USC PARTNERING OVERVIEW:
Connected Cars & Autonomous Driving

Prepared by
USC Stevens
Center for Innovation
Our mission is to maximize the translation of **USC research** into products for public benefit through **licensing, collaborations** and the promotion of **entrepreneurship and innovation**.

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Introduction

Innovations in connected vehicles, assisted driving, and autonomous driving have ushered the automobile industry into a new era where connected and autonomous cars revolutionize how people travel on the road and how their lives would be ever more integrated with their vehicles. USC is uniquely positioned as one of the top research institutions in the nation with comprehensive research capabilities in the following areas:

- Wireless communication
- Control systems
- Artificial intelligence
- Human-machine interface
- Autonomous wireless networks
- Intelligent cruise control
- Traffic prediction
- Intelligent navigation systems
- Big data analysis
- LiDAR image processing
- Natural language processing
- Robotics and autonomous systems
- Virtual/mixed reality
- Cybersecurity

Collectively, these capabilities are crucial components to improve the implementation of complex connected vehicle and autonomous driving technologies.

The mission at the USC Stevens Center for Innovation is to maximize the translation of USC research into products for public benefit through licensing, collaborations, and the promotion of entrepreneurship and innovation. In order to achieve maximum impact, USC will need meaningful collaborative public and private partnerships. We welcome the opportunity to share with public and private sectors the breadth and depth of USC’s unparalleled resources focused on research related to autonomous driving and explore partnering opportunities.
Collective **29 years** of experience in the private sector and **43 years** of experience working for academic/research institutions
USC Stevens: Corporate Engagement

TYPES OF ENGAGEMENT
- Involvement with researchers
- Student-oriented engagement
- Access to resources
- Involvement with centers of expertise and schools
- Economic development

TYPES OF RELATIONSHIPS
- Sponsored Research
- Licensing
- Incubator access
- New Co. creation
- Equity investment
- Flexible, multi-faceted
Connectivity

Vehicles are expected to connect wirelessly to other vehicles, mobile devices, infrastructures, and other electronic appliances in homes and offices. Vast amounts of data and information will be shared between these nodes wirelessly. As a result, to ensure sufficient speed and accuracy, new wireless data communication algorithms and schemes that offer low-latency, high accuracy, high bandwidth, and secured connections are needed. USC has research expertise in these areas of wireless communication technologies; the following highlights some of the research groups at USC tackling these new challenges for connected vehicles.

VEHICULAR NETWORKS

Autonomous Networks Research Group (ANRG)
Partly in collaboration with General Motors Research, the ANRG is investigating and developing new architectures, algorithms, and protocols to allow cars on the road to talk to each other. These include a novel hybrid information-centric architecture for vehicular networks; efficient content storage in the vehicular cloud using erasure codes; engineered epidemic propagation techniques for information dissemination and aggregation; and queue-based routing with adaptive redundancy for low-latency high-throughput data delivery.

Bhaskar Krishnamachari, Ph.D.
Director, Autonomous Networks Research Group and Professor of the Department of Electrical Engineering at the Viterbi School of Engineering

WIRELESS COMMUNICATION

Wireless Devices and Systems Group
The main emphasis of WiDES’s research is on the physical layer of wireless communications. The group also deal with overall wireless systems integration, wireless positioning and radar, and cross-layer design for wireless sensor networks. The research goal of WiDES is to develop techniques that make wireless communications either more spectrally efficient or more energy efficient.

Andreas Molisch, Ph.D.
Director, Wireless Devices and Systems Group and Professor of the Department of Electrical Engineering at the Viterbi School of Engineering
Control Systems

Adaptive cruise control and self-parking are part of the new assisted driving experiences already available to drivers. The next steps would be the gradual deployment and adoption of fully autonomous vehicles. Self-driving cars require sophisticated control and object recognition systems to drive on existing road infrastructures and to keep passengers, pedestrians, and other vehicles from getting involved in traffic accidents caused by self-driving vehicles. These control systems are not yet perfect and continuing research and development efforts are necessary to make autonomous vehicles part of mainstream transportation. USC’s research expertise in vehicle dynamics and control, coordination for robots, and object detection/recognition are part of the solution.

VEHICLE DYNAMICS AND TRAFFIC FLOW CONTROL

Center for Advanced Transportation Technology (CATT)
CATT’s main focus is on the use of advanced technologies for making current and future defense and commercial transportation infrastructure more efficient. Research areas include: vehicle dynamics and control, adaptive cruise control, traffic flow modeling and control, transportation modeling and planning, and human factors engineering for vehicle design.

