FINAL REPORT

to

THE FLORIDA DEPARTMENT OF TRANSPORTATION
SYSTEMS PLANNING OFFICE

On Project

# "University of Florida Advanced Technologies Campus Testbed"

FDOT Contract BDV31 977-74

UF | University of Florida Transportation Institute

September 30, 2017

Submitted by

The University of Florida

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# METRIC CONVERSION CHART

## U.S. UNITS TO METRIC (SI) UNITS

### LENGTH

| SYMBOL | WHEN YOU KNOW | MULTIPLY BY | TO FIND | SYMBOL |
|---|---|---|---|---|
| in | inches | 25.4 | millimeters | mm |
| ft. | feet | 0.305 | meters | m |
| yd. | yards | 0.914 | meters | m |
| mi | miles | 1.61 | kilometers | km |

## METRIC (SI) UNITS TO U.S. UNITS

### LENGTH

| SYMBOL | WHEN YOU KNOW | MULTIPLY BY | TO FIND | SYMBOL |
|---|---|---|---|---|
| mm | millimeters | 0.039 | inches | in |
| m | meters | 3.28 | feet | ft. |
| m | meters | 1.09 | yards | yd. |
| km | kilometers | 0.621 | miles | mi |

**Technical Report Documentation Page**

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16. Abstract

The University of Florida (UF) and its Transportation Institute (UFTI), the Florida Department of Transportation (FDOT) and the City of Gainesville (CoG) are cooperating to develop a smart transportation testbed on the University of Florida (UF) main campus and adjoining city streets. As part of this effort, the research team reviewed the state-of-the-art for existing pilots and testbeds, and based on these developed priorities for the Gainesville-based testbed. This report first describes international, national, statewide and local deployment efforts related to connected vehicles (CV) and autonomous vehicles (AV), and other advanced transportation technologies. It also examines the development of these testbeds in time, and common elements found in many testbeds. A series of meetings, including the peer exchange meeting in Tallahassee, were held to refine the novel ideas and form an effective roadmap for the testbed project. The findings of the literature review and the input from the meetings and peer exchange were used to formulate a roadmap for the testbed.

The report provides the initial vision and components related to the testbed deployment and operation, including an overview of planned infrastructure and data management procedures for the testbed. It also summarizes the proposed management procedures for the testbed along with a marketing and communications plan. A list of projects is presented outlining current, planned, and potential projects.

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# EXECUTIVE SUMMARY

The University of Florida (UF) and its Transportation Institute (UFTI), the Florida Department of Transportation (FDOT) and the City of Gainesville (CoG) are cooperating to develop a smart transportation testbed on the University of Florida (UF) main campus and adjoining city streets. As part of this effort, the research team reviewed the state-of-the-art for existing pilots and testbeds, and based on these developed priorities for the Gainesville-based testbed. This report first describes international, national, statewide and local deployment efforts related to connected vehicles (CV) and autonomous vehicles (AV), and other advanced transportation technologies. It also examines the development of these testbeds in time, and common elements found in many testbeds. A series of meetings, including the peer exchange meeting in Tallahassee, were held to refine the novel ideas and form an effective roadmap for the testbed project. The findings of the literature review and the input from the meetings and peer exchange were used to formulate a roadmap for the testbed.

The literature review indicates that in the US, connected and autonomous vehicles (CAVs) deployments range from federal level programs to public-private-academia level collaborations. Activities range from small-scale temporary pilots to national level substantial investments. We classified these activities into 5 categories: (1) Connected Vehicle Pilot Deployment Program (CVPDP), (2) Connected Vehicle Testbed, (3) USDOT Automated-Vehicle Proving Grounds, (4) Smart-City Challenge (SCC) and (5) University driven efforts. Except for the fourth category, all others are under-development. Florida has been one of the most active states in promoting CAV implementation. A total of 6 cities from Florida submitted proposals for the SCC. Florida was the second state after Nevada to pass a bill allowing the operation of AVs on its highways. There are multiple pilot deployments and activities around the state. Although there are many similarities in the projects across the countries in terms of applications, and also most projects target safety, mobility and environmental objectives, we observed significant differences in the nature of the projects from one country and continent to another.

The next part of the report briefly documents FDOT's peer exchange held on April 25–27, 2017, along with a summary of the discussions. The theme of this peer exchange was to discuss state DOT research roadmaps in the contexts of national agenda/activity and emerging technologies, and to explore how a program can work to be aware, agile, and relevant in this environment.

The last part of the report provides the initial vision and components related to the testbed deployment and operation, including an overview of planned infrastructure and data management procedures for the testbed. It also summarizes the proposed management procedures for the testbed along with a marketing and communications plan. A list of projects is presented outlining current, planned, and potential projects.

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# LIST OF ACRONYMS

| | |
|---|---|
| AACVTE | The Ann Arbor Connected Vehicle Test Environment |
| ACM | American Center for Mobility |
| ACTIVE | Alberta Cooperative Transportation Infrastructure and Vehicular Environment |
| ADAS | Assessing Advanced Driver Assistance Systems |
| ARTC | Automotive Research and Testing Center |
| ASD | After-Market Safety Device |
| AURORA | AUtomotive test bed for Reconfigurable and Optimized Radio Access |
| AV | Automated Vehicle |
| AVL | Automatic Vehicle Location |
| BlueTOAD | Bluetooth Travel-Time Origination and Destination |
| BSM | Basic Safety Message |
| C2X | Car to X |
| CAV | Connected and Autonomous Vehicles |
| CCSA | China Communications Standards Association |
| CCTV | Closed-Circuit Television |
| CETRAN | Centre of Excellence Testing and Research of Autonomous Vehicles |
| CICAS | Cooperative Intersection Collision Avoidance Systems |
| C-ITS | Cooperative Connected and Automated Mobility ITS |
| COG | City of Gainesville |
| ConOpt | Concept of Operation |
| Coop TS | Cooperative Test Site |
| CPT | Cable Propelled Transit |
| CTR | Center for Transportation Research |
| CV | Connected Vehicle |
| CVII | Commercial Vehicle Infrastructure Integration |
| CVPDP | Connected Vehicle Pilot Deployment Program |
| DGPS | Differential Global Positioning System |
| DITCM | Dutch Integrated Testsite Cooperative Mobility |
| DSRC | Dedicated Short Range Communication |
| EMC | Electro-Magnetic Compatibility Lab |
| EU | European Union |
| EV | Electric Vehicles |
| FAV | Florida Automated Vehicles |
| FDOT | Florida Department of Transportation |
| FHWA | Federal Highway Administration's |
| FMVSS | Federal Motor Vehicle Safety Standards |
| FTE | Florida Turnpike Enterprise |
| GPRS | General Packet Radio Service |
| HART | Hillsborough Area Regional Transit |

| | |
|---|---|
| HAV | Highly Autonomous Vehicles |
| HOT | High-Occupancy Toll |
| ITS | Intelligent Traffic Systems |
| ITS JPO | Intelligent Transportation Systems Joint Program Office |
| LAN | Local Area Network |
| LTA | Land Transport Authority |
| LTE | Long-Term Evolution |
| MLFF | Multi-Lane Free Flow |
| MORPC | Mid-Ohio Regional Planning Commission |
| NHTSA | National Highway Traffic Safety Administration |
| OBE | Onboard Equipment |
| OBU | Onboard Unit |
| ODYSA | Optimization of Traffic Flow Through Dynamic and Individual Speed Advice |
| ORT | Open Road Tolling |
| PVD | Probe Vehicle Data |
| R&D | Research and Development |
| REL | Reversible Express Lanes |
| RSE | Roadside Equipment |
| RSU | Roadside Unit |
| RTS | Regional Transit System |
| SAFER | Vehicle and Traffic Safety Center |
| SAVI | Singapore Autonomous Vehicle Initiative |
| SCC | Smart City Challenge |
| SCMS | Security Credential Management System |
| SCORE@F | System Coopératif Routier Expérimental Français |
| SIM | Safe and Intelligent Mobility |
| SISCOGA | SIStemas COoperativos Galicia |
| SMOOTH | Smart Mobile Operation: OSU Transportation Hub |
| SPaT | Signal Phase and Timing |
| SPMD | Safety Pilot Model Deployment |
| SR | State Road |
| SSA | Stop Sign Assist |
| SwRI | Southwest Research Institute |
| TEN-T | Trans-European Transport Network |
| TFHRC | Turner-Fairbank Highway Research Center |
| THEA | Tampa-Hillsborough Expressway Authority |
| TRB | Transportation Research Board |
| TTI | Texas A&M Transportation Institute |
| UF | University of Florida |
| UFTI | University of Florida Transportation Institute |
| UMTRI | University of Michigan Transportation Research Institute |

| | |
|---|---|
| UMTS | Universal Mobile Telecommunication System |
| UNECE | United Nations Economic Commission for Europe |
| V2I | Vehicle to Infrastructure |
| V2V | Vehicle to Vehicle |
| V2X | Vehicle to X |
| VAD | Vehicle Awareness Device |
| VCC | Virginia Connected Corridor |
| VII | Vehicle Infrastructure Integration |
| VMS | Video management system |

## 1. Introduction

It is likely that in the not-too-distant future, vehicles with various levels of autonomy and connectivity will operate in large numbers on our nation's highways alongside conventional vehicles. According to the Rand Corporation (http://www.rand.org/pubs/research_reports/RR443-2.html), the automotive industry will likely change substantively, with significant benefits to social welfare. The Transportation Research Board (TRB) Special Report 319 (2016) indicates that information and communication technologies provide an unprecedented number of transportation services including ridesharing (such as Uber, Lyft, bikesharing, and microtransit.) Therefore, there is a strong need to accomplish the following:

a) Examine the impact of various technologies (autonomous/automated vehicles – AVs - and connected vehicles - CVs, smart phones, sensors, autonomous transit etc.) on transportation operations and safety across multiple modes

b) Develop novel strategies and tools (including hardware and software) that use these advanced technologies to improve the highway network

c) Develop new tools for collecting, analyzing, and disseminating various types of data and data analytics

d) Attract industry to evaluate and refine these new strategies and tools so that they can be used broadly across Florida and nationwide

e) Bridge the gap between research and implementation and system-approach research and implementations

f) Evaluate new technologies from a systems-perspective, considering several modes.

The University of Florida (UF) and its Transportation Institute (UFTI), the Florida Department of Transportation (FDOT) and the City of Gainesville (CoG) are cooperating to develop a smart transportation testbed on the University of Florida (UF) main campus and adjoining city streets. As part of this effort, the research team reviewed the state-of-the-art for existing pilots and testbeds, and based on these developed priorities for the Gainesville-based testbed. This report first describes international, national, statewide and local deployment efforts related to connected vehicles (CV) and autonomous vehicles (AV), and other advanced transportation technologies. It also examines the development of these testbeds in time, and common elements found in many testbeds. A series of meetings, including the peer exchange meeting in Tallahassee, were held to refine the novel ideas and form an effective roadmap for the testbed project. The findings of the literature review and the input from the meetings and peer exchange were used to formulate a roadmap for the testbed.

The objectives of this project were to a) conduct a thorough literature review to document similar efforts elsewhere and to outline the state-of-the-art and state-of-the-practice with respect to advanced technologies in transportation; b) engage with industry to have a better understanding of planned efforts in technology development (to the degree industry will be willing to share such information); c) assist FDOT with a peer exchange whose focus is to explore effective transportation research road mapping within the contexts of other state and national research programs and emerging technologies; and d) develop a roadmap along with specific projects to implement and operate the testbed.

This report summarizes the work conducted to achieve these objectives. The next chapter summarizes the literature review, while the third chapter provides an overview of the peer exchange. The fourth chapter discusses the roadmap for the testbed, along with an initial set of recommended projects based on our findings.

