street because that pedestrian is obscured by another vehicle stopped for the pedestrian. It will be important to determine how vehicles with pre-crash warning and crash imminent braking (CIB) capabilities perform in these scenarios. We will also develop pedestrian/cyclist crash scenario simulations in which we can incorporate the bioinjury model to predict the pedestrian/cyclist injury for different crash scenarios using computer simulation and the driving simulator. Finally, we will use driving simulation experiment results to refine the simulation model and to inform on safety improvement technologies, such as earlier warning or automated braking.

[12] Fisher, D. L. and Garay-Vega, L. (2012). Advance yield markings and drivers' performance in response to multiple-threat scenarios at mid-block crosswalks. *Accident Analysis and Prevention, 44,* 35-41.

This project will leverage the CrIS UTC team's significant experience with vehicle-pedestrian crash scenarios. IUPUI has been developing and evaluating vehicle-pedestrian pre-crash warning and braking systems. A large amount of vehicle pre-crash performance data will be collected using two 2013-model-year vehicles with pre-crash warning and CIB capabilities. The data will include the relative motion history of the vehicle and pedestrians, their motion trajectories and speeds, the time and distance that the vehicle pre-crash system starts warning and braking, and the vehicle and mannequin speeds at crash. Similar work is planned for cyclists in 2014.

Project 6. Safety Policy Implications and Information Dissemination

Investigators—Schuelke-Leech (OSU), lead; Ü. Özgüner (OSU), Weisenberger (OSU); Woods (OSU)

Research Plan—Year 1: Assess the impact of policy and regulatory approaches on proposed pre-crash scenarios and technology development hypotheses to be undertaken by the Center. **Year 2:** Develop and modify pre-crash scenarios and experiment plans to better align with hypotheses and outcome assessments that inform policy recommendations.

This project directly addresses CrIS UTC research Strategy S4, and has connections to all of the other UTC projects. This project will include, at the earliest stages, a policy component of the hypothesis testing, experiment planning, and outcomes assessment elements of the research approach in Figure 1, with the goal of positioning the UTC's research program to have maximum awareness of, and alignment with, policy needs. This alignment is expected to result in earlier adoption of autonomous and intelligent vehicle technologies, thereby accelerating improvement and impact of US DOT's safety performance metrics and goals.

We will conduct research on policies and regulations that can either support or hinder the adoption of new safety technologies and intelligent vehicle systems. This research will include widespread interviews with policymakers, engineers, automotive manufacturers, suppliers, and drivers. We will also determine whether there are differences among driver population groups (e.g., by age, race, socio-economic status) in their interactions to and sentiments about autonomous and intelligent vehicle systems. In this way we can identify factors that may affect the adoption and use of these technologies by different segments of drivers. The outcomes of this project will be used to shape experiment designs in the experimental track, and to inform behavioral models in the modeling track (see Figure 1).

Project 7. Technology and Enhancements to Improve Pre-Crash Safety

Investigators— Ü. Özgüner (OSU), lead; Chen (IUPUI); Homaifar (NCA&T); Ekici (OSU); F. Özgüner (OSU); Redmill (OSU)

Research Plan—Year 1: Assess viable driver attention technologies and V2V/V2I technologies that are likely to improve pre-crash safety. **Year 2:** Experimentally test promising technologies in pre-crash scenarios using the driving simulator facility.

This project focuses on technology improvements that can be implemented in intelligent and autonomous vehicles toward the goal of improving pre-crash safety. Several

specific lines of research will be taken in the initial program; we expect new technology-enhancement projects will result from initial experiment outcomes and modeling predictions in the latter part of the program.

First, with autonomous vehicles being on the verge of deployment as part of city infrastructure, the need for autonomous vehicles to be capable of anticipating human driver intent is inescapable. Newer technologies and potentially controversial sensing options, such as gaze direction, driver body language/weight shifting, and even electroencephalogram (EEG) sensors, are available for exploration. Recent research has shown the crucial importance of gaze monitoring. For example, on the approach to curves, driver gaze direction can predict speed at the apex and crashes[13]. Drivers' gaze duration on external signs can predict their ability to keep in their lane[14]. We propose to explore technologies for sensing driver attention and their impact in pre-crash scenarios. In conjunction with Project 1, we will design and test biomonitors and their value in improving crash safety. We will also predict, using the Modeling Track behavior models, the extent to which monitoring information can be effective in improving pre-crash safety.

Second, we will study the value of V2I and V2V communications for improving pre-crash safety. Using simulator studies—and later, field tests for promising approaches—we will study scenarios in which location and heading information for nearby vehicles is used, and we will test its value in averting crashes or minimizing crash injury. An important element of this understanding is how the (in)accuracy of this information impacts safety performance. V2V hardware testing facilities in OSU's Control and Intelligent Transportations Research (CITR) Laboratory will be used to quantify location accuracy in realistic scenarios. We will also study information accuracy as it impacts information trust in the corresponding behavioral models being developed in Project 3.

Third, we will study the impact of both intra-vehicle and inter-vehicle communication cybersecurity on pre-crash scenarios. A number of issues are of concern: external "snooping"; injection of false information externally; and "hacking" the vehicular software. Several countermeasures are being developed, including key generation and filtering. Our focus in the CrIS UTC will be on the implications of cyber-threats on pre-crash safety. For example, cybersecurity countermeasures result in data latency; we will investigate how this latency degrades safety margins. As a second example, inaccurate information, including false warning indicators that may result from either compromised security or communication noise reduce driver trust in the data, and result in a change of driver behavior in response to these indicators. We will study these changes using the behavior models in Projects 2, 3, and 5, and assess the safety impact.

Multimodality and Multidisciplinarity of the Research Activities

The primary focus of the CrIS UTC will be on passenger vehicle crash safety, both in highway and urban driving modes. However, the research program of the UTC will have impact on other transportation modalities in a number of ways. Project 5 is focused on

[13] Muttart, J. and Fisher, D.L. (2013). Comparing response behaviors of newly licensed drivers to exemplary drivers at high risk curves and turning locations. *Proceedings of Driving Assessment 2013, Lake George, NY*. Iowa City: Public Policy Center, University of Iowa.

[14] Divekar, G., Pradhan, A.K., Pollatsek, A. and Fisher, D.L. (in press). External Distractions: Evaluation of their effect on younger novice and experienced drivers' behavior and vehicle control. *Transportation Research Record*.

crash safety involving vehicles with pedestrians and cyclists. Also, the driver behavioral models developed under Projects 2 and 3 apply to all types of drivers, including transit drivers. Finally, technology improvements studied in Project 7, and policy implications of proposed improvements studied in Project 6, will apply to other highway and road traffic vehicles, including freight and emergency response vehicles.

The CrIS UTC is multidisciplinary along several dimensions and brings together researchers from four disciplines: intelligent vehicle technology; human factors; bioinjury mechanics; and transportation policy. In addition, the research approach includes a tight collaboration of modeling and prediction researchers with experiment design and experimental studies researchers.

Research Program Management and Peer Review

The CrIS UTC will employ a combination of internal and external peer review principles to maintain a high-quality and relevant research program that advances its vision and strategic plan. The Research Program Leadership Committee, comprising representatives from each UTC consortium member, oversees internal peer review. This committee will ensure that the research projects are of high quality, collectively address the major objective and strategies of the UTC's research agenda, and are connected in the formulation of hypotheses, experiment plans, and comparisons of model prediction outcomes with experimental outcomes. Smaller, multidisciplinary working groups will be established to collaborate specific topics of interest and to suggest needed new research directions. External peer evaluation includes an annual research review by both the Technical Advisory Board and the External Advisory Board to ensure that the research portfolio is comprehensive and impactful (see Section 3, Figure 4).

Research Performance Metrics

The success of the UTC's proposed research activities will be assessed with the following metrics:

- Reduction of roadway fatalities and serious injuries, as predicted by scenario simulations considered both with and without proposed technology improvements
- Reduction of pedestrian and cyclist fatalities and serious injuries, as predicted by scenario both with and without proposed technology improvements
- Number of publications and citations of faculty work in UTC related areas
- Number of undergraduate and graduate students participating on research projects funded by the UTC
- Number of new research initiatives, and special projects that build on intellectual leadership in fields related to the mission of the UTC
- Number of new research collaborations in related fields
- Number of technology deployments and transfers
- Relevance of the research plan as assessed by policymakers in the field.

Metrics will be gathered by the UTC Program Manager via quarterly reporting by project investigators. Safety prediction metrics will be obtained and tracked for each experiment scenario from experiment outcome and modeling prediction outcome data.

2.a.ii. Capability and Experience

The partners in the CrIS UTC offer an extensive range of capabilities to carry out the proposed research program, including facilities, researchers, and domain experts. This UTC will leverage extensive existing facilities to develop a common, networked driver simulation capability with unprecedented ability to experimentally address pre-crash safety. The connection of this simulation capability with field experiments conducted at the Transportation Research Center, Inc. (TRC) will further extend the fidelity and impact of our research program.