Petros Ioannou, Ph.D.
Director, Center for Advanced Transportation Technologies and Professor of the Department of Electrical Engineering at the Viterbi School of Engineering

MULTI-ROBOT COORDINATION

Robotics and Autonomous Systems Center (RASC)
The Automatic Coordination of Teams Lab within the RASC conducts research in the area of coordinated multi-agent systems in 4 main areas: planning and control of multi-robot systems; automatic control synthesis; coordination of teams of robots; and end-to-end solutions for multi-robot coordination. The Robotic Embedded Systems Lab within the RASC conducts research in algorithms for the control and coordination of multi-robot systems including connectivity control, topology-constrained control, multi-robot task allocation, and distributed control.

Gaurav S. Sukhatme, Ph.D.
Director, Robotic Embedded Systems Lab and Professor of the Department of Computer Science at the Viterbi School of Engineering

Nora Ayanian, Ph.D.
Director, Automatic Coordination of Teams Lab and Assistant Professor of the Department of Computer Science at the Viterbi School of Engineering
Control Systems (Continued)

OBJECT DETECTION

Computer Graphics and Immersive Technologies Laboratory
Research and development related to processing, producing, and interacting with images. Activities in the lab range from fundamental algorithms and mathematical methods to systems and application prototypes. A research project example in this lab is the “Detection and Classification of Street Furniture in Urban Point Clouds” that focuses on detecting and classifying pole-like urban objects such as utility poles, from point clouds obtained with laser range and camera sensors. The project involves combining local feature and deep learning cluster classification.

Ulrich Neumann, Ph.D.
Professor of the Department of Computer Science at the Viterbi School of Engineering

Suya You, Ph.D.
Research Assistant Professor of the Department of Computer Science at the Viterbi School of Engineering

Electrical Engineering - Hossein Hashemi’s Group
Professor Hashemi’s research group analyzes, designs, and implements integrated circuits and systems for communications, sending, and imaging applications. An research example is the design of an optical phased-array transceiver for LiDAR.

Hossein Hashemi, Ph.D.
Associate Professor of the Department of Electrical Engineering at the Viterbi School of Engineering

Institute for Robotics and Intelligent Systems
The institute aims to build an efficient, scalable framework to provide activity inference for Wide Area Aerial Surveillance from aerial imagery. The institute is developing methods for WAAS including accurate aerial image mosaicking, video stabilization, efficient object detection and tracking, and activity inference from wide area aerial videos. The institute has also developed a persistent people tracking and face capture system that covers a wide surveillance area using a single PTZ camera.

Gérard G. Medioni, Ph.D.
Professor of the Department of Computer Science at the Viterbi School of Engineering
Human Machine Interface

The next generation of vehicles will provide drivers with a high-level user experience that fully engages them with their vehicles. Drivers would expect their vehicles to know them on a very personal level, from their in-cabin preferences to optimizing/predicting the drivers’ needs. One major component of user interface in a car is verbal communication between the driver and the car; as a result, it is very important for the driver to be able to have natural conversations with the vehicle to establish effective controls. Also, in order to accurately gauge the driver’s satisfaction level of interacting with the onboard computer, the ability to measure the drive’s stress level is crucial as facial queues from the driver can sometimes be misleading. USC’s advanced research in natural language and speech processing directly apply to HMI in cars. The following highlights our research in this space.

NATURAL LANGUAGE/SPEECH PROCESSING

Institute for Creative Technologies - Natural Language Dialogue Group
The primary goal of the ICT Natural Language Dialogue Group is to create computational models of purposeful communication between individuals. These models can be used for analyzing the structure and content of human conversation and to create artificial agents who can engage in human-like interaction with people and other agents. The group has R&D expertise in a range of enabling areas, including dialogue systems, spoken and natural language understanding, dialogue management, natural language generation, speech synthesis, and evaluation of dialogue systems.

David Traum, Ph.D.
Director, ICT Natural Language Dialogue Group

Information Sciences Institute - Natural Language Group
The NLG conducts research in natural language processing and computational linguistics, developing new linguistic and mathematical techniques to make better technology. Current projects include statistical machine translation, question answering, summarization, ontologies, information retrieval, and natural language generation.