## 2. Literature and State-of-the-Art-Review

In the past few years, the research and deployment of transportation emerging technologies have proliferated quite rapidly. This rapid growth is not solely in the United States; in fact, many nations around the world have initiated implementation and research on these technologies. Industry has also been developing various applications and products to expedite real-world connected and automated transportation operations. Several agencies (NHTSA, NCHRP, AASHTO, FHWA, state DOTs, etc.) have published roadmaps, guidelines and vision statements on vehicle connectivity, automation and deployments of emerging technologies [1-3].

Previous research has addressed the costs and benefits of connected and automated vehicles (CAVs). Researchers have focused on topics such as minimizing delay at intersections, and enhancing safety by minimizing human error [4]. Despite the vast research, national and international programs and numerous Concept of Operations (ConOps) and vision proposals, comprehensive deployment remains rare. However, there are numerous efforts around the globe to implement various types of applications related to CVs and AVs. Each of these efforts has a different focus with widely varying applications.

The objective of this chapter is to summarize the literature and on-going work on advanced transportation technologies, review the operations of testbeds across the US and internationally, examine the industry state-of-the-art, and review federal policy and regulations related to AVs and CVs. The findings from this work are used in the development of a testbed in Gainesville, Florida, to develop priorities and specific projects to advance the state of the art in CV and AV implementation.

A total of over 400 international activities and testbeds were identified and studied. In the past few years, several initiatives have been undertaken at the federal level to facilitate CAV deployments, including the USDOT Smart City Challenge (SCC), the Connected Vehicle Pilot Deployment Program (CVPDP) and the USDOT Automated Vehicle Proving Grounds. Also, many public-private partnerships have been formed to develop transportation advanced technologies and testbeds. In the literature review, we direct our focus on the ConOps, vision proposals, technical memorandums and lessons learned from these efforts globally, while we also review some of the most important research articles on CAVs.

To complete our review, we conducted electronic searches for information throughout the world. Due to the different policy and regulation, environments and goals of CAV activities in the US, we focus primarily on national efforts. There are hundreds of CAV initiatives globally. Therefore, we direct our attention to those activities which satisfy at least one of the following conditions: (1) it is funded, (2) it is deployed/are in the process of deployment, (3) it is relatively large in scope and extended in duration, (4) it is the result of a national program, coalition or partnership, (5) it encompasses a variety of technologies, environments and entities. The detailed literature review is provided in Appendix A. A summary of the literature review findings follows.

Over 30 countries have been exploring CAV technologies. Some of the European and Japanese deployments and pilot projects have proven the capability of CAV in improving transportation systems. Activities in Europe typically involve large-scale coalitions of governments, as well as academia and industry. Japan has already deployed a CV network using cellular, infrared, and DSRC communication.

In the US, CAV deployments range from federal level programs to public-private-academia level collaborations. Activities range from small-scale temporary pilots to national level substantial investments. We classified these activities into 5 categories: (1) Connected Vehicle Pilot Deployment Program (CVPDP), (2) Connected Vehicle Testbed, (3) USDOT Automated-Vehicle Proving Grounds, (4) Smart-City Challenge (SCC) and (5) University driven effort. Except for the fourth category, all others are under-development.

Florida has been one of the most active states in promoting CAV implementation. A total of 6 cities from Florida submitted proposals for the SCC. Florida was the second state after Nevada to pass a bill allowing the operation of AVs on its highways. There are multiple pilot deployments and activities around the state. One of the earliest CV initiatives in the state was launched in 2011 for the ITS congress as a Connected Vehicle Testbed along I-4 in Orlando. The Tampa-Hillsborough Expressway Authority (THEA) Pilot deploys a variety of V2V and V2I apps, as well as AV transit in order to mitigate congestion, collisions, and wrong way entry. FDOT's Florida Turnpike Enterprise (FTE) is committed to construct a new transportation technology testing facility, SunTrax, as part of the USDOT AV Proving Grounds program along with developments in multiple other sites in the central Florida area.

Although there are many similarities in the projects across the countries in terms of applications, and also most projects target safety, mobility and environmental objectives, we observed significant differences in the nature of the projects from one country and continent to another.

## 3. Research Peer Exchange

23 CFR Part 420, Subpart B, contains four provisions that each state must meet to be eligible for Federal Highway Administration (FHWA) planning and research funds for its research, development, and technology transfer (RD&T) activities. One requirement is to conduct peer exchanges that consider improvements in the state's RD&T management process or some aspect of the research program and to be willing to participate in peer exchanges held by other states' programs. This report briefly documents FDOT's peer exchange held on April 25–27, 2017, in partial fulfillment of these requirements.

The theme of this peer exchange was to discuss state DOT research roadmaps in the contexts of national agenda/activity and emerging technologies, and to explore how a program can work to be aware, agile, and relevant in this environment. Three panel sessions were held on day one, focusing on national activity, university and industry activity, and state DOT activity, respectively. The afternoon working session focused on the concept of a transportation research roadmap. The goal of the first half of day two was to workshop and synthesize the ideas generated from a presentation on the FDOT ROADS (Reliable Open Accurate Data Sharing) initiative and its implications for research data needs and data creation. The afternoon of day two was devoted to emerging technologies, typified by, but not limited to, automated and connected vehicle issues, and, in the context of the previous sessions, with the goal of developing recommendations for program improvement.

By the end of the third panel, twenty two main ideas were evolved to benefit the testbed roadmap. The panel suggested distinguishing between thematic goals which have direction and measurable purpose: safety, mobility, tech transfer, information, equity, sustainability, economic development. Ideas on collaboration including semiannual meetings with a group of 20-30 to revisit transformational technologies issues was also proposed. A fair amount of time was also dedicated to discuss how big data is a complementing and vital component of the roadmap. Further information is available on the FDOT Research Center Webpage at: http://www.fdot.gov/research. Additional information on the peer exchange is also provided in Appendix B.

## 4. Testbed Roadmap

The roadmap for deployment and evaluation of advanced transportation technologies at the UF testbed was developed to provide guidance to ensure the safe implementation and operation of the testbed, put procedures in place for interacting with industry, and disseminate the testbed capabilities and research findings to the transportation community. The plan also provides a process that allows for continuous evaluation of previous research and development of new research projects.

Information regarding other testbed operations has been used to identify the best strategies to implement and coordinate the operation and testing of different projects and assessments. A list of projects with preliminary descriptions has been created, which can be used as a starting point for initiating research and proceeding with the development, implementation, and testing of selected advanced technologies.

This section first provides the initial vision and components related to the testbed deployment and operation, including an overview of planned infrastructure and data management procedures for the testbed. Next, the proposed management procedures for the testbed are presented, followed by the marketing and communication plan. Finally, a list of projects is presented outlining current, planned, and potential projects.

### a. Testbed vision and components

It is envisioned that the testbed will transform the transportation network on campus to support cross-communication between personal and mass transit vehicles, pedestrians, and traffic signalization along critical routes. With the support of FDOT, the CoG, RTS, and participating industry partners, autonomous/connected vehicles and other advanced communication and data analysis technologies will be introduced to optimize traffic operations and increase safety within the campus and surrounding areas. We will seek to form multiple high-profile industrial partnerships with companies such as IBM and Tesla to deploy technologies in our 'living laboratory.' It is envisioned that the testbed will facilitate the development of new products and control strategies, which can ultimately be deployed elsewhere in Florida and nationally.

### i. Existing and Currently Planned Infrastructure Overview

The advanced technology testbed is located on the University of Florida main campus and surrounding roadway network. All traffic signals are maintained by the City of Gainesville. The current scope of infrastructure technology enhancements consists of several planned projects: I-75 FRAME, Accelerated Innovation Development (AID), Gainesville Autonomous Transit Shuttle (GAToRS), and Gainesville SPaT Trapezium. The area covered by these projects is shown in Figure 1.

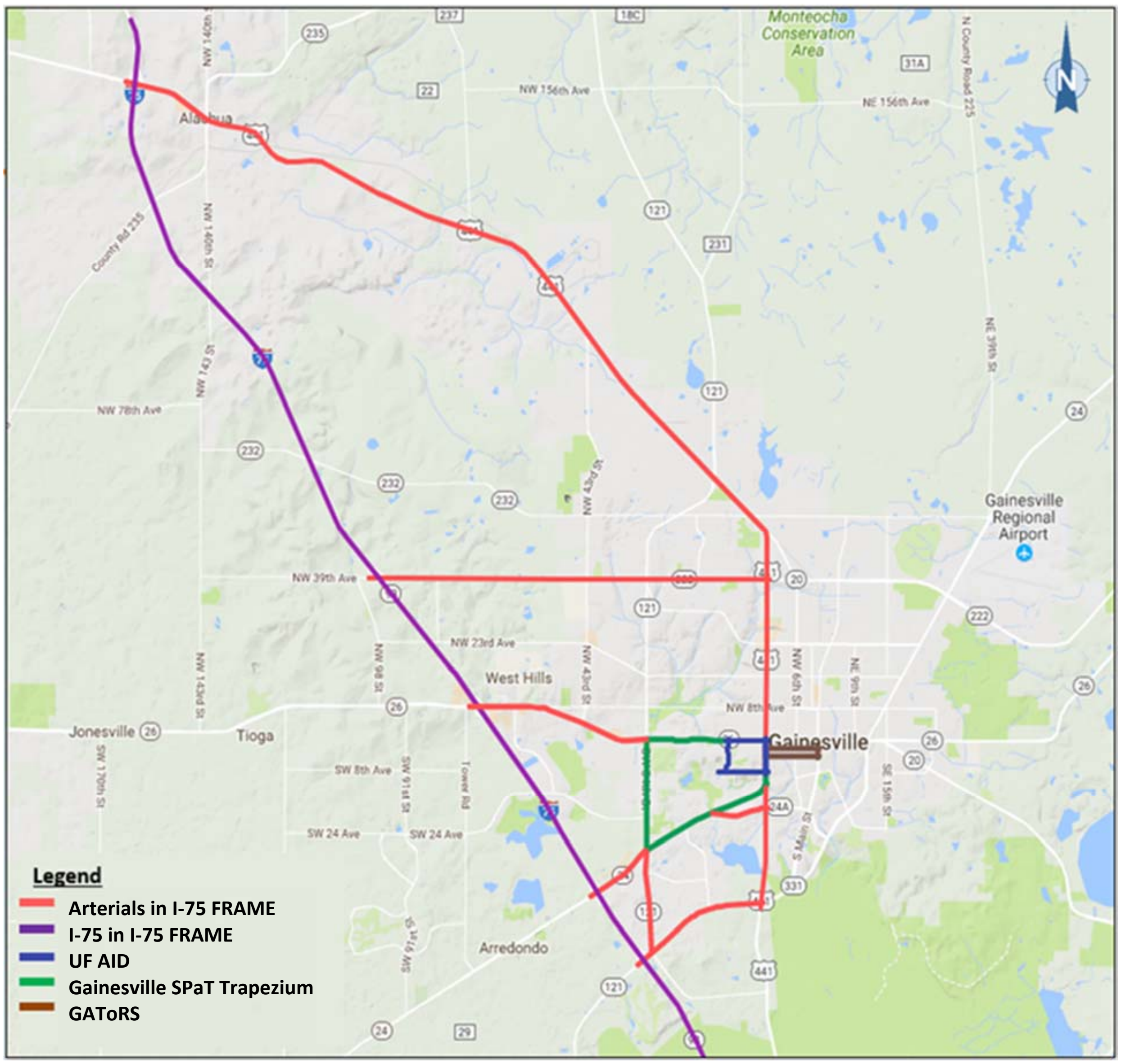


**Figure 1 Testbed Corridors**

The core infrastructure improvements are within the CoG limits, however some components of the I-75 FRAME project extend outside its limits. The following technology deployments are planned through these projects:

- **I-75 Florida's Regional Advanced Mobility Elements (FRAME)**

The I-75 FRAME will deploy Roadside Units (RSUs) every two miles along I-75 in Alachua County at existing Closed-circuit television (CCTV) locations. RSUs will also be installed every two miles along a 50-mile rural segment of US 301/US 441 at proposed CCTV locations. The RSUs will also be installed at signal locations with Multi-Modal Intelligent Traffic Safety Systems (MMITSS). In total, approximately 150 RSUs are planned for installation in order to reduce crashes on I-75 and the corresponding impact of diverted traffic on the arterial roadways. The RSUs will send and receive messages to and from connected vehicles, transit, freight, and emergency vehicles, and other RSUs using the 5.9 GHz Dedicated Short Range Communication (DSRC). Additionally, the I-75 FRAME will deploy 50 miles of fiber optic cables along the US 301/US 441. There is existing communication infrastructure installed along all other I-75 FRAME routes. Wireless communications will be explored on some rural segments as a cost- effective solution.