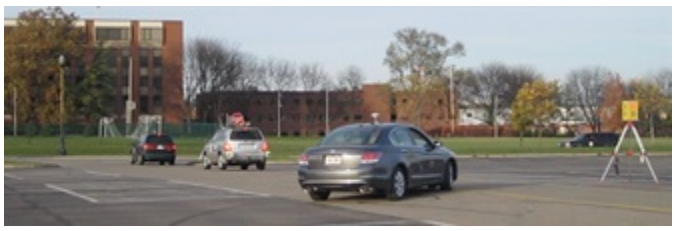
2.a.ii.1 Existing Research Resources

Collectively, the five universities that constitute the CrIS UTC have already built outstanding facilities and expertise that can be leveraged in the execution of the Center's research agenda. These include:

- OSU: Control and Intelligent Transportation Research Laboratory
- NCA&T: Autonomous Control and Information Technology Center
- IUPUI: Transportation Active Safety Institute
- OSU: Driving Simulation Laboratory
- OSU: Cognitive Systems Engineering Laboratory
- UW: Cognitive Systems Laboratory
- UMass: Human Performance Laboratory
- OSU: Injury Biomechanics Research Laboratory (IBRL).

In addition, TRC, the nation's largest independent automotive proving ground with comprehensive vehicle testing capabilities, will be a major asset to the UTC. These facilities are described below.

Control and Intelligent Transportation Research (CITR) Laboratory. OSU's CITR has a comprehensive set of facilities that will support the UTC's simulations, scale-model experiments in a laboratory setting using robotic platforms, and full-scale demonstrations involving multiple vehicles (see photo below). These capabilities allow researchers to design, implement, and test a sensing, control, or behavioral strategy using a modular, staged approach beginning with simulated vehicles in a purely simulated environment and ending with a mixture of real and virtual full-scale vehicles operating in a real-world, outdoor environment.



An outdoor testbed provides five instrumented test automobiles. Three are automated: a fully autonomous car, a longitudinally automated car, and a fully automated six-wheeled off-road vehicle. These three vehicles are equipped with 360-degree world sensing through multiple LIDAR, RADAR, and image processing sensors, high-accuracy localization and pose-estimation sensors, wireless communications capabilities, and onboard computing and power systems to provide sensor processing, fusion, situation awareness, and vehicle control. Two other non-automated vehicles can be equipped with GPS receivers and wireless communications equipment as needed. The testbed also provides wireless dedicated short-range communication (DSRC) radios for V2V and V2I communications,

and wireless modems for longer range communication and cellular 3G/4G wireless internet access (see photo, which shows four collaborating cars). OSU researchers have expertise in a number of simulation environments, including Player/Stage open-source software, the SUMO traffic simulator, and validated Matlab/Simulink simulation models, as well as with an 802.11p/WAVE simulation environment that models RF propagation in both line-of-sight and non-line-of-sight situations.

Autonomous Control and Information Technology (ACIT) Center. NCA&T's ACIT Center administers two major laboratories that will assist in simulating, testing and analyzing pre-crash scenarios. The Autonomous and Intelligent Systems (AIS) and Conventional and Approximate Reasoning Control laboratories are dedicated to conducting research in autonomous and intelligent systems, including autonomous robots, vision systems, and decision-making systems. They also address the simulation and validation of the algorithms being developed for intelligent and cooperative control of distributed agents including unmanned aerial vehicles and mobile robots. The laboratory houses a variety of mobile agent platforms, as well as the ZEUS multi agent modeling environment for knowledge assimilation and inter-agent communication protocol implementations. The robotic platforms include Khepera miniature differential drive robots and Activemedia Pioneer II mobile robots.

Cognitive Systems Engineering Laboratory (CSL). UW's CSL focuses on cognitive engineering for joint human-technology systems, including ground transportation, teleoperation, and process control. Laboratory research foci include the distraction potential of in-vehicle information systems and the role of trust and reliance in the supervisory control of automation. This laboratory also includes a Realtime Technologies, Inc., driving simulator with a 1-degree-of-freedom pitch motion base and 240-degree cylindrical screen.

Cognitive Systems Engineering Laboratory (CSEL). OSU's CSEL has a set of simulation, design, and testing resources for the study of human-automation collaboration with professional decision makers in high risk settings. Relevant CSEL capabilities include the simulation of future operational settings; the infrastructure for this capability consists of a wide array of advanced digital production, 3-D modeling, game engines, and visualization tools which are used to build animated mock ups of how future operational systems would handle different situations based on cognitive task analysis results. CSEL also houses the artificial attention SimMod test bed, in which a model of control of attention runs as a simulation that takes in visual feeds from sensor networks and robotic platforms at both natural human scale—a feed based on a person or robot moving through a scene of interest—and beyond human scales—multiple feeds from a network of sensor platforms.

Human Performance Laboratory. The Arabella Insurance Human Performance Laboratory at UMass focuses on driver behavior and driver safety. Research thrusts have identified factors that increase the crash risk of novice and older drivers, impact the effectiveness of traffic signs and signals, improve the interface of in-vehicle equipment such as collision warning signals and music retrieval systems, and influence drivers' understanding of advanced in-vehicle systems. This

laboratory also houses a Realtime Technologies, Inc., driving simulator (see photo). In addition, a fully instrumented van can be used for on-road studies, and a truck simulator with programmable image side view mirrors is available for use.

Transportation Active Safety Institute (TASI). IUPUI's TASI houses a 980-square-foot driving simulator laboratory that features a DriveSafety DS-600c driving simulator comprising a Ford Focus cab with three screens, as well as a desktop STISIM WT-2000 driving simulator. Equipment for physiological measurement includes a Compumedics physiological data monitoring system capable of measuring ECG, EMG, EEG, and ocular activity.

Driving Simulation Laboratory (DSL). OSU's DSL occupies approximately 5,800 square feet within OSU's SciTech Research Park. The laboratory houses three different simulator setups.

1. A full-immersion simulator, consisting of a fully instrumented vehicle cab (2010 Honda Accord), mounted on a 6-degree-of-freedom MOOG 2000e motion base, with a 260-degree front-projection cylindrical edge-blended screen and six high-resolution projectors. The cab features an interior display that can be used to test concepts for in-vehicle infotainment and warning systems (see photo).

2. A turntable drive-on for testing full vehicles with a single front-projection screen. All internal controls (steering wheel, etc.) are those of the actual vehicle.
3. A desktop simulator for creating and troubleshooting driving scenarios. This simulator includes a gas and brake pedal, as well as a steering wheel, for the driver to use when completing a driving scenario.

All three simulators are manufactured by Realtime Technologies, Inc., and all use the same software for scenario rendering, creating and modifying vehicle dynamics, and recording driver behavior.

A three-camera eye-tracking system (SmartEye Systems) records user gaze, blink rate, and pupillometry, and a BioPac system is used for measuring physiological correlates of workload and stress, including heart rate, blood pressure, respiration rate, galvanic skin response, vibromyography to assess muscle activity, and functional near-infrared optical imaging of oxygen activity in the prefrontal cortex. Many of the BioPac sensors are wireless, minimizing disruption to the driver.

Injury Biomechanics Research Laboratory (IBRL). OSU's IBRL has capabilities to test with both anthropomorphic test devices and post-mortem human subjects donated through the willed body donor program at OSU. The 1,100-square-foot laboratory focuses on experimental testing to measure the response of the human body to impact, modeling, and simulation of high-energy impact scenarios such as automobile crashes, and non-injurious volunteer testing to measure human response to everyday loading. The laboratory works to improve the biofidelity of anthropomorphic test devices and to

develop injury criteria for various aspects of the human body (see photo). The laboratory also has expertise in researching crash databases, such as NASS CDS, CIREN, and FARS, to better understand injury mechanisms of real-world crashes.

Transportation Research Center, Inc. (TRC). TRC is an independent automotive proving ground providing research and development, and compliance and certification testing for vehicles and components for crash, emissions, dynamics, and durability. The impact laboratory offers a comprehensive vehicle safety development facility for crash, HYGE Sled, static testing, and instrument calibration in vehicle impact. It includes a crash barrier capable of testing vehicles up to 10,000 lbs at velocities up to 60 mph, and an outdoor impact area that can manage impact of two moving vehicles at any angle at velocities up to 100 mph. An impact simulator features a 24-inch HYGE pneumatic drive that can simulate crash speeds up to 100 mph. A 9,000-ft skid pad and 50-acre vehicle dynamics area are complemented by a winding road course and dynamic handling course. A 7.5-mile oval test track contains four asphalt lanes on the front straightaway and curves and five asphalt lanes on the back straightaway. Parabolic banking allows neutral speeds up to 140 mph (see photo). A wide variety of pavement types, including gravel, cobblestone, and paved rough roads are available for testing.

2.a.ii.2 New Research Resources CrIS Will Obtain

Three CrIS consortium members—OSU, UW, and UMass—already have Realtime Technologies driving simulator facilities. The CrIS UTC will purchase Realtime Technologies desktop simulators to be located at IUPUI and NCA&T, thereby providing driving simulator capability from the same vendor at all five consortium universities. In addition, we will undertake simulator networking efforts to enable real-time simulation studies involving multiple vehicles, thereby providing an unprecedented capability for simulating multi-vehicle pre-crash scenarios. The desktop simulators enable all consortium members to collaborate in designing simulation experiments, carrying out experiments from a common scenario setup, and analyzing outcome data.

The network of simulators, along with the TRC test track and the CITR Lab's outdoor testbed, provides a unique national resource. Autonomous and human-driven vehicles at the TRC Test Track or on the OSU campus can be linked (in real-time) to the networked driving simulators, allowing for complex scenarios that provide a rich experimental environment for evaluating human responses and the overall efficacy of autonomous vehicle systems.