Kevin Knight, Ph.D.
Director, ISI Natural Language Group, Professor of the Department of Computer Science at the Viterbi School of Engineering

Signal Analysis and Interpretation Laboratory
Research in the Lab spans both fundamental and applied aspects of speech processing and spoken language communication. The research is interdisciplinary: in addition to signal processing and communication theory, our work relies on knowledge from a variety of fields including AI/Computer Science, Linguistics, and Psychology. Current research directions are: speech to speech translation; emotion recognition from voice; behavioral signal processing; and media informatics and content analysis.

Shrikanth S. Narayanan, Ph.D.
Professor of the Department of Electrical Engineering at the Viterbi School of Engineering
Human Machine Interface (continued)

USER INTERFACE

Institute for Creative Technologies Mixed Reality Lab
The Mixed Reality Lab explores techniques and technologies to improve the fluency of human-computer interactions and create visceral synthetic experiences. One research area is the 2D surface computing and 3D sensing (gesture) systems.

Evan Suma Rosenberg, Ph.D.
Research Assistant Professor of the Department of Computer Science at the Viterbi School of Engineering

Mobile and Environment Media Lab at the School of Cinematic Arts
Using a variety of in-car and cloud-based computing technologies, the Mobile and Environment Media Lab is developing a suite of integrated real-time applications that monitor and analyze the activities of both driver and vehicle in order to safely and seamlessly present and archive customized storytelling, interaction, play, and social experiences across a range of devices and contexts. This interdependent “ecosystem” of analytics, interactive systems and visualization is intended to produce an evolving and ever-deepening relationship between car and driver, making the vehicle, its subsystems, and the spaces it traverses more intelligible, meaningful, and emotionally engaging.

Scott Fisher, M.S.
Associate Dean of Research and Professor and Founding Chair, Interactive Media Division of the School of Cinematic Arts, and Director of the Mobile and Environment Media Lab

Neural Systems Engineering & Information Processing Lab
The Lab develops algorithmic solutions to problems in basic and clinical neuroscience that involve the collection and manipulation of neural signals. The research work combines algorithm development and modeling with in vivo experimental implementation and testing, and is conducted in close collaboration with a variety of experimental labs. One problem of particular interest to the lab is the design of closed-loop brain-machine interface architectures.

Maryam Shanechi, Ph.D.
Associate Professor of the Department of Electrical Engineering at the Viterbi School of Engineering
Big Data

Modern vehicle transportation involves collecting and analyzing large amount of sensor and traffic data. These data enable a high degree of personalization of the vehicle to its driver and enable intelligent traffic routing to ease congestion. Researchers at USC are using real-time traffic data from infrastructures and drivers, as well as spatial crowd sourcing data to develop algorithms that route traffic intelligently in real time and algorithms that enable on-demand ride sharing as well.

TRAFFIC PREDICTION

Information Laboratory
The mission of the Information Laboratory is to investigate new approachers to the management of unconventional data types within atypical architectures. The Lab’s research in traffic prediction utilizes traffic datasets from CCTV cameras and GPS devices, and the spatiotemporal behaviors of rush hours and events to perform a more accurate prediction of both short-term and long-term average speed on road-segments, even in the presence of infrequent events (e.g., accidents). By utilizing both the topology of road network and sensor dataset, the Information Laboratory is able to overcome the sparsity of sensor dataset and extend the prediction task to the whole road network.

Cyrus Shahabi, Ph.D.
Director of the Information Laboratory and Professor of Computer Science at the Viterbi School of Engineering

INTELLIGENT TRANSPORTATION

Integrated Media Systems Center
The Integrated Media Systems Center developed a real-world data driven intelligent transportation framework that enables real-time traffic sensor data collection, analysis and visualization of dynamic transportation systems. The framework allows users to create customized spatiotemporal queries through an interactive web-based map interface.

Cyrus Shahabi, Ph.D.
Director of the Integrated Media Systems Center and Professor of Computer Science at the Viterbi School of Engineering

METRANS Transportation Center
The METRANS Center is a joint partnership of USC and California State University Long Beach. The Center aims at solving transportation problems of large metropolitan areas by studying these three areas: integrated management of freight and passenger systems; sustainable and efficient urban freight transportation; and urban mobility. Current research includes examination of relationships between land use and freight flows, development of applications for transportation system analysis using archived real-time data, and analysis of commercial and residential development around transit stations.

Genevieve Giuliano, Ph.D.
Director of METRANS Transportation Center and Professor at the Sol Price School of Public Policy
Cybersecurity

In the context of vehicle transportation, cyber security involves protecting the integrity of data that is communicated to vehicles; protecting the vehicles from unauthorized access that can result in the control system highjacks; and the personal privacy of driver generated data. USC not only has research expertise in the above-mentioned aspects of cyber security, we also house a cyber security test bed for scientific testing of cyber security systems.