- **UF Accelerated Innovation Deployment (AID) Demonstration project**

The planned AID infrastructure is shown in Figure 2. The project corridors include thirteen (13) signalized intersections and seven (7) mid-block crossings without signals (some with single post flashing beacons). The signals will broadcast Signal Phase and Timing (SPaT) messages while the mid-block crossings will be equipped with passive pedestrian detection. These intersections will have the ability to receive information from DSRC equipped vehicles. This base infrastructure investment will provide the opportunity to research and develop Vehicle to Infrastructure (V2I) based applications for intersection control, safety applications, performance measurement, and other traffic management initiatives. A total of 20 RSUs and passive pedestrian detection are anticipated to be deployed.

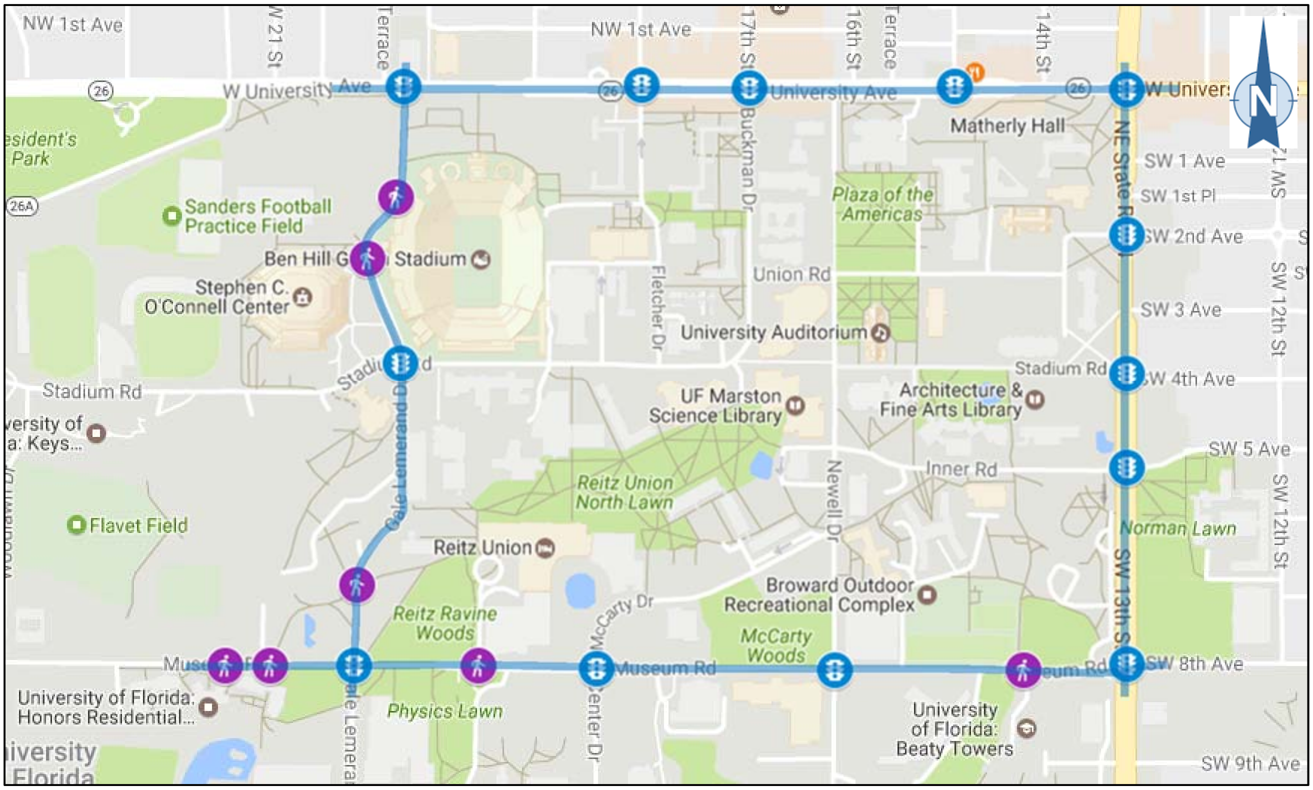


**Figure 2 AID Project Area**

Legend: Traffic Signals Mid-Block Crossing (no signal) Project Corridors

- **Gainesville Trapezium**

Planned infrastructure improvements related to the Gainesville Trapezium project are shown in Figure 3. Approximately 45 Roadside Units are installed along four corridors forming a trapezium surrounding the UF main campus, including 27 signalized intersections broadcasting SPaT information through DSRC.

- **Gainesville Autonomous Transit Shuttle (GAToRS)**

The GAToRS autonomous shuttle project will deploy service between the Gainesville downtown area and the University of Florida main campus. It is anticipated the vehicle will use V2I DSRC capability between shuttles and traffic signals and the potential for other Vehicle to Vehicle (V2V) applications as they become available.

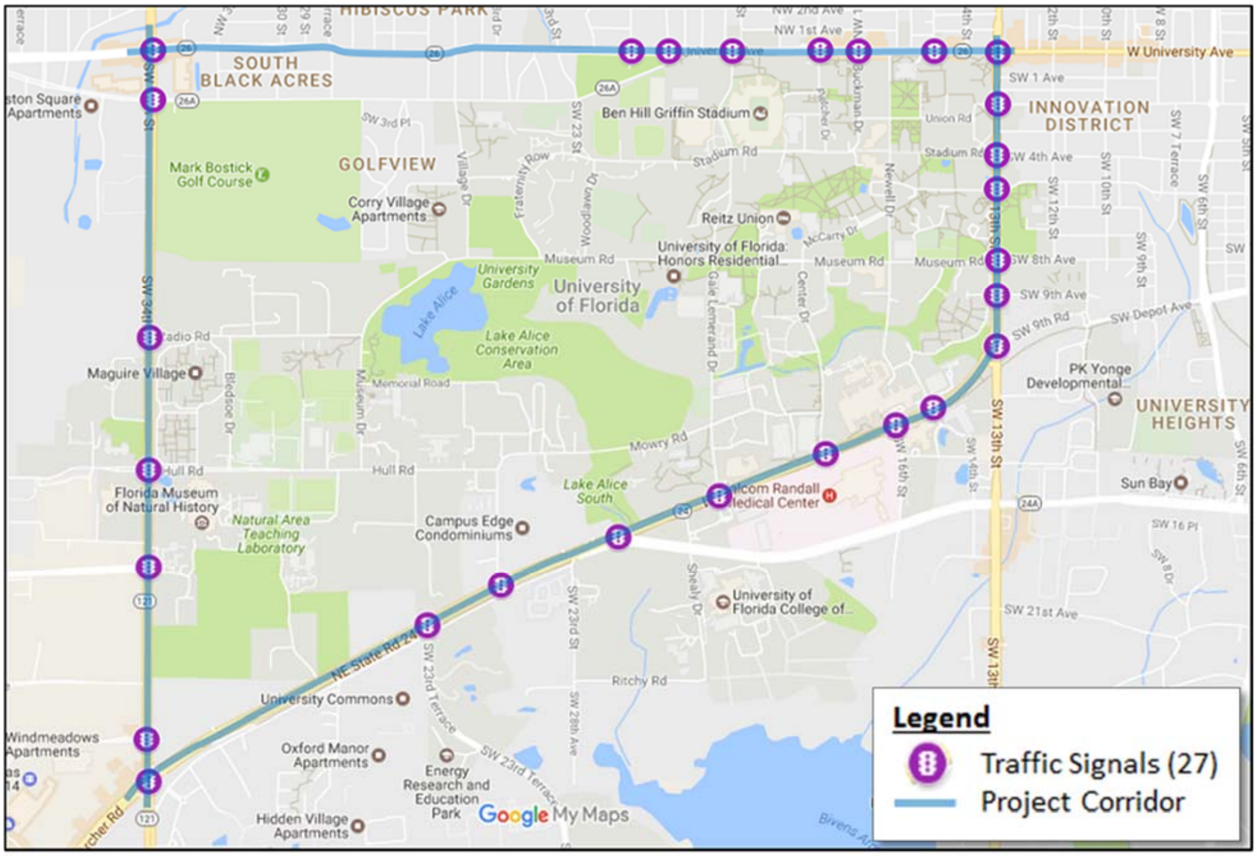


**Figure 3 Gainesville SPaT Trapezium Planned Infrastructure**

In the near future, the installation of radar and video cameras on signal heads will allow for better tracking and processing of unequipped vehicles, bikes, scooters and pedestrians. This technology will provide opportunities for applications and control strategies to improve operations and safety.

As projects progress it is anticipated that additional technologies will become permanent fixtures of the testbed including LIDAR, WIFI equipped cabinets, and other emerging sensor technology. In addition, based on industry and testbed needs, additional corridors in the vicinity of Gainesville may be used for deployment of smart infrastructure and sensors.

The research team has proposed the use of the acronym I-STREET (Implementing Solutions from Transportation Research and Evaluation of Emerging Technologies) to represent the testbed.

### ii. Data Management Support

An important aspect of the testbed is the handling of the tremendous amount of data that will be produced from sensors, vehicles, and communication technology. It is envisioned that this data will be uploaded to the cloud and made available for research, traffic management, and performance measurement. A data management strategy has been developed, and an FDOT-funded project currently underway (led by Dr. Sanjay Ranka, Professor in Computer Science) will complete the following tasks:

1. Identify all the potential sources of data and sensors that will be used and quantify the volume of data that is expected from each source. This includes collecting existing data from CoG, FDOT, and UF, that may be included in the data warehouse.
2. Build the hardware/software infrastructure for data analytics.
3. Design data warehouse architecture for local servers and clouds.
4. Develop applications to provide a data exploration and visualization framework. This includes guidance on how to access the data, and a list of data included in the database.

## b. Proposed Management Procedures for the Testbed

This section outlines procedures recommended to ensure the safe and efficient operation of the testbed and its components. The following processes are recommended:

### i. Testbed Manager

The testbed manager is responsible for the entire testbed operation, and will work closely with FDOT, CoG, RTS, the UF Police Department (UFPD), and industry partners. The testbed manager, in collaboration with the entities listed above, will maintain the testbed's safety management plan. The responsibilities of the testbed manager are as follows:

- Coordinate all testbed operations with FDOT, CoG, RTS, and the UFPD. A steering committee with representatives from each of these entities will meet quarterly to evaluate ongoing and upcoming test activities. Each entity interested in conducting a test will submit suitable documentation to the testbed manager and the steering committee for review and approval. Results of the tests will also be submitted to the steering committee along with any safety concerns and incidents. Any safety concerns will be reported, and testing that is deemed unsafe will immediately stop.