2.a.ii.3 New and Continuing Research Directions

The CrIS UTC leverages several ongoing research programs of research at OSU and the consortium universities in autonomous and intelligent vehicles, driver behavior, and bioinjury and biomechanics. However, the proposed activities for the UTC represent new research collaborations among these established groups. In the cases of faculty members Woods (OSU), Homaifar (NCA&T), and Schuelke-Leech (OSU), their prior research activities have not directly engaged ground transportation applications. The remaining researchers on the UTC team all have current ground transportation research programs. The novel and innovative thrust of the CrIS UTC is the focus on the intersections of these research programs, rather than the continuation of these programs on a stand-alone basis. The ways in which data from autonomous system evaluation, human-vehicle interaction modeling and experimentation, and bioinjury and biomechanics studies can inform improved designs for autonomous vehicle systems and suggest optimized driver behaviors and control transfers represent a coordinated approach to safe transportation. In this way, CrIS will build upon established resources and assets in transportation research across the partner universities to create new projects and educational opportunities.

2.a.ii.4 Research Foci and Activities and Qualifications of Primary Investigators

The investigators working together in the CrIS UTC possess a wide range of expertise in the areas necessary to have a strong impact in increasing safety in human interaction with autonomous vehicle systems. Table 1 highlights the qualifications of selected members of our team.

Table 1. The proposed team members bring together a wide range of expertise to meet program objectives.

Name and Role	Qualifications Summary
Autonomous Vehicle Systems	
Ümit Özgüner, OSU Professor, Electrical and Computer Engineering TRC, Inc., Chair of Intelligent Transportation Systems *Center Director* *Projects 2 and 7, Lead Investigator* *Projects 1 and 6, Investigator*	• Research focus in intelligent transportation systems, automated highway systems, large-scale intelligent systems modeling and optimization, hybrid systems, and decentralized control • Fellow of IEEE, past president of the IEEE Intelligent Transportation Systems Council, and past Technical Program Chair of the IEEE ITS Conference and other international meetings • Supervised 26 PhD students and more than 40 master's theses • Author of over 400 published papers, proceedings, and book chapters • Co-authored *Autonomous Ground Vehicles* (Artech House, 2012).
Keith Redmill, OSU Assistant Professor of Practice and Research Scientist, Electrical and Computer Engineering *Center Coordinator for Facilities and Experiments* *Projects 1 and 7, Investigator*	• Research focus on autonomous ground and aerial vehicles and robots, intelligent transportation systems, transit and traffic monitoring, sensor fusion, and wireless communication for V2V and V2I systems • Oversees the design of capstone group experiences for undergraduate students in electrical and computer engineering and will bring this expertise to the educational programming in the proposed Center • Co-authored *Autonomous Ground Vehicles* (Artech House, 2012)
Füsun Özgüner, OSU Professor, Electrical and Computer Engineering *Center Coordinator for Education and Workforce Development and Diversity* *Project 7, Investigator*	• Research focus on mapping and scheduling in heterogeneous computing, parallel and fault-tolerant systems, and in-network computation in sensor networks • Author of 46 peer-reviewed publications and more than 100 conference presentations, and has filed four invention disclosures • Has served as associate editor for *IEEE Transactions on Computers*, and co-chaired the 2012 IEEE International Conference on Vehicular Electronics and Safety • Has supervised 18 PhD students and more than 40 master's theses

Name and Role	Qualifications Summary
Eylem Ekici, OSU Associate Professor, Electrical and Computer Engineering *Project 7, Investigator*	• Research focus in wireless ad-hoc and sensor networks and architectures and routing and multicasting protocols • Author of more than 50 publications in peer-reviewed journals • Has supervised 11 PhD and master's students • Serves as associate editor for the *Computer Networks Journal*
Yaobin Chen, IUPUI Professor and Chair, Electrical and Computer Engineering Director, Transportation Active Safety Institute *Project 5, Lead Investigator* *Project 7, Investigator*	• Research in modeling, optimization and control of electric and hybrid vehicle systems, intelligent transportation, and vehicle safety systems • Published more than 120 technical papers in refereed journals and proceedings, and is co-inventor on three U.S. patents • Supervised more than 40 graduate theses • Vice President of Technical Activities and board member of Governors for the IEEE ITS Society • Chaired several conferences and symposia for IEEE in intelligent vehicles and vehicular electronics and safety
Human Factors/Psychology/Human Systems Integration	
Donald L. Fisher, UMass Chair, Department of Mechanical and Industrial Engineering Director, Human Performance Laboratory *Projects 1, 2, and 3 Investigator*	• Research focus in human-computer interfaces, driving simulation, transportation ergonomics, testing of intelligent transportation systems. • Editorial Boards of *Human Factors* (since 1989) and *IIE Transactions on Occupational Ergonomics and Human Factors* • Panel member for the National Transportation Safety Board, Distracted Driving Panel in 2012 as well as numerous other NHTSA panels • Member, TRB Young Driver Subcommittee from January 2009 – present • Presented testimony on distracted driving before Congress in 2007 • More than 200 publications and scholarly presentations • Supervised 20 PhD and 34 master's theses. • Co-Editor with M. Rizzo, J. Caird, and J. D. Lee, of the *Handbook of Driving Simulation for Engineering, Medicine, and Psychology* (2010), the definitive resource for driving simulation research.
Abdollah Homaifar, NCA&T Duke Energy Eminent Professor, Electrical and Computer Engineering Director, Autonomous Control and Information Technology Center *Projects 1,2, 3, and 7 Investigator*	• Research focus in the design and automation of hybrid control for unmanned aerial vehicles, robotics, and applications in soft computing • Author or co-author of over 200 articles in journals and conference proceedings, one book, and three book chapters Associate editor of *Journal of Intelligent Automation and Soft Computing* • Has supervised more than 15 PhD dissertations and 40 MS theses
John D. Lee, UW Emerson Professor Director, Cognitive Systems Laboratory *Project 3, Lead Investigator* *Projects 1 and 2, Investigator*	• Research focus in cognitive engineering, interface design, trust in automation, human adaptation to technology, modeling human behavior • Fellow of the Human Factors and Ergonomics Society • Published 153 journal articles, 86 book chapters, 71 conference papers • Has edited or co-edited 14 books and conference proceedings • Co-editor of the *Handbook of Driving Simulation for Engineering, Medicine, and Psychology (2010)* and with A. Kirlik, will publish *The Oxford Handbook of Cognitive Engineering* later this year
Donald L. Stredney, OSU Director, Interface Laboratory at the Ohio Supercomputer Center Research Director, OSU Driving Simulation Laboratory *Project 1, Investigator*	• Research focus in high-performance computing, advanced interface technology, theories of representation • Has published more than 40 peer-reviewed journal articles and is author of numerous conference presentations • Co-recipient of the Smithsonian Institute/Computerworld 1996 Information Technology Leadership Award sponsored by Cray Research, Inc.
Janet M. Weisenberger, OSU Senior Associate Vice President for Research Director, Driving Simulation Laboratory *Project 1, Lead Investigator* *Projects 4 and 6, Investigator*	• Research focus in multisensory integration in virtual environments • Fellow and past Vice President of the Acoustical Society of America, past chair of the IEEE Haptics Symposium • Founding member of the IEEE Technical Committee on Haptics • Co-editor-in-chief of the journal *Presence: Teleoperators and Virtual Reality* • Strong commitment to providing research opportunities to undergraduate students, and has supervised 42 undergraduate honors theses • Has published more than 50 articles in the area of multisensory integration

Name and Role	Qualifications Summary
David D. Woods, OSU Professor, Integrated Systems Engineering Director, Cognitive Systems Engineering Laboratory *Project 2, 3, and 6, Investigator*	• Research focus on how human and team cognition contributes to success and failure in complex, high risk systems • Fellow and Past-President of the Human Factors and Ergonomics Society • President of the Resilience Engineering Association • Fellow of the American Psychological Association and the Association for Psychological Science • Has published 4 books, 68 book chapters, and 79 journal articles, and is co-inventor on five patents • Co-author of *Behind Human Error* (2010), a critical examination of the human contribution to safety and system failure
Biomechanics and Bioinjury	
John H. Bolte, IV, OSU Associate Professor, Anatomy Associate Professor, Mechanical & Aerospace Engineering Director, Injury Biomechanics Research Laboratory *Project 4, Lead Investigator*	• Recipient of the 2012 Elaine Wodzin Young Achiever Award, presented by the Association for the Advancement of Automotive Medicine (AAAM) for significant contributions to the prevention of automotive injuries • Strong proponent of young researcher development • For the past 9 years has hosted the annual Injury Biomechanics Symposium, designed to foster communication between established and developing researchers in the field, which draws participants from across the U.S. and internationally
Public Policy	
Beth-Anne Schuelke-Leech, OSU Assistant Professor, John Glenn School of Public Affairs *Project 6, Lead Investigator*	• Research focus in the intersection of engineering, technology, and public policy • Holds degrees in engineering, management, and public administration and policy, and worked as a financial analyst and product engineer for General Motors before returning to academia

2.b. Leadership

The CrIS UTC team includes several international leaders in transportation research. We will leverage this existing leadership to accelerate the creation of the next generation of transportation research leaders, through providing (1) a comprehensive program of graduate student training, (2) opportunities for strong researchers who traditionally work outside of the ground transportation field to bring their expertise to bear on surface transportation problems, and (3) leadership opportunities within the UTC for early-career faculty members.