COMPUTER, NETWORK, APPLICATION SECURITY

Center for Computer Systems Security
The Center conducts research in technologies supporting confidentiality, integrity, resiliency, privacy, intrusion detection and response, and survivability of critical infrastructure.

Clifford Neuman, Ph.D.
Director of the Center for Computer Systems Security and Research Associate Professor of Computer Science at the Viterbi School of Engineering

Cyber Defense Technology Experimental Research Testbed
The testbed is an experimental infrastructure network and scientifically rigorous testing frameworks and methodologies to support the development and demonstration of next-generation information security technologies for cyber defense.

Terry Benzel, M.A.
Deputy Director for the Computer Networks Division at the Information Sciences Institute
## Available Technologies for Licensing

### CONNECTIVITY

<table>
<thead>
<tr>
<th>Tech ID #</th>
<th>Technology Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>3966</td>
<td>A Novel Path-Sharing True Time Delay Transceiver Architecture for Ultra Wideband Antenna Arrays</td>
</tr>
<tr>
<td>2016-201</td>
<td>System design and algorithm for judicious pilot training in low complexity transceivers</td>
</tr>
<tr>
<td>2016-091</td>
<td>Remote localization and radio-frequency identification (RFID) using a combination of structural and antenna mode scattering responses</td>
</tr>
<tr>
<td>2016-010</td>
<td>An Algorithm to Localize an Unknown Number of Targets in Indoor Environments Exhibiting Correlated Blocking and Multipath</td>
</tr>
<tr>
<td>2015-145</td>
<td>WR-SBL: A Received Signal Strength Transformation Method to Achieve Better Indoor Radio Frequency (RF) Localization</td>
</tr>
<tr>
<td>2015-078</td>
<td>Estimation and Cancellation of Transmit to Receive Leakage in Communication Systems</td>
</tr>
<tr>
<td>2014-153</td>
<td>Performance Modeling of Next-Generation Wireless Networks</td>
</tr>
<tr>
<td>13-396</td>
<td>Scalable Synchronization for Distributed Multiuser MIMO</td>
</tr>
<tr>
<td>12-681</td>
<td>Algorithm for timing synchronization of wireless networks</td>
</tr>
<tr>
<td>12-630</td>
<td>AirSync: enabling distributed multiuser MIMO with full multiplexing gain</td>
</tr>
<tr>
<td>11-595</td>
<td>A scheme for Lossy Joint Source-Channel Coding at the Application Layer</td>
</tr>
<tr>
<td>09-006</td>
<td>Channel State Feedback by Quantization of the Time-Domain Coefficients in MIMO-OFDM Systems</td>
</tr>
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</table>

### CONTROL SYSTEMS & OBJECT DETECTION

<table>
<thead>
<tr>
<th>Tech ID #</th>
<th>Technology Title</th>
</tr>
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<tbody>
<tr>
<td>3359</td>
<td>Detection of Moving objects from a moving platform by defining a dynamic background model</td>
</tr>
<tr>
<td>2017-003</td>
<td>JeVois Open-Source Machine Vision Software and Hardware</td>
</tr>
<tr>
<td>2015-201</td>
<td>Rectification Method for Stereo Image and Apparatus Thereof</td>
</tr>
<tr>
<td>2015-197</td>
<td>Visibility-consistent Mesh Reconstruction</td>
</tr>
<tr>
<td>2015-198</td>
<td>Mesh Refinement</td>
</tr>
<tr>
<td>2014-330</td>
<td>Noise-boosted Convolutional Neural Networks for Image Processing</td>
</tr>
<tr>
<td>2014-221</td>
<td>Progressive 3D Model Acquisition with a Commodity Hand-held Camera (Improvement to 13-575)</td>
</tr>
<tr>
<td>2014-222</td>
<td>Progressive 3D Model Acquisition with a Commodity Hand-held Camera (Software)</td>
</tr>
<tr>
<td>2014-147</td>
<td>Intelligent Parking Assist</td>
</tr>
<tr>
<td>13-732</td>
<td>Integrated Driver/Vehicle Diagnostics System</td>
</tr>
<tr>
<td>13-575</td>
<td>Joint camera pose estimation and dense reconstruction on urban modeling</td>
</tr>
<tr>
<td>12-272</td>
<td>3D modeling and texture mapping software system</td>
</tr>
</tbody>
</table>
## Available Technologies for Licensing