- Participate in the US DOT's Community of Practice if invited, and communicate testbed developments to the broader community.
- Coordinate testing and instrumentation with industry and academia partners who are interested in deploying advanced technologies at the UF/Gainesville testbed.
- Ensure that testbed operations adhere to all federal, state and local laws and regulations.
- Disseminate test results to the transportation community, and also coordinate with other researchers, to ensure a broad distribution of data and findings from our work.
- Work with the broader community to scale up deployment of autonomous vehicles.
- Stay engaged with the broader transportation community to ensure findings from other testbeds are taken into consideration in our work.

The testbed manager will report directly to the UFTI Director. Dr. Clark Letter serves as testbed manager.

### ii. Safety Management Plan

A safety management plan has been developed and will be provided on the testbed website. The safety management plan provides guidance and procedures to account for various safety-related issues that may occur during testbed usage. These issues are related to specific scenarios related to applications and technologies planned or deployed at the testbed. Safety scenarios are classified at both the system and application level.

The level of risk for each scenario is assessed based on the ISO 26262 ASIL risk assessment approach. A safety operational concept is developed for each scenario identified as high or medium risk. This includes specific actions to be taken with the deployment to reduce the likelihood and potential impacts of each test scenario. All applications and technologies are required to implement a fail-safe mode and an associated stakeholder response in the event of any safety-related events. This response is to ensure the safety of lives and equipment during any unforeseen failures. For high and medium risk applications a backup plan will be in place to account for system failure associated with testing. Unless otherwise stated in the backup plan, the deployment will return to the state it was before a particular application or technology was deployed. In the event of a severe accident, weather, or planed event, the testbed will follow the Emergency Transportation Operations plan developed by the State of Florida, and the City of Gainesville.

The testing of any technology related to facilities at the testbed must be communicated to the testbed manager at least 7 days prior to testing. This will allow sufficient time to notify individuals at the CoG, UF, and FDOT. This also ensures no conflicts with facility scheduling for testing. All testing must comply with the safety management plan.

### c. Industry Involvement

The testbed provides an opportunity for industry to engage in research, as well as a venue to demonstrate technology ready for deployment. To this end, a request for information (RFI) has been developed (Appendix C) seeking to identify interested industry partners. The RFI has been distributed widely and posted on the I-STREET website. The website also provides sample agreements that can be signed between the university and industry partners, depending on the type of partnership formed.

### d. Marketing and Communications

As a part of the testbed operation, the UFTI marketing and communications coordinator (currently Ms. Elaine Khoo) will work with the testbed partners for the production of press releases related to testbed operations and research findings. Ms. Khoo will coordinate with her counterparts at FDOT, CoG, and UF. Information regarding current and completed projects will also be communicated through the testbed website. Additionally, the testbed operations and opportunities for collaboration will be publicized through presentations and involvement in conferences related to advanced transportation technology. Researchers will publish and present their work as a way to promote testbed activity.

The website (Figure 4) includes the status of current and planned projects, along with information for potential industry partners. Additionally, a brochure has been developed to help attract attention to the testbed activities.


**Figure 4 I-STREET Banner**

### e. Current and Proposed Projects

A schedule of currently proposed and planned projects is provided in Figure 5. As indicated earlier, the continuous evaluation process planned will be reviewing the list of projects and their scope on a regular basis, and will adjust them accordingly, as needs change and as research findings are offered from this testbed and elsewhere.

This schedule includes a timeline for completion of each project, as well as a projected budget, if available. Additionally, Table 1 provides short descriptions of each of the current projects (contract in place), Table 2 summarizes the draft scope of work for planned projects, and Table 3 lists potential projects to be considered.

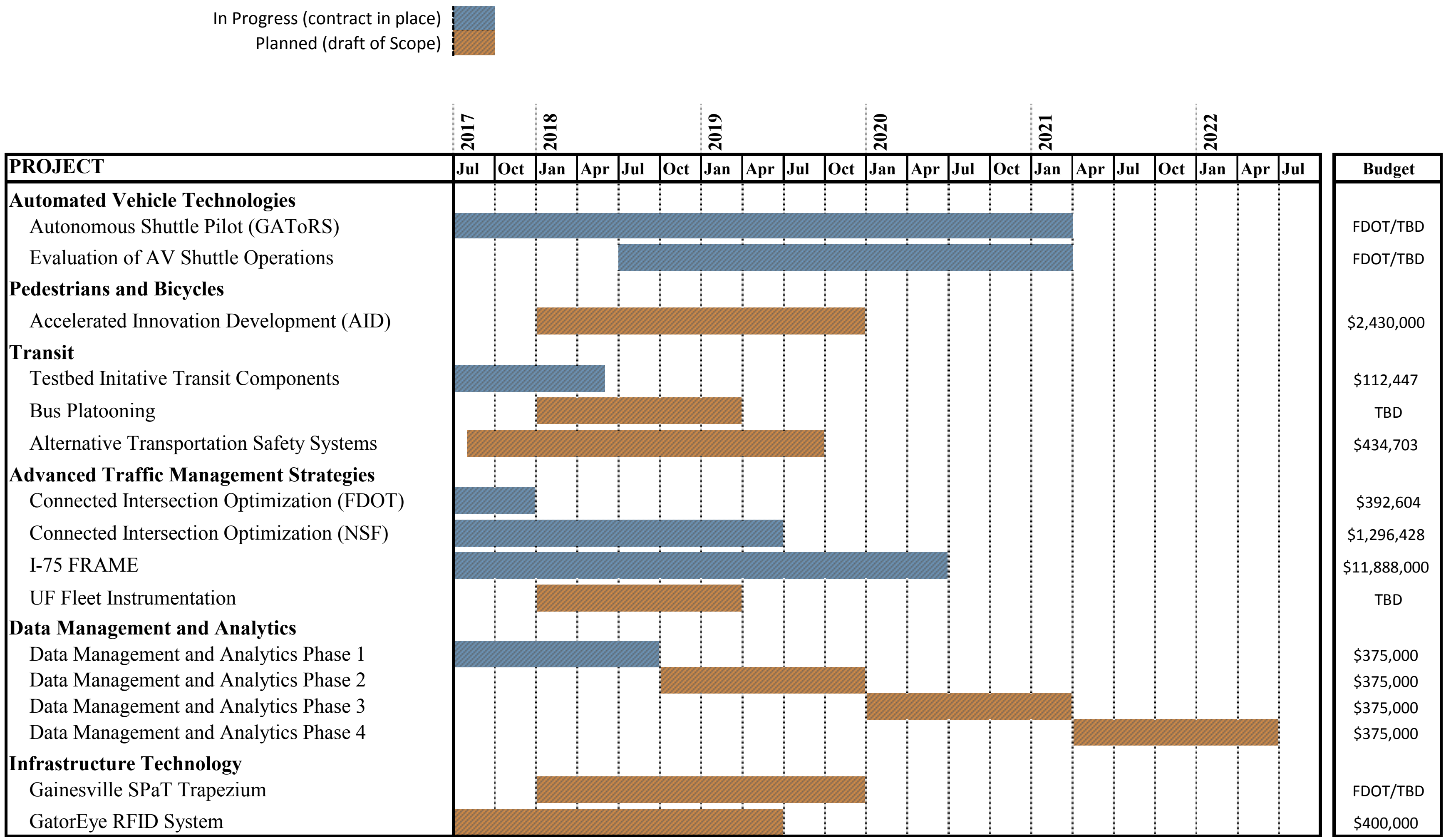


**Figure 5 Schedule of Current and Planned Projects**

**Table 1 Current Projects (Contract in Place)**

| **Project Title** | **Description/Objective** |
|---|---|
| Autonomous Shuttle Pilot (GATORS) | The introduction of an autonomous shuttle system will improve connectivity between the UF campus and downtown Gainesville. It is envisioned that real time information will be obtained from the shuttle operations, which will further help improve autonomy logic and transportation planning |
| Evaluation of AV Shuttle Operations | Data and performance of the autonomous shuttle will be evaluated. Results of the evaluation will help improve autonomy logic and transportation planning. |
| I-75 FRAME | I-75 FRAME seeks to optimize the use of transportation infrastructure for improved safety and mobility. Through the project road condition information will be disseminated through the Florida 511 smartphone app and website. Advanced transportation management technologies will be deployed such as Adaptive Signal Control Technology (ASCT); Multimodal Intelligent Traffic Signal System (MMITSS) with Intelligent Signal (I-SIG) to emit Signal Phasing and Timing (SPaT) data, Pedestrian Signal (PED-SIG) safety technology, Transit Signal Priority (TSP), Freight Signal Priority (FSP) and Emergency Vehicle Preemption (PREEMPT) on select corridors. New arterial technologies are used to improve operations, monitor traffic and infrastructure and add data-driven signal performance measures on select corridors. Connected vehicle OBU's will be used for transit buses to increase travel time reliability and on-time performance. Advanced safety systems will be deployed through V2I and mobile app technology. Transportation system performance data will be collected, analyzed and disseminated. |
| Testbed Initiative Transit Components | Develop sensor technology that can detect bicycle usage per rack position. This will increase use of ITS technology in transit, improve transit and bicycle mode attractiveness, and maximize cost effectiveness of infrastructure investments by better understanding travel patterns of bicycle users. |
| Connected Intersection Optimization (FDOT) | Over the past several years the UFTI has been developing algorithms for optimizing traffic operations with autonomous vehicles in the traffic stream. The main objective of this project is to refine an existing optimization algorithm and develop and test the necessary software and hardware for enhancing traffic signal control operations simultaneously with vehicle trajectories, when the traffic stream consists of connected |

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| | vehicles, autonomous vehicles, as well as conventional vehicles (i.e., with no operating connectivity or autonomy) |
| Connected Intersection Optimization (NSF) | The project develops and implements optimization processes and strategies considering a seamless fusion of multiple data sources, as well as a mixed vehicle stream (autonomous, connected, and conventional vehicles) under real-world conditions of uncertain and missing data. Since trajectories for connected and conventional vehicles cannot be optimized or guaranteed, the project examines the impacts of the presence of autonomous vehicles on the following vehicles in a queue. The project also integrates advanced sensing technology needed to control a mixed vehicle stream, as well as address malfunctioning communications in connected and autonomous vehicles. The project also develops and uses simulation tools to evaluate these strategies as well as to provide tools that can be used in practice to consider the impacts of autonomous and connected vehicles in arterial networks. |
| Data Management and Analytics | UF in collaboration with FDOT and CoG is planning to develop a data analytics platform for assembling and analyzing the wealth of data expected from the new instrumentation, as well as for existing data currently obtained but not analyzed or synthesized. The objective is to design and maintain a data warehouse to process and archive data generated by the UF smart testbed. |