2.b.i National and International Leadership in Transportation

Collectively, the researchers on the CrIS UTC team provide international and national leadership in transportation-related activities, including publishing major-impact articles, books, and conference presentations, serving on committees, organizing and participating in conferences, and presenting testimony to national leaders. As a team, the group of investigators for this UTC has published some 700 papers in relevant areas and supervised hundreds of doctoral, master's, and undergraduate theses. The team and its advisory boards include a National Academy of Engineering (NAE) member and several members of National Academy of Sciences (NAS) and National Research Council (NRC) committees and task forces, fellows and officers of numerous national and international professional associations, recipients of prestigious awards and honors, journal editors and editorial board members, panel members for NHTSA and Transportation Research Board (TRB) activities, and organizers of transportation-related international conferences. Many of the leadership activities are summarized in Table 1. Below, we provide selected examples of this leadership across the team.

Ümit Özgüner, Center Director, OSU: Dr. Özgüner has provided extensive leadership within the IEEE framework in the area of intelligent vehicles and control. He is past President of the IEEE Intelligent Transportation Systems (ITS) Society, and served in numerous ITS leadership positions. He has been Chair or co-Chair for five international symposia since 1994, including: General Chair, 2002 Conference on Decision and Control; General Chair, 2003 IEEE Intelligent Vehicles Conference; and General Chair, 2009 IEEE International Conference on Vehicle Electronics and Safety. He will co-chair the upcoming 2014 IEEE Intelligent Vehicle Symposium.

Yaobin Chen, IUPUI: Dr. Chen is currently serving on the IEEE ITS Society Board of Governors and is Vice President of Technical Activities. He is past Editor-in-Chief for the IEEE ITS Society Newsletter, and chairs the IEEE Medal for Environmental and Safety Technology committee. Dr. Chen was general Chair for the 2010 and 2011 IEEE International Conference on Vehicular Electronics and Safety, will co-chair the upcoming 2014 IEEE Intelligent Vehicles Symposium.

David Woods, OSU: Dr. Woods has is a national leader in human factors for transportation safety. He received the 1995 Laurels Award from *Aviation Week and Space Technology* for contributions to human factors in automated cockpit safety. He has testified before Congress in the Senate Committee on Commerce, Science, and Transportation. He served as a Technical Advisor to the FAA Human Factors Study team from 1994 to 1996, and contributed to several National Aeronautics and Space Administration (NASA) workshops on designing for safety and automation in commercial aviation. He was a recent member of the Defense Science Board Task Force on Autonomy. He presented an invited talk titled *Hindsight Bias and Traffic Accident Causal Analysis* to the TRB 2005 meeting.

Donald Fisher, UMass: Dr. Fisher is an international leader in human factors for driving safety. He has served as panel member for the NTSB Distracted Driving Panel, the TRB Young Driver Subcommittee, TRB Committee on Simulation and Measurements of Vehicle and Operator Performance, and NHTSA Office of Behavioral Safety Research panels on Inattentive Driving and Younger Drivers. Dr. Fisher has appeared on the Today Show, ABC Nightly News, WCFR, and WBZ, and has been quoted in the *Boston Globe* and the *New York Times.*

John Lee, UW: Dr. Lee is an international leader in human factors and driver attention. He served on the AAA Foundation Panel on Measuring Cognitive Distraction in the Vehicle, the TRB Committee on Marine Safety and Human Factors, the NAS Committee on Electronic Vehicle Controls and Unintended Acceleration, the US DOT Driver Distraction Summit, the NAS TRB Committee on Naval Engineering in the 21st Century, the NRC Committee on Human Factors, and the Society of Automotive Engineers (SAE) Subcommittee on In-vehicle Speech Systems. He has served on the Executive Council of the Human Factors Society.

2.b.ii Experience in Developing Leaders and Plans for Future Development

The team of investigators in the proposed UTC has a record of experience in developing leaders. We provide three examples from our team. First, former students of Dr. Özgüner have gone on to leadership positions in academia (university presidents, deans, and professors), as well as government (US DOT Federal Motor Carrier Safety

Administration [FMCSA], Sandia National Lab) and industry (IBM, TRW, GM, Ford, Caterpillar). As a second example, Dr. Fisher provides active leadership mentoring for students in his laboratory. Several of his students have received research awards, including the Volpe National Transportation Systems Center Research Award, the Eno Transportation Foundation Leadership Development Fellowship, and the Honda Outstanding Student Paper Award in Driving Assessment. As a third example, Dr. Lee's students have also received numerous student awards, including student paper awards in the Surface Transportation Technical Group at the Human Factors and Ergonomics Society; the Intel Outstanding Student Paper Award at the 4th International Conference on Automotive User Interfaces and Interactive Vehicular Applications; and best paper awards at the 3rd International Driving Symposium on Human Factors in Driver Assessment, Training and Vehicle Design, the Midwest Transportation Consortium, and the International Ergonomics Association. Other investigators in the proposed UTC have similar records of leadership and leadership development.

The CrIS UTC will develop future leaders through a targeted program of leadership training. We will develop and deliver of new set courses at the intersection of the UTC research activities that will be designed to provide students with the necessary foundations in human factors, intelligent vehicles, bioinjury, and transportation policy and that will equip them to become broadly-based thought leaders in the transportation safety field. These courses are described in Section 2.c. Dedicated seminar programs and special sessions at conferences will provide students opportunities to present research results and expose them to a broad range of research topics and approaches.

We will create opportunities for our students to interact with our industrial partners in the UTC in both formal and informal gatherings. The ability to learn about the needs of the automotive and insurance industries related to vehicle autonomy and human-vehicle interaction will broaden the perspective of these students beyond the boundaries of the university and prepare them to be effective leaders for vehicle and transportation safety.

CrIS will promote opportunities for developing entrepreneurial and commercial activities for both students and faculty by leveraging a wealth of resources available across our universities. These include entrepreneurship competitions, technology incubators working with the universities, access to university-leveraged venture capital funding, and state support for commercialization acceleration through programs such as the Ohio New Entrepreneurs Fund and the Ohio Entrepreneurial Signature Program.

2.b.iii Proposed Performance Metrics

The success of UTC leadership activities will be assessed with the following metrics:

- Number of student publications and presentations at professional meetings
- Number of student awards for best paper
- Number and type of leadership awards by UTC researchers and students
- Number and type of student-industry engagements
- Number of entrepreneurial successes, including licenses, patents, company spin-offs, and external funding for entrepreneurial activities.

Metrics will be gathered by the UTC Program Manager via quarterly reporting from project investigators.

2.c. Education and Workforce Development

Our UTC team has a rich history of providing quality education programs related to ground transportation. Leveraging this foundation, we will expand our offerings, with a focus on human systems integration in pre-crash scenarios.

2.c.i. Degree-granting Programs

OSU has a broad range of degree-granting programs that educate students in surface transportation. Table 2 lists the number of students who have completed transportation-related degrees at OSU in the past decade. Based on career placement records, a significant fraction of these students are employed in the transportation workforce, including departments of transportation and other government agencies, vehicle manufacturers and suppliers, and consulting companies.

Table 2. OSU offers a wide range of engineering programs that educate students in surface transportation.

Degree Program	Faculty Members	Undergraduate Honors Theses in Transportation 2003–2012	MS Graduates in Transportation 2003–2012	PhD Graduates in Transportation 2003–2012
Civil and Environmental Engineering	23	11	87	15
City and Regional Planning	12	0	29	1
Computer Science and Engineering	34	1	2	0
Electrical and Computer Engineering	50	6	2	25
Integrated Systems Engineering	14	0	14	8
Mechanical and Aerospace Engineering	54	53	123	103
Materials Science and Engineering	24	0	34	18
Welding Engineering	6	0	9	6
Total	**207**	**71**	**301**	**176**

The UTC will leverage OSU's Global Engineering Leadership Program, which grants joint degrees from the College of Engineering, the Fisher College of Business, and the John Glenn School of Public Affairs. We will develop a new course for this program using automotive safety and the research done at the UTC to highlight the interconnected nature of policy, technology, and business. In addition, courses specifically aimed at future engineers and regulators will be developed for the dual master's degree in Engineering and Public Affairs and will explore the policy process and the effects of innovations and changing technologies.

Graduate students can choose several transportation options. Five of the departments listed in Table 2 offer a graduate specialization in transportation. OSU offers a master's program in Urban Transportation Planning; graduates receive both an MS in Civil Engineering and an MCRP in City and Regional Planning. Another example is the Graduate Specialization in Automotive Systems Engineering that was created in 2005 as part of US DOE Graduate Automotive Technology Education (GATE) Centers of Excellence grants. OSU is the only university to have been selected in all of the three rounds of funding for GATE programs. Through the GATE program, students receiving graduate degrees in Mechanical and Aerospace Engineering, Electrical and Computer Engineering, Integrated Systems Engineering, and Materials Science and Engineering can choose to specialize in one of four transportation focus areas. More than 70 students, almost all of whom are employed in the automotive sector, have already completed the graduate specialization.

At UW, the Department of Civil and Environmental Engineering and the Department of Industrial and Systems Engineering offer MS and PhD degrees directly relevant to transportation and traffic safety. Students may choose one of five programs of study: Traffic Engineering, Traffic Safety Engineering, Highway Engineering, Transportation Planning, and Urban Systems Planning. The faculty emphasizes that safety must be the fundamental force behind all decisions and that engineers must integrate technical solutions with social, economic, political, and environmental concerns. The program combines core courses in transportation, urban development, and safety with related courses in computer science, economics, and human factors.

Within the School of Engineering and Technology at IUPUI, transportation and automotive engineering is one of the major focus areas of research and academic programs. Many MS and PhD students in Electrical and Computer Engineering and in Mechanical Engineering pursue coursework and research theses in transportation. IUPUI also offers two undergraduate degree and certificate programs in Motorsports Engineering and Energy Engineering; Energy Engineering includes a track area in transportation electrification. The School of Public and Environmental Affairs also offers policy-related courses in transportation and environmental affairs.