### CONTROL SYSTEMS & OBJECT DETECTION (CONTINUED)

<table>
<thead>
<tr>
<th>Tech ID #</th>
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<tbody>
<tr>
<td>11-671</td>
<td>Context Tracker: Exploring Supporters and Distracters in Unconstrained Environments</td>
</tr>
<tr>
<td>11-282</td>
<td>High Resolution Face Sequences From A PTZ Network Camera</td>
</tr>
<tr>
<td>09-378</td>
<td>Adaptive Notch Filter for Feedback Control Systems</td>
</tr>
<tr>
<td>09-336</td>
<td>USC Hierarchical Object Tracking System</td>
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<tr>
<td>4048</td>
<td>Spatio-Temporal Multiple Target Tracking using Markov Chain Monte Carlo Data Association</td>
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<tr>
<td>4035</td>
<td>Moving object detection on a runway in infrared UAV video stream</td>
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<tr>
<td>4004</td>
<td>Human Action Recognition and Segmentation System</td>
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<tr>
<td>3969</td>
<td>Method and Apparatus for 3-D Euclidean Reconstruction and Registration of Images of Near-Planar Surfaces</td>
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<tr>
<td>3942</td>
<td>An Image-based Facial Feature Point Extraction Algorithm for Face Pose Estimation</td>
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<tr>
<td>3941</td>
<td>Integrating Multiple Visual Cues for Robust Real-Time 3D Face Tracking</td>
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<tr>
<td>3894</td>
<td>Robotic Boat Navigation and User Interface Software</td>
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<tr>
<td>3869</td>
<td>USC Human Detection and Tracking System</td>
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<tr>
<td>3863</td>
<td>Detection and Tracking of Moving Objects from a Moving Platform in Presence of Strong Parallax (extension to #3527)</td>
</tr>
<tr>
<td>3692</td>
<td>Tensor Voting in High-dimensional Spaces</td>
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<tr>
<td>3573</td>
<td>Updated Version of the Tensor Voting Software</td>
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### Available Technologies for Licensing

#### HUMAN MACHINE INTERFACE

<table>
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<tbody>
<tr>
<td>2014-331</td>
<td>Noise-boosted Hidden Markov Models for Speech Recognition and other Applications</td>
</tr>
<tr>
<td>3234</td>
<td>The use of autocalibration methods in an augmented reality tool</td>
</tr>
<tr>
<td>2015-123</td>
<td>Question Answering software (aka Jerome)</td>
</tr>
<tr>
<td>10-104</td>
<td>Speech Acquisition Software (aka AcquireSpeech)</td>
</tr>
<tr>
<td>3956</td>
<td>Question-Answering Character Editing Software</td>
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<tr>
<td>2016-080</td>
<td>Virtual Human Mobile Platform</td>
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<tr>
<td>2016-066, 067, 068</td>
<td>Interactive Natural Language System</td>
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<tr>
<td>13-491</td>
<td>Forward Looking Reward Seeking Dialogue Manager</td>
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<td>4091</td>
<td>NVBG: Nonverbal behavior generator</td>
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<tr>
<td>09-252</td>
<td>Watson real-time head tracking and gesture recognition library</td>
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<tr>
<td>2015-283</td>
<td>SmartVoice</td>
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<tr>
<td>2015-143</td>
<td>SAWDUST a Semi-Automated Wizard Dialogue Utterance Selection Tool for domain-independent large-domain dialogue</td>
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#### BIG DATA

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<tr>
<td>2016-018</td>
<td>Noise-enhanced Markov Chain Monte Carlo Estimation and Simulated Annealing</td>
</tr>
<tr>
<td>2014-329</td>
<td>Noise-boosted backpropagation and deep learning in neural networks</td>
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<tr>
<td>2014-137</td>
<td>Noise-enhanced clustering and competitive learning algorithms</td>
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<td>13-038</td>
<td>Noise-enhanced Expectation-Maximization Algorithm</td>
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#### CYBERSECURITY

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<th>Tech ID#</th>
<th>Technology Title</th>
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<tbody>
<tr>
<td>2015-070</td>
<td>CASPER for ArcGIS: Intelligent capacity-aware evacuation routing</td>
</tr>
<tr>
<td>09-464</td>
<td>OPCGuard: Process Control Server security configuration and monitoring</td>
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<tr>
<td>12-708</td>
<td>Backpressure with Adaptive Redundancy (BWAR)</td>
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