**Table 2 Planned Projects (Draft Scope Developed)**

| Project Title | Description/Objective |
| --- | --- |
| Accelerated Innovation Development (AID) | This project will disseminate real-time traffic information to the two different road users (motorists and pedestrian/bicyclists) and transit vehicles, and to improve safety and operation along the corridors using V2I communications. The project objective is to accelerate emerging technology deployment in real-world and improve pedestrian and bicyclist safety, and to provide information to transit vehicles. |
| Bus Platooning | The platooning system will allow a bus to virtually link to a following instrumented bus to provide greater capacity on high demand routes. The leader will provide information to coordinate the motion of the following bus. Greater bus capacity can be achieved without the use of an articulated bus, or additional driver. |
| Alternative Transportation Safety Systems | The project will deploy an Advanced Driver Assistance System (ADAS) on RTS transit vehicles to identify behavioral and infrastructure conditions that lead to incidents or near incidents between transit vehicles and pedestrians/bicyclists. The outcome will be a structured driver-training program and a framework to prioritize ADAS investments for small and mid-sized transit agencies. Additionally novel infrastructure to person (I2P) communication technologies will be explored to promote pedestrian alertness while interacting with traffic. |
| UF Fleet Instrumentation | UF administration is planning instrumentation of the UF vehicle fleet with technology that would allow it to communicate with each other and with surrounding infrastructure (signalized intersections on campus and surrounding arterials, mid-block pedestrian crossings, etc.) This instrumentation will allow for communication of the Basic Safety Message (BSM) for all units of traffic, and it enhances safety by increasing the awareness of the operator. Additional components with various degrees of autonomy are also being considered as part of the instrumentation. |
| Gainesville SPaT Trapezium | This project will deploy and test connected vehicle technologies and applications along four roads forming a trapezium surrounding the University of Florida main campus. The goal of the project is to improve travel time reliability, safety, throughput, and traveler information. This project will also deploy pedestrian and bicyclist safety applications for both web-based and/or Smartphone-based applications. |

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| Gator Eye RFID System | The objectives of this project are (1) to implement a prototype of the GatorEye system consisting of a cat's eye, an RFID, and a plurality of sensors and (2) to investigate its feasibility and effectiveness as an important infrastructure element for enhanced safety, positioning, and navigation in smart transportation networks as part of the UF testbed initiative. |

**Table 3 Projects to be Considered**

| Project Title | Description/Objective |
|---|---|
| Demonstration and Evaluation of AV Passenger Car Operations | Testing of instrumented autonomous vehicles will provide data related to autonomy logic and connectivity with infrastructure, as well as evaluation of traffic operations. Analysis of the data could help improve algorithm performance and overall operation of autonomous vehicles in the traffic stream. Partnership with industry (Google, BMW, General Motors, Toyota, Uber, Lyft) will be sought. |
| Signal Control Optimization with Autonomous/Connected Vehicles | Previous research has developed algorithms for optimizing signal control with autonomous vehicles in the traffic stream. Early versions of the algorithm have been tested in a closed-course environment, and in simulation. This project would enhance UF's existing autonomous vehicle to test signal control optimization algorithms currently under development, as well as other technologies and management strategies developed internally within UF as well as by industry partners |
| Pedestrian Instrumentation | Implementation of technologies that would obtain pedestrian presence and tracking. One such approach is the development of a smart app (in conjunction with the existing RTS Gator Locator app) to track pedestrian movements on campus. This could provide the number of pedestrian crossings at different times of the day at a given intersection and would inform autonomous vehicle operations. The data collected can be used with sensor data and accident data to make suitable design changes. |
| Bicycle Instrumentation | Detection and monitoring movements for bicyclists. UF has a very significant bicycle presence, and being able to track bicycle movements and understanding origin and destination patterns would be very useful in designing suitable bicycle facilities, and in informing autonomous vehicle operations. The technology could also be leveraged to provide signal actuation for bicycles. |
| Scooter Instrumentation | The UF campus has a very significance presence of scooters, and it is important to understand their needs and challenges, as well as consider their presence when designing autonomous vehicle logic. Instrumentation similar to that for bicycles is being considered in order to understand their movement and travel patterns. |
| Traffic Management with Connected Vehicles | Instrumentation of the UF fleet for connectivity will allow for communication of vehicles with infrastructure as well as bicycles, pedestrians, and scooters, which can be used to enhance traffic management around the CoG. |

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| | Algorithms to enhance signal control will be developed. Also, safety applications through V2I and V2X will be explored. |
| Gator1 RFID | UF is exploring the possibility of using Gator One cards (the UF identification cards that are used for a variety of purposes) with passive RFID technology, for tracking and communicating between pedestrians/bicycles and the infrastructure or approaching vehicles. |
| Wi-Fi/Cellular Deployment of SPaT | The deployment of SPaT messages to cellphones will help pedestrians connect more easily to traffic signals. The development of an app could disseminate this information through Wi-Fi or cellular technology and be used to anonymously track pedestrian movement. The app could also potentially be used to actuate pedestrian signals. |
| AV Technology Enhancements | UF, in collaboration with its partners, is continuously enhancing UF's existing autonomous vehicle and improving its operations and reactions to traffic scenarios. UF is finalizing the development of a simulation platform that will test the autonomy algorithms on a commercially available traffic simulator environment (VISSIM). The simulator provides realistic traffic scenarios including pedestrian presence, transit, and signalization. UF will evaluate the reaction of the autonomous logic to a variety of conditions, and will revise and calibrate the UF vehicle's autonomous logic accordingly. The results of the work will be widely published and presented at professional conferences. |
| Driving Simulator Evaluations of driver/operator abilities and preferences | UF has a new state of the art driving simulator which will be used to assess the readiness of diverse populations to embrace the technology, to evaluate transitions between autonomy and conventional driving, and to quantify the minimum criteria necessary for being a safe operator of autonomous vehicles as a function of the degree of autonomy. Also, the perception of travelers can be evaluated through surveys, interviews, focus groups, and social media. |
| App Development for SPaT Controllers | The development of a (cellphone/tablet) application to receive SPaT messages and effectively relay this information to the driver. Several app formats will be developed and tested to determine the best method of delivery to the driver. A user survey will be conducted to determine the effectiveness of each app. Testing could be performed in the field and in a closed driving simulation environment. |
| Freeway Merging Assistance | This project will develop a system that advises merging vehicles of available gaps in the freeway traffic. An app will be developed |

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| | to visualize the merging situation and provide guidance on gap selection, speed and acceleration suggestions. Freeway traffic can be detected by either radar, camera, DSRC data or a combination of these technologies. This information will be used to send recommendations to the merging ramp vehicle. |
| Smart Parking | Parking lots on-campus will be sensor-equipped that relay real-time information on the number of available parking through integrated parking apps. Drivers will have a better understanding of their parking options. Commuters will also be able to book a parking lot for certain hours a day online in order to minimize unnecessary delays. The parking app will be capable to relay information on events, from event parking management center. A potential industry partner (WGI) has expressed interest in partnering. |
| Electric Vehicle Infrastructure | AV friendly recharge stations which are wireless inductive charging enabled. Tesla supercharger stations which minimize charging duration. There will be preferred parking for alternative electric vehicles: NEVs, scooters, etc. and users can book parking spaces with EV charging capabilities via integrated parking app. |
| Smart Lighting and Wi-Fi | Motion-responsive LED street lights in order to create a safer and more walkable campus and reduce electricity usage. Light poles will be Wi-Fi enabled for the parts of campus with no Wi-Fi coverage. The project considers leveraging GE intelligent and connected lighting |

## f. Process for Continuous Evaluation and Adjustment of the Roadmap

The continuous assessment and adjustment of ongoing and planned projects is vital so that the testbed can remain relevant and react quickly to technology developments and research findings. As projects evolve, goals need to be re-assessed and the direction of a particular project may shift based on initial results. It is envisioned that the testbed will employ both a "top-down" and a "bottom-up" approach to its activities. A "top-down" approach involves identifying a particular area of need and finding a viable solution using emerging technologies. These areas may include: safety, mobility, information/decision making, sustainability, equity, technology transfer, and economic development. A "bottom-up" approach involves identifying emerging technology that may be useful in solving different transportation-related issues. Through the process of analyzing the capabilities of a technology, an application may be identified to enhance one of the areas listed above.

As part of the testbed operation, we propose holding meetings of the stakeholders every 6 months, to provide status updates, reassess projects, and plan new efforts. The PI's of each project will be required to present their research to representatives from FDOT, CoG, and UF. In addition to evaluation of on-going work, those meetings can serve to discuss and further develop industry partnerships, and to learn more about related activities across the country. Appendix D provides a proposed agenda for such semi-annual meetings.

In addition to meeting with the stakeholders on a semi-annual basis, it is recommended that researchers working on groups of related projects meet frequently to coordinate parallel and related tasks. For example, projects that relate to the same mode of operation or technology should coordinate their activities; two projects that use DSRC communication at signalized intersections should coordinate to ensure the radios at the signals are functioning properly; the data analytics work should be coordinated with several other projects that are expected to produce data. This continuous communication between researchers will ensure tasks stay on schedule and equipment issues can be identified and communicated on a timely manner.

As projects are progressing, researchers will be expected to post updates related to the status of the project on the testbed website. This includes completion of major tasks (implementation of technology, testing, and results) as well as any publications resulting from the work. A communications plan has been developed for handling the dissemination of material related to the testbed (Appendix E).

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# Appendix A: Technical Memorandum on Literature and State-of-the-Art-Review

# 1. Task 1 - Literature and State-of-the-Art-Review

During this task, we conducted a comprehensive review of relevant published literature on advanced technologies; ongoing research; testbeds across Florida, the US and internationally; industry state-of-the-art, and federal policy and regulations related to automated and connected vehicles. The terms Automated/Autonomous Vehicle (AV) and Connected Vehicle (CV) are frequently used in this report as the implementation of these technologies are the focal point. The term autonomous or self-driving refers to vehicular technology which performs driving task without human intervention. In detail, an autonomous vehicle is deals with vehicle operation, while an Automated Vehicle (AV) also communicates with other vehicles (V2V), infrastructure (V2I), or any other units (V2X) to enhance the transportation systems performance. A connected vehicle is typically driven by a human driver.

A total of over 400 international activities and testbeds have been identified and carefully studied. In the past few years, several initiatives have been undertaken at the federal level to facilitate CAV deployments, including the USDOT Smart City Challenge (SCC), the Connected Vehicle Pilot Deployment Program (CVPDP), and the USDOT Automated Vehicle Proving Grounds. Also, many public-private partnerships have been formed to develop transportation advanced technologies and testbeds. In the literature review, we direct our focus on the Concept of Operations (ConOps), vision proposals, technical memorandums and lessons learned from these efforts globally, while we also review some of the most important research articles on CAVs. The next sub-section surveys the most remarkable international projects. Next, we review the activities in the United States and finally in the state of Florida. The subsections on international efforts are organized based on (1) the continent and (2) the scope and significance of projects in each continent. In section '2.2. National Scan of Deployment Efforts', activities are clustered according to the program (e.g. CVPDP, Smart City Challenge). The projects inside each cluster do not follow any specific hierarchy as they are similar in terms of significance, scope, funding and progress. Finally, the activities in Florida are sorted based on the completion date/progress in sub-section 'Deployments and Pilot Activities', and with no specific order in sub-section 'Smart City Challenge Participants'.

## 1.1. International Scan of Deployment Efforts

There are several major guidelines and initiatives on Cooperative, connected and automated mobility (C-ITS) in Europe. In 2013, the basis for the establishment of a Trans-European Transport Network (TEN-T) was adopted, which set the framework for development and discusses certain provisions for C-ITS until 2030 [1]. The European Commission has also initiated under the GEAR 2030 Project a CAV working group, to advise on regulatory measures and investments in order to ease the adoption of CAVs. The Platform for the C-ITS deployment in the EU was created by the European Commission services under DG MOVE with the goal of providing support for the emergence of a common vision across all players involved by gathering insight from public and private stakeholders [2].

- *Cooperative ITS Corridor (Rotterdam - Frankfurt/Main - Vienna) Netherland, Germany, Vienna*

In 2015, Austria, Germany, and the Netherlands initiated a C-ITS project from Rotterdam to Frankfurt and Vienna [3]. This cross-national North-European ITS Corridor is envisioned to introduce deployment-level and real-world advanced technologies. Initial applications include work zone warning and probe vehicle data (PVD) for enhanced traffic management. The objective is to equip the corridor with RSUs required to provide connectivity among vehicles traveling the route and employ mobile variable message systems to avoid collisions. The equipment utilizes DSRC (i.e., 802.11p, 5.9 GHz) and cellular networks (e.g., 3G or 4G) for communication. In late 2014, the first test drive (Communicating Cars project) was completed on the C-ITS Corridor. The test drive involved five Honda vehicles that drove along 800 miles of roads in the corridor.