New Courses: As part of this UTC, we will develop four new courses focused specifically on the cross-disciplinary issues associated with safety, human factors, and policy, and will work toward the creation of a new specialization in human-vehicle interaction within the current framework of transportation options. Three of these courses, listed in Section 2.c.ii, will be developed as both non-degree online open courses and new OSU curricular courses. A fourth graduate course, Vehicle Active Safety, will be developed by IUPUI.

2.c.ii. Non-degree Programs

As part of this UTC, we intend to develop and deliver a set of Massive Online Open Courses (MOOCs) that will engage a much wider audience than can be accessed directly by the UTC and its facilities. The courses will leverage the cross-disciplinary expertise in the UTC, and also leverage OSU's membership in Coursera as a MOOC delivery mechanism. The courses are as follows.

- **Public Policy for Ground Transportation Safety (Professor Schuelke-Leech)**. This course will consider the interplay of policy and technology as it relates to ground transportation safety. This course will bring in invited speakers from different sectors to lecture about automotive safety, engineering, regulation, testing, and emerging technologies.
- **Joint Human and Automation Systems (Professor Woods).** This course will study design strategies for development of automation systems and their human interfaces. The course will consider autonomy in ground vehicles as a focus area.
- **Vehicle-Based Safety in Intelligent Transportation Systems (Professor Ü. Özgüner).** The course will focus on design of sensor and control systems in intelligent vehicles, with a focus on system strategies for safe operation.

2.c.iii. Proposed Seminars/Workshops/Training Courses

The CrIS UTC will also develop an interdisciplinary seminar series that aligns with the pre-crash safety research agenda of the program. The seminars, open to the public,

will have the primary objective of educating participants on pre-crash safety issues and solution approaches that integrate human factors, intelligent vehicles, bioinjury, and policy. Experts from around the nation will be invited to speak.

2.c.iv. Proposed Outreach and Educational Activities

Two new programs will be developed by the CrIS UTC that will engage young students in transportation safety and security program— Women in Engineering Transportation and Hack My Ride, a vehicle cybersecurity program. These are described below.

Women in Engineering Transportation. We will develop K-12 outreach and education transportation modules to attract underrepresented (African American, Hispanic, Native American) female student populations to transportation fields. We will leverage the highly successful OSU Women in Engineering (WiE) Program, and integrate into existing WiE summer camps. OSU's WiE program has a demonstrated record of success in attracting and retaining women to engineering; each year, WiE's programs reach more than 1,300 undergraduates, 550 graduate-level students, and 1,000 K-12 students.

We will integrate transportation programs into the WiE's Reaching a Career in Engineering (RACE) program and WiE's respected, involved, skilled, empowered (RISE) programs. WiE RACE is a 6-day summer residential camp for high school students who will be entering the 10th or 11th grade; about one-half of the participants are female. WiE RISE is also a 6-day summer residential camp offered to female students who will be entering the 12th grade. These programs, which receive applications from across the country, are designed to increase participants' knowledge and understanding of engineering and the opportunities available to engineering students enrolled at OSU. Under this UTC, we will develop transportation safety modules in both of these WiE programs. We will also leverage WiE's partnership with Columbus Chapter of Women in Transportation Systems (WTS) to engage women transportation professionals in developing and presenting modules and in student mentorship programs.

Participants experience hands-on engineering challenges during WiE RACE.

Hack My Ride. The UTC will partner with Battelle Memorial Institute, the world's largest not-for-profit R&D organization, to offer Hack My Ride summer camps to high school students. The camps will give participants an understanding of the interplay between cybersecurity and vehicle safety. We will leverage Battelle's successful 2012 program—The CyberAuto Challenge—held in Maryland, in which 24 students participated in a 1-week

Students participating in the 2012 CyberAuto Challenge experienced hands-on opportunities to learn about vehicle cybersecurity.

program; 40 percent of these were women and minorities. One of the sessions taught students how to (legally) reverse engineer a car's systems to find potential problems as a basis for improving the car's design. The 2013 offering will be held in Columbus, OH; participants will include TRC, NHSTA, and automotive manufacturers.

2.c.v. Proposed Education and Workforce Development Activities

We will leverage an existing interdisciplinary capstone design program in OSU's Engineering Education Innovation Center to develop a new capstone design course in Human System Integration for Vehicle Safety. The course will engage students from multiple engineering and non-engineering disciplines to work in small teams to develop new intelligent vehicle information interfaces for drivers. Designs will be validated using the OSU Driving Simulator facility. Dr. Keith Redmill from our team coordinates capstone programs already as part of his teaching duties at OSU, and will oversee the CrIS UTC's capstone offerings at OSU.

All five UTC consortium members have active engineering internship and co-op educational programs at the undergraduate level. Through the industrial and government advisors of the UTC, we will encourage new internships in areas that align with the research focus of this UTC. In particular, we will leverage both State of Ohio and OSU cost-sharing funds in this grant to provide financial cost-sharing scholarships for up to 10 summer internships or co-op experiences annually in areas aligned with this UTC's mission. An open competition for these scholarships will be developed and run by the UTC staff.

Undergraduate research opportunities will be offered to engage gifted students in early research experiences with the goal of encouraging these students to pursue graduate degrees in transportation. The UTC will offer up to three scholarships for undergraduate students to engage in summer research programs.

At the graduate level, we will offer internships and semester-long projects on the connection between engineering and public policy, using transportation safety and regulation as one of the main educational anchors.

2.c.vi. Performance Metrics

The success of UTC education and workforce development programs will be assessed with the following metrics:

- Number of students who enroll in new courses introduced as part of this UTC
- Number of students who enroll in the three proposed MOOCs
- Number of students who engage in the Women in Engineering Transportation and Hack My Ride programs, and fraction of those students who pursue undergraduate STEM degrees or transportation-related non-STEM degrees
- Number of students who engage in capstone design or undergraduate research opportunities, and fraction of those students who pursue transportation-related careers or graduate education opportunities
- Number of UTC-related seminar and symposium participants.

Metrics will be gathered by the UTC Program Manager via quarterly reporting from project investigators and MOOC instructors and via end-of-program reporting from outreach programs.

2.d. Technology Transfer

This UTC will engage in several forms of technology transfer, expanding a rich existing infrastructure to efficiently and effectively disseminate the results of our research program and to bring new ideas into practice.

2.d.i Planned Technology Transfer Activities

OSU, in partnership with the Children's Hospital of Philadelphia, houses the Center for Child Injury Prevention Studies (CChIPS)[15], a National Science Foundation Industry/ University Cooperative Research Center that focuses exclusively on making children and adolescents safer. Through CChIPS, researchers work in partnership with industry members to conduct translational research that is practical to industry. CChIPS research is focused on preventing traffic injuries, the leading cause of injury and death for children, youth, and young adults. CChIPS has 20 corporate and government sponsors, including 8 automotive original equipment manufacturers (OEMs), child safety equipment manufacturers, and insurance companies. This UTC will leverage CChIPS to disseminate results and also to transfer technology through direct industry sponsorship.

OSU has a vibrant patenting and commercialization ecosystem, anchored by its Technology Commercialization Office (TCO) and closely partnered with TechColumbus, central Ohio's technology incubator located adjacent to the OSU campus. TCO facilitates patenting, licensing, and spinout companies from OSU faculty and student innovations. For example, Professor Ü. Özgüner, this UTC's Center Director, launched a spinout company based on bus tracking technology.

We will develop special sessions at transportation-related conferences and will propose special issues of archival journals to showcase the interdisciplinary research results developed under this UTC, such as the following:

- A special session on Human Factors for Intelligent Vehicle Safety as part of the 2014 Intelligent Vehicle Symposium to be held in Detroit. Professor Ü. Özgüner is the General Co-Chair of this symposium with Professor Chen at IUPUI
- A special issue of the Institute of Electrical and Electronics Engineers (IEEE) Intelligent Transportation Society Transactions focused on Human Factors for Intelligent Vehicle Safety, using the special session discussed above as a corpus for this special issue
- The annual Injury Biomechanics Symposium, expanded to include an annual special session on Vehicle Safety and Autonomy that will disseminate research supported by the CrIS UTC. The Biomechanics Symposium is hosted annually by OSU, and is the nation's preeminent symposium on the topic. The symposium is currently in its ninth year and is supported by sponsorship from automotive manufacturers, insurance companies, child car seat manufacturers, and NHTSA.

The CrIS UTC will also disseminate the Computer-assisted Alcohol Infusion System (CAIS), developed by IUPUI. The CAIS generates precise, prescribed trajectories of a subject's brain exposure to alcohol, and generates an output file of performance and results. The software includes drivers that run infusion pumps, and a physiologically based pharmacokinetic model of alcohol distribution and elimination kinetics, along with

[15] see http://www.research.chop.edu/programs/cchips/index.php

graphics displays for subject monitoring. CAIS is currently used, for non-transportation applications at several universities in the United States as well as at several international sites. Under this UTC, we propose to extend the application domain to driving simulator and test track environments, including both operations manuals and an electronic users forum for use in these environments.

Our continuing education program will include MOOC development, as described in Section 2.c.

We will integrate policy outreach and education into our UTC information transfer activities. Through a program of seminars, white papers, and forums, we will link technical experts with policymakers, automotive manufacturers, and insurance companies to facilitate understanding of effective technologies and the corresponding regulatory advancements that result in improvements to crash safety technologies. The forums—to be modeled after a successful energy technologies forum hosted at OSU in 2012 by a member of this UTC team—will bring together stakeholders from different sectors to improve both understanding and communication around specific issues.

In May 2013, Dr. Bolte will host a 3-day continuing education program at OSU focused on basic human anatomy and injury relationships for safety engineers employed in industry. The program will introduce the engineers to the anatomy aspect of injury, and give them an understanding of that subject that can be applied to improve crash safety designs for their companies. Under the UTC, we will extend and expand this program.

The UTC will maintain a current website that highlights activities, disseminates results, and advertises upcoming education and outreach events and activities. In addition, research outcomes will be disseminated through the US DOT Research Hub.

2.d.ii. Performance Metrics

The success of UTC technology transfer programs will be assessed with the following metrics:

- Number of students who enroll in the three proposed MOOCs
- Number of patents, licenses, and new companies resulting from UTC research
- Number of participants in continuing education courses and policy information forums
- Number of special sessions at conferences hosted by UTC team
- Number of archival journal special issues organized by UTC team.

Metrics will be collected by the UTC Program Manager via quarterly reporting from project investigators.

2.e. Collaboration

The proposed UTC represents collaboration among OSU, NCA&T, UW, UMass, and IUPUI. The team has come together to leverage strengths in the areas of autonomous vehicles, human-vehicle interaction and human systems integration, and bioinjury/ biomechanics, which are essential to meeting the goals of the proposed research.

2.e.i Plans for Collaboration

Of particular value to the human-vehicle interaction work proposed here, three of the universities have driving simulators manufactured by Realtime Technologies; this

will greatly facilitate the sharing of scenarios, experimental designs, and data across institutions. In addition, it affords the opportunity to create simultaneously shared driving scenarios, which will permit multiple human actors in an environment with autonomous, semi-autonomous, and non-autonomous vehicles. The unpredictability of multiple human actors creates a situation close to that encountered in real life.

These institutions vary in location and size, and, because all are state-funded universities, they have diverse student populations. To enhance the diversity of students in the UTC's proposed educational and research activities, OSU is extending its established partnership with NCA&T, which ranks highest in the United States in awarding engineering degrees to African-American students. The Colleges of Engineering at OSU and NCA&T have collaborated on several programs over the past decade.

Further, the OSU Driving Simulation Laboratory has already established ties with several other Ohio universities, including Wright State University in Dayton, OH, and Ohio University in Athens, OH. Both universities are engaged in driving simulation work and are part of the academic consortium of the laboratory. We are currently in discussions with researchers at another university in Ohio, Miami University-Middletown campus, to conduct collaborative work relevant to the aims of the proposed UTC.

The proposed UTC has a specific focus, but solutions for a safe motor vehicle transportation system require attention not only to the systems in vehicles themselves, but also to roadways and infrastructure, transportation networks, freight movement, and transit systems. OSU and the CrIS UTC consortium members participate in several regional UTCs that address some of these other issues (specifically, the Region V NEXTRANS UTC at Purdue and the MIT-based New England UTC). We plan to leverage the work proposed for this UTC with these ongoing efforts. From a research perspective, the issues that will be addressed in the proposed UTC overlap well with some of the priorities of freight movement and transportation system research agendas.

OSU has a strong tradition of involvement with industry and government partners. In 2012, the university had research relationships with more than 700 external companies, including many in Ohio as well as across the United States and internationally. Many of OSU's corporate partners are in the automotive sector, which is one of the most significant sectors in Ohio's economy. OSU and the UTC team universities will work to create a broad network of government and industry partners, leveraging existing relationships from several sources such as OSU's Center for Automotive Research (CAR). CAR has a broad network of government and industry partners; 55 of them are automotive industry partners, including major automakers (Chrysler, Ford, General Motors, Honda, Hyundai-Kia, Mazda, Nissan, Renault, Toyota, and Volvo) and automotive suppliers. In addition, CAR interacts with numerous government and nonprofit entities, including FHWA, RITA, NHTSA, Michigan DOT, Ohio DOT, branches of the Department of Defense (Army, Air Force), and several national laboratories (Argonne, Oak Ridge, Sandia). The proposed UTC will use these contacts to create a broad network of partners with whom new discoveries, technologies, and data can be shared. Government and industry partners will be invited to attend workshops, policy briefings, and annual meetings of the proposed UTC, where research outcomes will be shared with this broad audience.

2.e.ii Advisory Committees

We will ensure that our government and industry partners have a voice in the directions of research and education within the proposed UTC. Similar to other centers at OSU, the proposed UTC will have both internal technical and external stakeholder advisory boards that provide guidance to its activities. The internal advisory board will include Professor William S. Marras, a world leader in biomechanics and member of the National Academy of Engineering; Professor Giorgio Rizzoni, a fellow of IEEE and SAE and director of OSU's CAR; Professor Mark McCord from the OSU Department of Civil, Environmental, and Geodetic Engineering and leader of OSU's partnership involvement in the Region V UTC, NEXTRANS*;* OSU's Vice President for Research; and the deans of the Colleges of Engineering and Arts and Sciences. The planned external advisory board will include members of the industry and government community, specifically corporate partners Honda R&D, Battelle, Nationwide Insurance, TRC, Ohio DOT, the Mid-Ohio Regional Planning Center (MORPC), and the NHTSA Vehicle Research and Test Center (VRTC). Other members may be added to the internal and external advisory boards, as needed.

2.e.iii Performance Metrics

The success of UTC collaborations will be assessed with the following metrics:

- Number of projects involving collaboration among researchers from across the consortium
- Number of projects involving collaboration of facilities from across the consortium
- Number of students from partner universities who are brought into the UTC for research and educational programs
- Number of patents and licenses associated with proprietary intellectual property that are developed under the auspices of the UTC by team universities
- Number and diversity of members of the team universities
- Number and impact of industrial deployments/technology transfers achieved through collaboration.

Metrics will be collected by the UTC Program Manager via quarterly reporting from project investigators.

2.f. Program Efficacy

2.f.i. Institutional Resources

All five of the universities teamed for the UTC are state-funded research universities, and all have the necessary institutional resources to execute and manage research grants. These include financial management and tracking, purchasing, human resources, and the necessary classroom, distance education, outreach, and research space and facilities to carry out the research programs.

The respective university Offices of Research administer sponsored research projects, oversee compliance for research activities, manage protocols and the infrastructure surrounding animal and human subjects, establish commercialization pathways for research outcomes, and invest financial resources into promising areas of future

research. These offices provide comprehensive training and education programs to meet the research needs of key personnel (faculty, staff, postdocs, students).

2.f.ii. Other Centers of Transportation Studies or Research

Related centers of transportation studies at the CrIS UTC member universities include:

- The **University of Massachusetts Transportation Center (UMTC)** has active research and training projects that focus on transportation congestion, safety, and air quality. A major focus of the research to date has been in transportation and human factors, especially as it relates to safety.
- At UMass**,** the **Regional Transportation Information Center (RTIC)** provides real-time travel-time and congestion information in the Pioneer Valley of Western Massachusetts using video imaging technology.
- NCA&T's **Transportation Institute (TI)** is housed in the School of Business and Economics and has been a leader in transportation-related research, education, and technology transfer with a focus on logistics.
- The **National Center for Freight and Infrastructure Research and Education (CFIRE)** at UW is a Tier 1 UTC. Its focus is logistics and commercial vehicle operations.
- OSU and UW are members of the **US DOT Region V UTC, NEXTRANS**, which focuses on an efficient and secure intermodal freight transportation system.
- OSU's **Center for Automotive Research (CAR)** focuses on research and education in advanced and alternative powertrains, alternative vehicle control systems, energy storage, and vehicle intelligence.

The proposed UTC, with its focus on crash imminent safety for intelligent and autonomous vehicles, is readily distinguishable from all of these centers, except UMTC, in its research program. The UTC will have research synergy with UMTC, and is distinguishable by our focus on crash-imminent human factors with intelligent vehicles. The networked simulator capability provided by UTC will be a valuable experimental enhancement to UMTC, and we intend to collaborate with UMTC in this area. All of the centers listed above provide synergistic collaboration opportunities in education, workforce development, K-12 outreach, and development of future transportation leaders. To facilitate these collaborations, CAR's Director, Dr. Giorgio Rizzoni and NEXTRANS' OSU representative, Dr. Mark McCord, will both serve on the Technical Advisory Board for the UTC.

2.f.iii. Management and Oversight of Fiscal and Technical Activities

The UTC will be directed by Dr. Ümit Özgüner, professor of electrical and computer engineering at OSU. The Center Director will organize meetings of the UTC's advisory committees; monitor and report on performance metrics and program time lines; and serve as primary point of contact to the US DOT.

The budget for the proposed center includes funding for a dedicated Program Manager to facilitate day-to-day center operations. The Program Manager will work under the direction of the Center Director and will be responsible for the following key functions:

- Develop and maintain the UTC website
- Establish project accounts through OSU's Office of Sponsored Programs and monitor project status and overall program status
- Prepare monthly reports for the Center Director
- Prepare quarterly federal financial reports for Center Director's review and submission to US DOT
- Prepare annual recipient share reports for the Center Director to review and submit
- Monitor and manage reporting on subawards.

The Program Manager will utilize OSU's institutional resources, including an online system for tracking expenditures.

2.f.iv. Procedures for Tracking and Coordinating Research

The research team will coordinate their activities, including progress toward agreed upon milestones, through regularly scheduled internal review sessions with the Center Director, scheduled and facilitated by the Program Manager.