- *Driving Implementation and Evaluation of C2x Communication Technology (Drive C2x) - Italy and EU*

Another continent-scale effort was carried out under Driving Implementation and Evaluation of C2x Communication Technology (Drive C2x) in Europe to create a V2X communication system and a functional prototype that could be used in the future. The initial effort took place in 2011 and currently a total of seven testbeds have been or are being developed to be involved in this project (Figure 1). The list along with information for some of the testbeds is provided below:


**Figure 1 Drive C2x Scope**

i. Dutch Integrated Testsite Cooperative Mobility (DITCM) (Helmond, Netherlands)

This testbed is the master testbed of the project cluster. The test site is 6 kilometers of highway and urban roadway. Also 20 vehicles are equipped with communication OBUs [4]. The corridor contains two traffic lights, four bridges, an entrance and exit, a bus entrance, and 48 poles for equipment installation, which currently includes 11 communications units UMTS/3G, 802.11p, and Differential Global Positioning System DGPS, 47 fixed cameras, and nine dome cameras.

ii. Cooperative Test Site Finland (Coop TS Finland) (Tampere, Finland)

The Finnish testbed includes an eight-kilometer stretch and a closed test area. The open road section contains three roadside ITS units (802.11p) and one moveable roadside unit (3G/802.11p) [2]. This facility includes a closed test facility (Nokian Tyres Proving Ground in Ivalo, Finland) 18 Km from Tampere. It can simulate almost any driving situation. The track includes a 1.8 km lap, 5 intersections, portable RSU for V2I tests and two fully equipped VTT vehicles with 3G connectivity. The deployments on this testbed include road weather warnings, construction warnings, traffic sign assistance, car breakdown assistance, slow vehicle warnings, and emergency vehicle warnings.

iii. SIStemas COoperativos Galicia (SISCOGA) (Galicia, Spain)

The 60 km long test area contains 15 roadside units (5.9 GHz, 802.11p), 19 variable message signs, 7 vehicles, 21 camera units, and inductive wiring spots located along the corridors, network technology GPRS, UMTS, and 802.11p, 7 meteorological stations as well as multiple ITS instrumentation: construction warnings, traffic warnings, weather warnings, post-crash warnings, emergency brake warnings, car breakdown assistance, cooperative merging assistance, traffic sign assistance, speed limit notification, traffic information and recommended itinerary, and floating car data [5].

iv. Test Site Italy (Brenner Motorway, Italy)

The site includes ten equipped vehicles. Network coverage along the site include UMTS/3G, GPRS, and 802.11p variable message signs, TVCC cameras to study traffic warnings, construction warnings, car breakdown assistance, slow vehicle warnings, traffic sign assistance, and point-of-interest notification.

v. Vehicle and Traffic Safety Center (SAFER) (Gothenburg, Sweden)

SAFER provides, safety-focused innovation and research, as well as collaboration to pursue vision zero objectives. Chalmers University of Technology operates and maintains the center. Research areas include Pre-Crash, Crash, Post-Crash and Traffic Safety Analysis.

vi. Safe and Intelligent Mobility (SIM) Test Germany (Frankfurt/Main, Germany)

The project focus is safe and intelligent mobility through V2X communication and its applications. The project started in 2008 in Frankfurt am Main area with the collaboration of German government and six auto manufacturers. Numerous pilots and projects were deployed and tested in 'sim'; monitoring of traffic situation and complementary information/basic functions, traffic flow information and navigation, traffic management, local danger alert, driving assistance, internet access, and local information services are the main clusters of the project [6].

vii. System Coopératif Routier Expérimental Français (SCORE@F) (Yvelines, France)

In 2014, Volvo, Scania, Autoliv and AstaZero testbed formed a partnership to deploy and test traffic warnings, construction warnings, car breakdown assistance, traffic sign assistance, optimal speed advisory for traffic lights, and floating car data [2]. The proving ground is surrounded by a 3.5-mile highway and includes rural, urban, and multilane roads. It includes signal controllers using 802.11p and VMSs, Delphi OBUs, and equipment from EuroFOT: touch screens, naturalistic loggers and cameras, and a fleet of 20 vehicles. Network technologies include UMTS, 3G, GPRS, and 802.11p.

- *AstaZero Proving Ground – Gothenburg, Sweden*

This testbed is the outcome of the collaboration of Volvo, Scania, Autoliv, and Test Site Sweden to conduct vehicle research with innovative projects related to a set of traffic solutions, such as AV technology [7]. The site has a surface area of 21.5 million square feet approximately (2,000,000 square meters), and a paved surface of 2.7 million square feet (~250,000 square meters). The proving ground is surrounded by 3.5-mile (5.7 kilometer) highway. Test environments include various urban and rural facilities, namely rural roads, city areas, multilane roads, and a high-speed area.

Two closed testing facilities with different functionalities are also included in the testbed: Stora Holm and the City Race Track. Stora Holm is a Volvo-controlled test track that is used for two major applications: safety applications and testing non-traffic regulation compliant performance. The latter opened in 2009 and has hosted numerous demonstrations of cooperative systems. Several traffic signal control components are installed in the testbed. Controllers with 802.11p and VMSs, On-board units by Delphi, and equipment from EuroFOT including touch screens, naturalistic loggers and cameras are the main traffic controller elements of the testbed. Twenty cars form AstaZero proving ground's test fleet. Network technologies installed included UMTS, 802.11p, 3G, and GPRS. Other deployments include traffic warning systems, construction warnings, optimal speed advisory for traffic lights, car breakdown assistance, traffic sign assistance, and floating car data.

- *National Intelligent Connected Vehicle Testing Demonstration Base*

Initiated in June 2016 in Shanghai, China, this test-bed is dedicated to testing and certifying connected vehicle technologies and also to conduct vehicle research and innovation projects related to a range of traffic solutions, including AV technology [8]. The demonstration base is anticipated to support R&D, studies on standards and policy formulation. The center is instrumented with Wi-Fi, cellular, LTE-Vehicle (LTE-V), DSRC, and is expected to cover an area of 38.6 square miles (100 $km^2$) on the testbed by the end of construction. In addition, the base will be outfitted with DSRC and cellular LTE-vehicle communications infrastructure, available to partnering auto manufacturers and tech solution developers. Chinese companies and government have been innovating connected vehicle technologies through the China Communications Standards Association (CCSA). Cellular LTE-vehicle communication has been the main communication mode of this partnership. In fact, the A9 Digital Motorway Testbed on Germany's Autobahn uses LTE technology developed by Huawei, a Chinese telecommunication company. Two other facilities are developed along with the testbed: Standard Research Center of the China Alliance for Intelligent and Connected Vehicles, and Standardization Test and Research Base for Intelligent Connected Vehicles.

- *Centre of Excellence Testing and Research of Autonomous Vehicles (Cetran)*

The development of this testbed started in August 2016. It is expected to open in the second half of 2017. The project is a collaboration of Nanyang Technological University (NTU), Singapore's Land Transport Authority (LTA) and JTC Corporation (Singapore's state agency for industrial infrastructure development) for automated vehicles testing [9]. The center is a closed facility (Figure 2) with an approximate area of 5 acres with roundabouts, slopes, and an area with simulated rainfall. Test vehicles will be able to display and test the ability to maneuver in local conditions, obey traffic rules, and operate under different traffic behavior, road design, and climate.

**Figure 2 Centre of excellence for testing and research of autonomous vehicles [10]**

- *One-North District Test-Bed*

Another large-scale test-bed project in Singapore kicked off in August 2016 through the Singapore Autonomous Vehicle Initiative (SAVI), to address first-and-last mile solutions for commuters traveling between a mass transit station and their destination [11]. One-North is a partnership formed two years before the project kick-off between Singapore's Land Transport Authority LTA and the Agency for Science, Technology and Research (A*STAR) and the goal was to provide a technical platform for industry R&D and testing of AV technologies. Unlike the Centre of Excellence Testing and Research of Autonomous Vehicles (Cetran), this project is not a closed and controlled facility. One-North, is an initial staging test-bed to serve as a proof-of-concept for self-driving vehicle testing, and claims to be the first public road network testbed with a dedicated route approximately 4-miles long. The project is anticipated to be available to limited commercial services by 2018-2019, and to transfer into large-scale integrated mobility platforms across the country after 2020-2022.

- *Automotive Research and Testing Center (ARTC)*

ARTC is probably one of the oldest testbeds in far-east Asia. Established around 1990 in Taiwan, the project was a result of a collaboration between the Taiwanese Ministry of Economic Affairs and the Ministries of Transportation and Communication, Environmental Protection Administration. The intent was to help Taiwanese CV automotive-related companies test their products so that they can successfully launch them on the market [12]. Several CV-related initiatives have been successfully implemented and tested. Most of the pilots revolve around safety, namely, lane-departure warnings, forward collision warnings, parking assist systems which can calculate the reverse trajectory using a signal from the steering angle sensor in real time, blind spot information, and vehicle safety and security systems. This test-bed also includes an electro-magnetic compatibility lab (EMC), nine test tracks, including (1) test hills; (2) curvy and bumpy “Belgium Road” track; (3) coast-down test track; (4) noise, vibration, and harshness surface test track; (5) brake performance test track; (6) pass-by noise test track; (7) general durability test track; (8) high-speed circuit; and (9) general performance test track.

There are numerous additional pilots, testbeds and deployments currently active or under-construction around the world. We have reviewed over 400 activities in total, and briefly described some of the more notable and extensive testbeds. Most efforts in Europe have been based on ITS and communication to increase safety and reduce fatalities. Europe mostly relies on using existing technology for safety applications rather than developing new technologies. Asia follows a similar trend. However, Japan, China and South Korea have been active in developing advanced CAV technologies. Nevertheless, the majority of the effort is currently made by industry. In terms of advanced transportation testbeds, U.S.-based implementations appear to be a better resource for considering advanced transportation technologies. Most European testbeds which use public roads are connected corridors, rather than ‘smart testbeds’ and there are clear similarities between these and the connected vehicle testbeds in the U.S. In fact, there are few similarities to the testbed which is sought to be developed on the UF campus. Therefore, the primary focus of this literature review will be on national and regional CAV efforts. Additional information related to European Union projects is provided in [13], while an international survey on deployments is provided in [14].

## 1.2. National Scan of Deployment Efforts

The deployments in the US range from federal level programs to public-private partnerships and university collaborations. In this deliverable, we classify these activities into the following categories: (1) Connected Vehicle Pilot Deployment Program (CVPDP), (2) Connected Vehicle Testbed, (3) USDOT Automated Vehicle Proving Grounds, (4) Smart-City Challenge and (5) University driven efforts.