The UTC will establish a Research Program Leadership Committee comprising representatives from each consortium university and chaired by the Center Director. This committee is responsible for guiding the UTC in accomplishing its objectives in a cost-efficient manner. The Committee will meet monthly to review progress and coordinate projects. Both the Technical Advisory Board and the External Advisory Board will provide additional support and external review in ensuring that the UTC is accomplishing its fiscal and technical objectives.

OSU's Office of Sponsored Programs has the necessary tools to monitor and track project activity to ensure sound and timely fiscal and human resources management. OSU is subject to OMB Circulars A-21, A-110 and A-133. Both A-133 and independent audits are conducted annually.

2.g. Diversity

The proposed UTC is committed to broadening participation in the transportation field. All of our K-12 outreach activities are targeted toward building a pipeline of diverse students who are engaged early and mentored effectively toward transportation degree programs at the university level. Two programs in particular, Women in Engineering Transportation and Hack My Ride, are designed to increase interest in engineering and other science, technology, engineering and mathematics (STEM) fields. These programs are described in Section 2.c.iv. We also have as a team member, NCA&T, a Minority Serving Institution.

To enhance the diversity of students in educational and research aspects of the proposed UTC, we will extend OSU's established partnership with NCA&T. The Colleges of Engineering at OSU and NCA&T have collaborated on several programs over the past decade. NCA&T graduates the highest number of African-American engineers in the United States; 39 percent of these graduates are women. NCA&T has strong research programs in engineering technology areas related to surface transportation, but has had few research or educational programs directly focused on US DOT safety issues. Partnership in this UTC provides a significant opportunity to expand NCA&T's research and educational mission and to more strongly align it with

US DOT's interests. Students and faculty at NCA&T will be offered summer research fellowships at OSU to participate in research under the proposed UTC. NCA&T plans a senior capstone design experiment using the new Realtime Technologies driving simulator facility that will be acquired under this UTC.

3. Center Director and Key Staff

Ümit Özgüner, PhD, Professor of Electrical & Computer Engineering at OSU and holder of the TRC Inc. Chair on Intelligent Transportation Systems (ITS), will serve as **Center Director**. Dr. Özgüner brings to the UTC an exceptional, diverse background in ITS. Over the past 15 years, he has focused his research and education activities in ITS and intelligent vehicles (IV), all in the areas of autonomy and safety. He has created a course and published significantly, including coauthoring a noted book on autonomous ground vehicles (Ümit Özgüner, Tankut Acarman, and Keith Redmill, *Autonomous Ground Vehicles*, Artech House [Boston], 2011).

Dr. Ümit Özgüner

Dr. Özgüner, a Fellow of IEEE, is a proven leader and innovator in ITS. He was program chair of the first IEEE ITS Conference, and was the founding president of the IEEE ITS Council/Society. He also chaired the IEEE Intelligent IV Symposium and the IEEE International Conference on Vehicle Electronics & Safety (ICVES). He has demonstrated his commitment to engaging his students in unique educational activities, such as leading teams in FHWA's Automated Highway System, Demo'97, in all Defense Advanced Research Projects Agency (DARPA) Grand Challenges and Urban Challenges, and in the Grand Cooperative Driving Challenge in Holland. Additional information about Dr. Özgüner is presented in his Curriculum Vitae in Appendix i.

The OSU College of Engineering, in designating Dr. Özgüner as Center Director, supports his role in managing and operating all aspects of the UTC, dedicating more than 50 percent of his time to the UTC activities. As Figure 4 shows, OSU is also

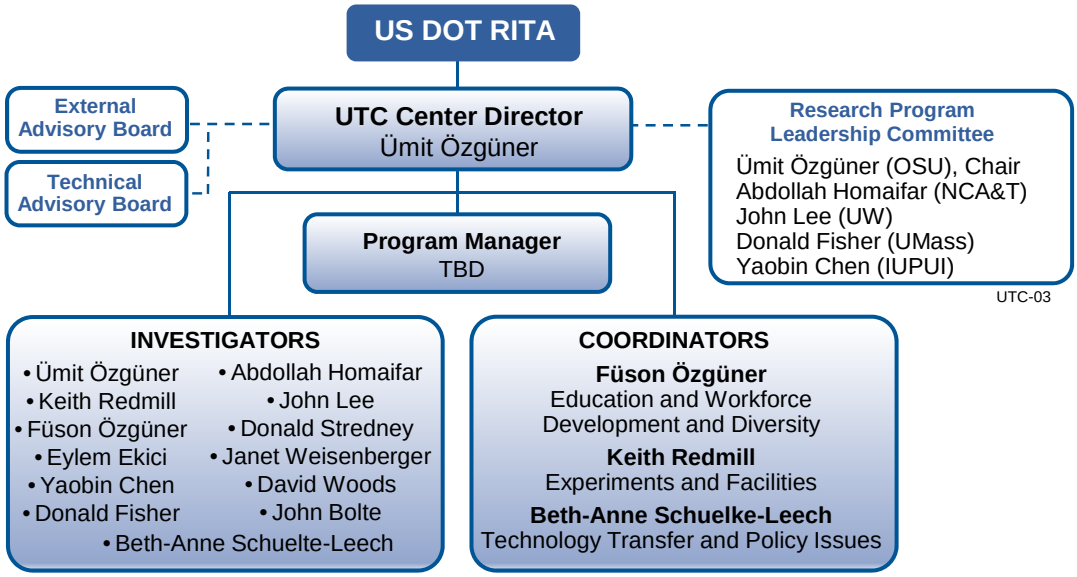


Figure 4. CrIS UTC organization chart.

committing a Program Manager to support the program, and has designated three faculty members—all of whom are also investigators in the proposed research—as Coordinators for key aspects of UTC activities. Coordinators will provide approximately 50 percent of their time to the UTC, including involvement in research. The Coordinators bring complementary capabilities that enhance the UTC's capability to address the proposed research focus.

Füsun Özgüner, PhD, Professor, Electrical and Computer Engineering, OSU, will serve as **Coordinator for Education and Workforce Development and Diversity.** She brings not only a proven capability in high-performance computing, vehicular electronics, networks, safety and security, but also a recognized commitment to students and their educational experiences. She served as the program co-chair for the 2012 IEEE International Conference on Vehicular Electronics and Safety (ICVES12). As the Graduate Studies Chair and faculty member in Electrical and Computer Engineering, she has been involved in developing and managing educational programs and has participated in numerous activities to support and recruit minorities in engineering. She also recruited women faculty members, invited diverse speakers, and established policies to hire women and minorities as teaching assistants to serve as role models for undergraduates. Currently she serves as the faculty advisor for women students in Electrical and Computer Engineering.

Keith Redmill, PhD, Assistant Professor of Practice, Department of Electrical and Computer Engineering, OSU, will serve as **Coordinator for Experiments and Facilities**. He is actively engaged in research in the Control & Intelligent Transportation Research Laboratory and the Center for Automotive Research. Dr. Redmill has collaborated with faculty and researchers in the departments of Electrical and Computer Engineering, Civil and Environmental Engineering, Mechanical Engineering, and Chemical & Biomolecular Engineering, as well as the Center for Mapping. He also has a longstanding on-site involvement with the US DOT NHTSA Vehicle Research and Testing Center. He presently manages the Electrical and Computer Engineering department's Capstone Design Course, coordinating the projects of approximately 100 students annually.

Beth-Anne Schuelke-Leech, PhD, is an Assistant Professor in OSU's John Glenn School of Public Affairs where she conducts research in the areas of engineering and public policy. She will serve as **Coordinator for Technology Transfer and Policy Issues**. Dr. Schuelke-Leech, who holds degrees in engineering as well as public policy, brings to the UTC a focus on engaging transportation professionals and other stakeholders in policy impacts of advanced transportation technologies. Her experience includes nearly 10 years in engineering, product development, and financial analysis for General Motors.

Table 3 summarizes the primary duties and responsibilities of the Center Director, the full-time Program Manager, area Coordinators, and designated project Lead Investigators.

Table 3. Clearly defining duties and responsibilities for each staff role enables the UTC to execute research projects that provide a framework for achieving its objectives of enhanced student experiences and value-added technology transfer.

Title	Duties and Responsibilities
Center Director *Ümit Özgüner*	• Represent the UTC at meetings with US DOT and other relevant events • Review and submit all required UTC grant deliverables to US DOT, including quarterly federal financial reports, annual recipient share report, final research reports, program progress reports, and annual performance indicators report • Submit project descriptions to US DOT within 1 month of award and post on UTC website • Work with US DOT and advisors to define project activities to advance the UTC's mission • Review progress of technical and fiscal activities for each project with designated Lead Investigator • Maintain communication through the UTC informational website and social media • Review overall UTC progress against established performance metrics with advisory committees and US DOT • Establish and direct Working Groups in specific topic areas to develop tutorials/workshops and generate new projects to be considered as the UTC continues • Work with Coordinators and Lead Investigators to ensure that all projects include student involvement in research and to identify outstanding students for UTC program awards • Work with Coordinators to define and sponsor community education-related events, such as "Hack My Ride" with local high schools
Program Manager *TBD*	• Develop UTC website within 3 months of award and post key personnel information • Maintain website • Establish and maintain UTC metrics for tracking • Establish project accounts through OSU's Office of Sponsored Programs • Use OSP-provided tools to monitor overall program status • Prepare monthly reports for Center Director • Prepare quarterly federal financial reports for Center Director to review and submit to US DOT • Prepare annual recipient share report for Center Director to review and submit • Monitor and report on any subawards
Coordinator, Education and Workforce Development and Diversity *Füsun Özgüner*	• Support Center Director in executing UTC's mission and objectives • Work with each consortium member during project planning to evaluate opportunities for education, workforce development, and diversity in projects • Support Lead Investigators in identifying and retaining support to execute activities • Support Lead Investigators and Program Manager in using social media and other mechanisms of communication • Establish performance metrics with each Lead Investigator • Monitor performance • Provide Center Director and Program Manager with monthly updates on performance metrics
Coordinator, Experiments and Facilities *Keith Redmill*	• Support Center Director in executing UTC's mission and objectives • Keep Center Director apprised of facility additions, modifications, and availability • Work with each Lead Investigator at project initiation to define project plan and identify experiment milestones and facility needs • Coordinate experiment and facility scheduling • Establish performance metrics with each Lead Investigator • Monitor performance • Provide Center Director and Program Manager with monthly updates on performance metrics
Coordinator, Technology Transfer and Policy *Beth-Anne Schuelte-Leech*	• Support Center Director in executing UTC's mission and objectives • Work with each Lead Investigator during project planning to identify technology transfer opportunities • Work with each Lead Investigator during project planning to assess potential public policy impacts of research and determine path forward for technology transfer • Establish performance metrics with each Lead Investigator • Monitor performance • Provide Center Director and Program Manager with monthly updates on performance metrics
Lead Investigators	• Work with Center Director to finalize project scope in accordance with UTC's mission • Work with Center Director and Program Manager to prepare project plan with defined milestones, deliverables, and metrics • Use home university's established project monitoring tools to monitor expenditures, commitments, and deliverables for specific projects • Provide monthly status updates to Program Manager

Appendix i. Biographical Sketch

ÜMIT ÖZGÜNER

PROFESSIONAL PREPARATION:

Istanbul Technical University	MSEE, Electrical Engineering	1971
University of Illinois	PhD, Electrical Engineering	1975
IBM T.J. Watson Research Center	Postdoctoral Researcher	1975 – 1976

APPOINTMENTS:

09/88 to Present	**Professor,** Electrical & Computer Engr., The Ohio State University
10/83 – 09/88	**Associate Professor,** Electrical & Computer Engr., The Ohio State University
01/81 – 09/83	**Assistant Professor,** Electrical & Computer Engr., The Ohio State University
06/99 to Present	**TRC, Inc. Chair on Intelligent Transportation Systems**, The Ohio State University
01/10	**IEEE Fellow** "for contributions to Intelligent and Autonomous Vehicles"
01/92 – 07/92	Sabbatical leave at Ohio Aerospace Institute and NASA Lewis Research Center
08/91 – 12/91	Sabbatical leave at Ford Motor Company, Dearborn, MI
03/06-06/06	Sabbatical leave at Istanbul Technical University
09/79 – 08/80	**Visiting Asst. Professor,** Electrical Engineering, University of Toronto, on leave from Istanbul Technical University
1978 – 1979	**Lecturer,** Mathematics, Bogazici University
1976 – 1980	**Asst. Professor,** Electrical Engineering, Istanbul Technical University, Title of Dozent conferred in 1980
1975 – 1976	**Postdoctoral Research,** I.B.M. T.J. Watson Research Center, Yorktown Heights, NY

PUBLICATIONS: *Over 400 publications in journals, conference proceedings, and book chapters.*

Publications Related to Proposed Project:

1. A. Kurt and **Ü. Özgüner**, "Hierarchical Finite State Machines for Autonomous Mobile Systems," *Control Engineering Practice*, Volume 21, Issue 2, Pages 184–194, Feb 2013.
2. K. Redmill, S. Biddlestone, R. Miucic, and **Ü. Özgüner**, "An Integrated 802.11p WAVE DSRC and Vehicle Traffic Simulator with Experimentally-Validated Urban (LOS and NLOS) Propagation Models", *IEEE Trans on ITS,* 13:4 (2012), p. 1792-1802.
3. **Ü. Özgüner**, T. Acarman, and K. Redmill, *Autonomous Ground Vehicles*, Artech House (Boston), 2011.
4. A. Kurt and **Ü. Özgüner**, "Virtual Environments for Testing Complex Cyber-Physical Systems", *Proceedings of the Special International Conference on Complex Systems: Synergy of Control, Computing & Communications*, Ohrid, Macedonia, Sep 2011.
5. **Ü. Özgüner** and K. Redmill, "Sensing, Control, and System Integration for Autonomous Vehicles: A Series of Challenges," *SICE Journal of Control, Measurement, and System Integration* 1:2 (Mar 2008), p. 129-136.

Other Relevant Publications:

1. A. Kurt, M. Vernier, S. Biddlestone, K. Redmill, K., and **Ü. Özgüner,** "Testing of Intelligent Vehicles Using Virtual Environments and Staged Scenarios," *Advances in Intelligent Vehicles*, Ed. Chen, Y. and Li, L., Academic Press, 2013.
2. S. Biddlestone, K. Redmill, and **Ü. Özgüner***, "*Coordination of Ad-hoc Groups Formed in Urban Environments," *Proc. 14th IEEE Conference on Intelligent Transportation Systems, ITSC 2011,* October 2011.
3. Y. Zhu, Y. Zheng, and **Ü. Özgüner**, "Waypoint Selection in Constrained Domains (for cooperative systems)," in *Advances in Cooperative Control and Optimization*, M. J. Hirsch, P. M. Pardalos, R. Murphey, and D. Grundel (eds.), *Lecture Notes in Control and Information Sciences*, Springer, 369: 191-202, 2007.
4. Y. Zheng and **Ü. Özgüner**, "A Composite Model for Vehicle Formation and Path Selection on a Cellular Structured Map," *Journal of Dynamic Systems, Measurement, and Control,* Volume 129, Issue 5, pp. 644-653, September 2007.
5. Z. Tang and **Ü. Özgüner**, "Cooperative Sensor Deployment for Multi-Target Monitoring," *International J. Robust and Non-linear Control*, Vol. 18, Issue 2, pages 196 – 217, 2007.

SYNERGISTIC ACTIVITIES:

- IEEE ITS Council, President 1999, 2000 (elected), IEEE ITS Society Member of BOG, 2005-2007 (elected). Elected VP Conferences (2006-2009).
- Conference Organization: General Chair, 2002 Conf. On Decision and Control, Las Vegas; General Chair, IEEE Intelligent Vehicles Conference., June 2003, Columbus; General Chair, IEEE International Conference on Vehicle Electronics and Safety, Sept. 2008.
- Associate Editorship: IEEE ITS Transactions, Special Issue Editor
- Coordinator and Team Lead for OSU (Finalist) Teams in the 2004 and 2005 DARPA Grand Challenges and the 2007 DARPA Urban Challenge, the (finalist) team for 2010 Multi Autonomous Ground-Robot International Challenge (MAGIC), and OSU team lead collaborating with Team MEKAR in the 2011 Grand Cooperative Driving Challenge, The Netherlands.
- Developer of an "Autonomous Ground Vehicles" Senior/Graduate Course at OSU and an associated lab (SimVille) for class and research use, and an associated book.

COLLABORATORS AND OTHER AFFILIATIONS:

Recent Collaborators:

Research Collaborations (last 5 years): Profs. S. Tsugawa (Meijo U., Japan), A. Broggi (U. Parma, Italy), N. Tuncay, L. Guvenc (Okan U., Turkey), T. Acarman (Galatasaray U., Japan), C. Stiller (Karlsruhe Inst. Tech., Germany).

Post-doc advisee: N. Hashimoto (AIST, Japan).

Co-editors: Prof. S. Ukkusuri (Purdue), S. Tsugawa (Meijo U., Japan)

Recent Doctoral Students:(25 total doctoral students and 40 total MS thesis students)

- Rong Xu, 2007. (Foxborough Corporation)
- Yiting Liu, 2007. (Cisco Corporation)
- Yongjie Zhu, 2008 (General Motors)
- Lina Fu, 2010, (Xerox Corporation)
- Arda Kurt, 2011, (Ohio State University)
- Scott Biddlestone, 2013, (Bluefin Robotics Corporation)

Appendix i. Position Description—UTC Program Manager

Reports to:

Center Director

Function Statement:

To plan and manage a major continuing education/community service program, project or series.

Duties:

Incumbents may perform some or all of these duties or other job-related duties as required.

- Act as liaison to faculty and organizations inquiring about Center and interpret policies, procedures, and services
- Participate in establishing policies and implement them as they relate to programs. Plan and supervise the scheduling of events
- Interview, hire, train and evaluate professional and support staff
- Plan and manage the preparation of articles, proposals, reports, and educational materials for publication
- Review and update program curricula
- Participate in research activities in the evaluation and selection of seminar topics, instructional materials, and speakers
- Assist in preparing budgets and monitor expenses for programs
- Explore new areas of training needs and recommend new programs to meet these needs: plan and supervise program evaluations and studies
- Evaluate and authorize payments for materials, facilities, staff, and instructional faculty. Develop and/or select training materials
- Develop and maintain website
- Track progress metrics for the UTC
- Establish and monitor project accounts through the Office of Sponsored Programs
- Prepare monthly reports for Center Director
- Prepare quarterly federal financial reports for Center Director's review and submission to US DOT
- Prepare annual recipient share report for Center Director to review and submit
- Monitor and report on any sub-awards.

Supervision Exercised:

Functional and administrative supervision is exercised over professional and support staff.

Qualifications:

A Master's degree in an appropriate field or equivalent combination of education and experience is required. Experience in program planning and administration is required. Teaching experience is desirable.