- *Connected Vehicle Test-beds*

The U.S. DOT Connected Vehicle Program targets dedicated short-range communication (DSRC) applications in a vehicular environment (WAVE). The goal of this program is to allow information-sharing, testing and cooperative development of CV technologies. Since 2009, these testbeds have been funded through the U.S. DOT Pooled Funds Study, and are scheduled to be completed in 2017. There are two ongoing projects (as of November 2016) being run through the Connected Vehicle Pooled Fund Study. Several cities and universities were involved in this program. This section will review these activities across the US.

i. Connected Vehicle Test-bed: Anthem, AZ

Also called MCDOT testbed for SMARTDrive Program, it is the result of collaboration of Maricopa County Department of Transportation (MCDOT), ADOT and the University of Arizona. It aims to test different AV and CV applications, such as advance multiple vehicle signal priority technology with deployment on emergency response vehicles [15]. Kicked off in 2007 and upgraded in 2012, this 2.3 mile stretch on an arterial in Anthem, AZ., consists of DSRC devices at 11 signalized intersections, 6 freeway interchanges and 10 other freeway locations. The site also features integrated Wi-Fi and Bluetooth connections, closed-circuit television (CCTV) cameras, traffic detection software, data collection software, fiber optic systems, and communication connections to the TMC at MCDOT. Some of the most notable projects are MCDOT and University of Arizona Priority Based Traffic Signal Control for EV and Transit, performance improvements of traffic Controllers by data fusion and analysis (InFusion), and Smartphone Signal Alert Status (SmartCross).

ii. Connected Vehicle Test-bed: Palo Alto, CA

Initiated in 2005 and with upgrades most recently in 2014, this test-bed is the nation's first DSRC test-bed and was developed to assess and evaluate real-world implementations of vehicle infrastructure integration (VII), as well as to inform future investment decisions on system management programs [16]. The test bed spans 11 consecutive intersections along a 2-mile stretch of SR-82 in Palo Alto. It provides wireless connectivity in an open and operational environment among intersections, roadways, and vehicles. CAV applications at this test-bed are: (1) Traveler Information (using 511), (2) Electronic Payment and Toll Collection, (3) Ramp Metering, (4) Cooperative Intersection Collision Avoidance Systems (CICAS), (5) Curve Over-Speed Warning, (6) Auto Industry Applications (i.e., customer relations and vehicle diagnostics), (7) Multi-Modal Intelligent Traffic Signal System (Pooled fund study project): ISIG, TSP, PED-SIG, PREEMPT, FSP, (8) PATH Cooperative "Green Wave": Nissan and BMW, (9) At-Grade Light Rail Crossing Safety Research and (10) Intelligent Transit Stop Information System. Other equipment includes vehicles (OEMs; transit buses; commercial trucks, On-Board Equipment-OBEs from multiple vendors), Infrastructure Components (Roadside Equipment-RSE, PC104, Signal Sniffer, 2070 Signal Controllers) and Back End Servers (SDN @ 511 TIC in Oakland, Health Monitoring and management, Signage server).

iii. Connected Vehicle Test Bed-Michigan (Novi-Detroit-Oakland County)

Also known as Southeast Michigan Test Bed, it was developed to perform research and as a testing resource for developers to test DSRC-enabled applications [17]. This testbed consists of a 125-mile sensor installation near I-96 (close to General Motors Co.'s Milford Proving Grounds), I-94 from Ann Arbor to metro Detroit, and U.S. 23 from Ann Arbor to Brighton. It also features SPaT (with portable listener and GUI) and a Security Credential Management System (SCMS), 50 RSEs with 802.11p and 1609 standards, SPaT on 22 Telegraph Rd RSEs broadcasting both J2735 and CICAS-V standards, 30 RSEs with complete IPv4 and IPv6 connectivity to datacenter and internet, 9 vehicles dedicated for research and development, 2 portable SPaT listeners, along with a DSRC sniffer, 2 custom, portable and solar powered trailers for roadside equipment in targeted locations.

iv. Connected Vehicle Test Bed: Ann Arbor, MI

The Ann Arbor Connected Vehicle Test Environment (AACVTE) and Connected Vehicle Safety Pilot (University of Michigan) are two activities in Ann Arbor initiated in 2015 and 2012 respectively, in order to perform research and as a testing resource for private developers to test DSRC-enabled applications, transition from a model deployment to an early operational deployment, to continue to operate a robust, high quality environment for the benefit and use of all stakeholders, and transition from a federally funded program to an economically sustainable environment [18, 19]. The University of Michigan Transportation Research Institute (UMTRI) and the U.S. DOT launched the Safety Pilot Model Deployment (SPMD), which is a three-year, $30 million research project, to study the effectiveness of CV safety technology at reducing crashes. The project incorporated over 73 lane-miles of instrumented roadway, as well as 2,800 vehicles. After SPMD, UMTRI decided to expand the existing infrastructure footprint from northeast Ann Arbor to the entire 27-square miles of the City of Ann Arbor under the AACVTE project. This effort sought to deploy additional vehicles (1,500 per year). The testbed includes 45 street locations, 12 freeway sites, 27 square miles (the City of Ann Arbor), up to 5,000 equipped vehicles. The majority of vehicles will be equipped with a vehicle awareness device (VAD), which only sends the basic safety message

(BSM) and does not generate warnings. Several hundred vehicles will be equipped with an after-market safety device (ASD), which sends and receives the safety message and provides drivers with audible or visual feedback. VAD's transmit a BSM at the rate of 10 times a second. ASD's also transmit and receive a BSM.

v. Connected Vehicle Test Bed: Long Island (New York), NY

Launched in 2008 and with upgrades throughout 2009-2011, this testbed was opened at the ITS World Congress to demonstrate CV capabilities and applications for commercial vehicles. The ground includes 13 miles along the I-87 Spring Valley Corridor and 42 miles along the I-495 Long Island Expressway, and features CVII compliant 5.9 GHz DSRC OBE system CVII DSRC applications, namely CV driver I.D and verification, wireless vehicle safety inspection (brake condition, tire pressure, light status, etc.), CV to maintenance vehicles communication. It also enables implementation and testing of Grade Crossing Driver Warnings (In-vehicle signage & crossing signal activation), Heavy Vehicle to Light Vehicle Driver, Safety Warnings, Real time routing with driver warning. Other components include a fleet of 4 plow trucks (Mack & International), OBEs (retrofitted 5.9 GHz DSRC) plus 20 aftermarket devices (Kapsch), Infrastructure Components (31 Interstate RSEs plus 8 Arterial @ traffic signals), enhanced e-screening site with 2 RSEs and RSE along I-40, Greensboro, NC (CVII Testing) [20]. Notable deployments on the corridor are: travel time information, DMS messages, emissions calculations, intersection safety, transit priority, multimodal information, connected vehicle probe data, work zone safety warning, warning sign enhancement, curve warning, commercial vehicle routing information, and vehicle restrictions.

In addition to the DSRC roadside units that were already in place, an additional 13 DSRC units were deployed along NY Thruway I-87. By April 2011, two DSRC units were installed along I-90.

vi. Connected Vehicle Test Bed: Minnesota

Launched in 2015, this safety focused test-bed targets reduction of crashes with snowplows and other emergency and maintenance vehicles, end of queue crashes for vehicles close to work zones, bus-vehicle conflicts for Bus-On-Shoulder operations and to improve mobility by providing greater traffic, road condition and incident information to travelers. The Minnesota Connected Vehicle (CV) Pilot Deployment Project is mainly focused on providing operating efficiencies to maintenance and transit vehicles and on addressing real-world CV technology problems to improve safety, mobility and efficiency, and provide traveler real-time information to reduce delay. Some of the projected pilots are: (1) Minnesota Road Fee

Test in order to demonstrate technical feasibility of MBUF, to demonstrate flexibility of in-vehicle signage and to collect anonymous traveler info from consumer devices, (2) Cooperative Intersection Collision Avoidance System—Stop Sign Assist (CICAS-SSA) [21]: Obtain driver feedback on CICAS-SSA, (3) Clarus: Collect, process and use mobile weather data. The equipment includes a fleet of 500 volunteer vehicles for the first pilot, "driver clinic" type demo for the second pilot, and 80 MnDOT snow plows for the Clarus. Also, OBEs include Android platform DSRC equipment and AVL system with cellular communications [22].

vii. Connected Vehicle Test Bed: Northern Virginia, VA

The Northern Virginia Connected Vehicle Test Bed and Virginia Connected Corridor (VCC) tested connected vehicle technologies in congested urban areas [23]. This corridor is equipped with 46 RSE DSRC radio units to receive and relay data along Interstates 66 and 495 and Routes 29 and 50, and includes access to dedicated high-occupancy toll (HOT) lanes in conjunction with partner Transurban. This testbed provides initial testing on two closed facilities (Smart Road or Virginia International Raceway test track). Upon approval, each test migrates to Virginia Connected-vehicle Test Bed in Northern Virginia. The testbed offers research technologies and means to conduct phased testing and safety analysis. The test fleet includes 12 vehicles, including six cars, four motorcycles, a bus, and a semi-truck. These vehicles collect information such as acceleration, braking, curve handling, and emissions. Other featured components of the test-bed include: metro stations, HOT and HOV lanes, hospitals, major merge/diverge locations, emergency services, multiple schools, mixed-use commercial/residential areas, major roadway construction, 60+ RSE units for CV communication. Additional features of the two facilities are as follows:

- Smart Road Connected-Vehicle Test Bed

It was established in 2000 with upgrades in 2011, and it is a 2.2-mile controlled-access test track that was designed for ITS, human factors, and safety research at the Virginia Tech Transportation Institute, Blacksburg, VA. Half-mile of the road has weather-making facilities capable of producing rain, snow, and fog of different intensities. The facility is equipped with four hundred electronic sensors buried in the pavement to determine the weight and velocity of vehicles, as well as the stress on the pavement. The communication system includes a wireless local area network (LAN) that works with fiber optic and interfaces with several on-site data acquisition systems to transfer data between the vehicle, research building, and infrastructure.

- Virginia International Raceway Test Bed

The track is a semi-closed-controlled circuit with two courses of 2.25 and 1.65 miles. It allows 4 different route configurations with the full course of 3.21 miles. During off-peak seasons, the entire facility may be closed to the public.

viii. Connected Vehicle Test Bed: Mclean, VA

Better known as Turner-Fairbank Highway Research Center (TFHRC) and Saxton Lab [24], this site is dedicated to enhancing the state of the art for transportation operations. The Saxton Transportation Operations Laboratory is located at Federal Highway Administration's (FHWA) Turner-Fairbank Highway Research Center in McLean, VA. The laboratory is a proving-ground that enables FHWA to validate and refine new transportation services and technologies before migrating to larger scale research, testing, or deployment. This facility includes three sub-test-beds which enable study on the technologies for connected vehicles, can be used in prototype development, and enable researchers and R&D specialists to conduct tests on connected vehicles. The tools and equipment include: radar and ultra-sonic sensors, front and rear-facing cameras, 5.9 GHz DSRC, Wi-Fi, and 4G cellular/LTE communications, weather and global positioning system base station, WiMAX, Cellular, and DSRC Communications data collection and processing systems, localization system, electronic throttle and brake control units, vehicle preparation garage, connected traffic signal, Connected Mobile Traffic Sensing System (Microwave Vehicle Detection) and simulation and analysis tools among others.

ix. Connected Vehicle Test Bed: Denver, CO

Launched in 2009 to demonstrate multi-lane free flow (MLFF) and open road tolling (ORT) high performance tolling and enforcement. The system being used is based on 5.9 GHz DSRC to communicate between roadside tolling systems and vehicles. It was installed on three lanes next to an existing toll plaza on the E-470 highway for evaluating tolling systems. The installation also includes in-vehicle units, cameras with illumination units, overview cameras with external infrared (IR)-flashes and laser units. Some applications tested include toll tags and detectors, vehicle detection and classification, and automatic license plate recognition solutions.

- *U.S. DOT AV Proving Grounds*

The U.S. Department of Transportation (DOT) has designated 10 proving ground pilot sites across the nation to encourage testing and information sharing around automated vehicle technologies, as well as develop innovations that can safely improve mobility and help disadvantaged populations [25]. They will also provide insights into optimal big data usage through AV testing. Designees were selected from over 60 applicants from academic institutions, state DOTs, municipalities and the private sector. The USDOT initiated a Federal Register Notice soliciting proposals in November 2016, and announced the winners in early 2017. This section briefly discusses the winners and their anticipated implementations.

i. Larson Institute Automated Vehicle Proving Ground (Pittsburgh, PA)

The site has multiple facilities including a one-mile oval track (est.1969), hydrogen fueling station (1990s), electric vehicle pack testing equipment and multi-fuel stations (2010), 400-horsepower motoring chassis dynamometer (2010), certified emissions test stand (2010), DSRC radio network and dedicated DGPS base station (2015) and is anticipated to be upgraded with power and communication systems for rapid installation of vehicle-to-infrastructure (V2I) hardware, signage, and signalization equipment, as well as a control and management center for [26]:

- Telemetry collection and vehicle data processing with roadside measurements synchronization (traffic cameras, radio communications, and signage and traffic simulations) with telemetry obtained from vehicles at the track
- support loading-dock and docking operations for heavy autonomous trucks, by motion coordination, tracking, and testing of AVs
- vehicle platoon data collection for assessment of efficiency and fuel economy
- Tele-operated control of AV infrastructure for highway testing.

ii. Texas Automated Vehicle Proving Ground (Texas)

The partnership was formed with Texas A&M Transportation Institute (TTI), the University of Texas at Austin’s Center for Transportation Research (CTR), and the Southwest Research Institute (SwRI) to develop test-beds across the state of Texas. There are five clusters of test-beds proposed [27]:

- Austin Area (Austin-Bergstrom International Airport and Riverside Drive corridor)

Includes testing and deployment of electric, connected, and automated cars and buses along the East Riverside Drive Corridor and at Austin's Bergstrom International Airport, with DSRC and autonomous technology for both city fleet and public buses along the same corridor. This testbed also aims to implement advanced bicycle and pedestrian detection at intersections to allow for a safe AV and cyclist operation. Controlled public AVs (automated airport circulator at the Austin Bergstrom International Airport) is another component of this testbed.

- Dallas/Fort Worth/Arlington Area (UTA campus, Arlington streets, I-30 corridor and Managed Lanes)

An AV test environment along IH-30 in the central part of the Dallas-Fort Worth region and with three environments:

  - *Campus*: deployment of AVs in a low-speed and semi-closed environment
  - *Streets*: Deployment of AVs at low to moderate speeds on the roadways linking campus pathways to local streets. The planned project includes two AV long-running shuttle services which operate within the Entertainment District to link hotels and recreational destinations
  - *Highway*: IH-30 from IH-35W in Fort Worth to IH-35E in Dallas in a controlled-environment fashion.

- Houston Area (Texas Medical Center, Houston METRO HOV lanes, and Port of Houston)
  - *Houston METRO's HOV lane system*: To pilot CAV technologies, particularly bus platooning, on IH-45, US 59 North, IH-45 South, US 59 South, and US 290.
  - *The Texas Medical Center*: Slow speed AV pilot in an environment with 110 shuttle stops, 85 METRO bus stops, three METRORail platforms, and several other regional operators.
  - *Energy Corridor*: Transit, vanpooling, car-sharing, and biking AV pilots to address the first/last mile gap
- San Antonio Area (Fredericksburg Road/Medical Drive corridor and bus rapid transit system)

On Fredericksburg Road Primo (BRT system) three projects are to be implemented: (1) a GPS-based conditional traffic signal prioritization system, (2) AV to prevent pedestrian or vehicular conflicts, (3) free 4G LTE Wi-Fi on all buses.

- El Paso Area (Tornillo/Guadalupe Port of Entry)

Focuses on transit and conflicts at port area with deployments such as freight port, on-road, pedestrians and passenger vehicles.

TAMU, UT, and SwRI have test-beds that are operational today to support any AV research and testing, and by January 2018, each of the facilities are projected to have the equipment discussed and upgrades to support advanced AV research and testing [28].

iii. American Center for Mobility (ACM) Automated Vehicle Proving Ground (Willow Run, Ypsilanti (MI)

The site includes a 2.5-mile test track, which allows for test speeds up to 70 mph, with limited ACM improvements on the former Willow Run site [29]. Different traffic scenarios, such as a rural section and an urban section with buildings, variable lighting, traffic signals and intersections with speeds up to 50 mph are to be developed at this site. A tech park with buildings is designed with AT&T as a cyber security lab. The testbed is using several overpasses that make up U.S. 12 and a 700-foot curved tunnel for simulated driving conditions under different weather conditions (Figure 3). Plans for 2018 include enhancing the ACM headquarters building and adding more facilities. During 2019-2023 the entire facility development will conclude and a Future Master Planning concept will be in place to show the future expansion plans for the testbed.

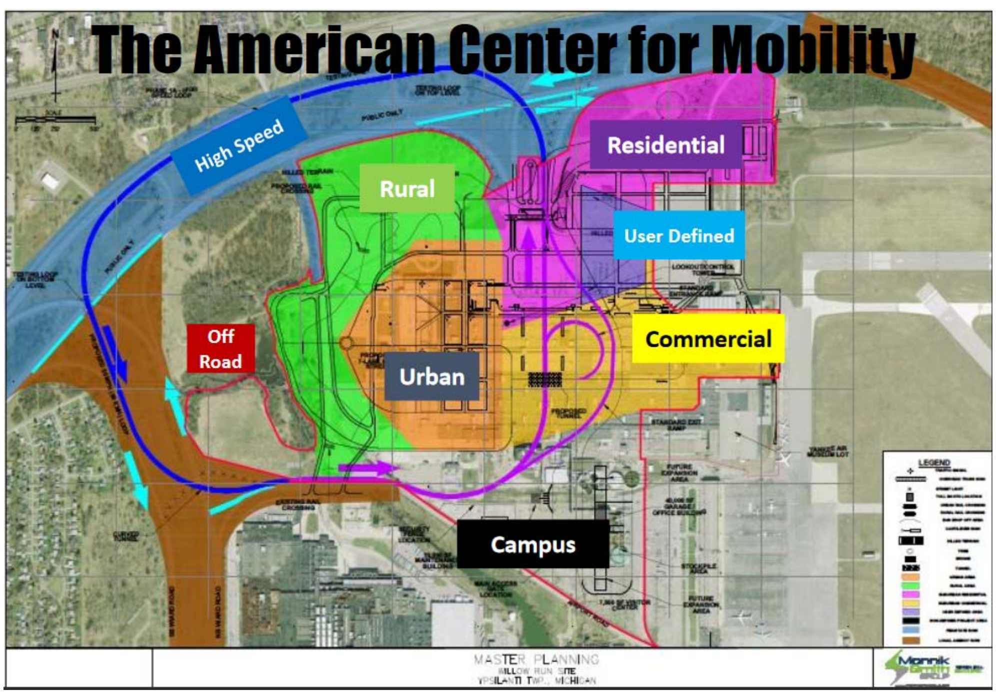



**Figure 3 American Center for Mobility Development Plan [29]**

iv. San Diego Association of Governments Automated Vehicle Proving Ground – Chula Vista (California)

There are three areas of expansion proposed for this proving ground: (1) The I-15 Express Lanes, which spans over 20 miles from SR 163 in San Diego to SR 78 in Escondido, is already a local testbed for modern traffic management technology and is expected to add several new components. (2) The South Bay Expressway, operated by SANDAG, is a 10-mile tolled facility that runs through Eastern Chula Vista to the U.S.-Mexico border. The road is tolled and has a number of traffic management assets ideal for AV testing. (3) City of Chula Vista**:** The local network of streets and roadways in Chula Vista. Throughout 2017, the San Diego Regional Autonomous Vehicle Proving Ground project team has been executing a work plan to prepare for the pilot project to be launched in early 2018.

v. Iowa City and Cedar Rapids Corridor Automated Vehicle Proving Ground (Iowa)

The focus is on the diversity of automated vehicle testing environments Iowa has to offer under a variety in climate, road users, and roadway landscapes, including a simulated virtual test-bed. The project also transforms a section of I-380 that connects Iowa City and Cedar Rapids into a data-rich corridor.

vi. University of Wisconsin-Madison Automated Vehicle Proving Ground

Three sites are expected to develop under this project [30]: MGA's Burlington site (400 acres of roadways and crash-testing facilities), a 4-mile racing circuit at Road America in Plymouth, and a sprawling headquarters of Epic Systems in Verona and UW-Madison's streets. The development at these sites include: (1) data and sensing including LIDAR, GPS, cameras, communications, and other sensors, (2) Interaction with pedestrians, bicycles, mopeds, cars, and traffic control devices, (3) vehicle operation characteristics (speed, acceleration and deceleration, performance on grades and curves, as well as range and charging time for EVs), (4) weather operations (snow, ice, fog, and high winds) (5) passenger comfort, perception, and safety improvement, (6) AV micro-transit developments and testing, (7) human-machine interfaces such as sensors, communications, and feedbacks.

vii. CCTA and GoMentum Station

The 5,000-acre GoMentum Station in Concord, California is a controlled testing facility for CAV technologies. It is an outcome of the Contra Costa Transportation Authority and its partners, including automobile manufacturers, communications companies, technology companies, researchers and public agencies. It is also built through a public/private partnership which allows the private sector space to innovate and test, while allowing the public sector to have access to new technologies developed to form policy, regulation and planning decisions. Research and testing currently includes private, shared, and commercial vehicles, in a multimodal environment. There is not much information released on future plans for this proving ground.

There are two other Proving-Grounds, namely, U.S. Army Aberdeen Test Center and North Carolina Turnpike Authority which have not released sufficient information on their existing facilities and plans.

Overall, although this program is comprehensive with respect to the types of components and applications envisioned, for most of these testbeds the research is in the planning stages and there are no field data or findings to report.

- *Connected Vehicle Pilot Deployment Program (CVPDP)*

On September 1, 2016, the USDOT awarded three cooperative contracts worth more than $45 million (combined) to initiate a "Design/Build/Test" phase of the CVPDP [31]. This program is sponsored by the USDOT Intelligent Transportation Systems Joint Program Office (ITS JPO) and is a national effort to deploy and test, mobile and roadside technologies to enable CV applications with the potential for immediate beneficial impacts, such as improving personal mobility, enhance economic growth, reduce environmental negative impacts, and transform public operations. Over the past one year, each of the three sites have prepared a comprehensive deployment concept and have embarked on a 20-month phase to design, build, and test the deployment of integrated technologies.

i. New York City (NYC) DOT Pilot

The objectives of this deployment are to improve the safety of travelers and pedestrians in the city through V2V and V2I technologies, aligning with the Vision Zero initiative, and to evaluate CV applications in dense urban intersections [32]. The project area covers three distinct areas in the boroughs of Manhattan and Brooklyn: (1) a 4-mile segment of Franklin D. Roosevelt (FDR) Drive in the Upper East Side and East Harlem neighborhoods, (2) four one-way corridors in Manhattan, (3) a 1.6-mile segment of Flatbush Avenue in Brooklyn (Figure 4). This deployment also involves nearly 5,800 cabs, 1,250 MTA buses, 400 delivery trucks, and 500 City vehicles. Using DSRC, the deployment will also include approximately 310 signalized intersections for V2I communication, 8 RSUs along the higher-speed FDR Drive to address challenges, namely short-radius curves, a weight limit and bridge clearance, and 36 RSUs at several critical locations in the City to reinforce system management operations. The pilot will also focus on pedestrians by reducing vehicle-pedestrian conflicts using in-vehicle pedestrian warnings and by equipping roughly100 pedestrians with personal devices to detect and assist them while crossing streets. Table 1 lists the different components considered in the deployment and Table 2 shows the CV technology devices planned for deployment. At the moment, the project is in design, implementation and testing phase and it is anticipated to enter phase three (full operation and maintenance) in May 2018 [33].


**Figure 4 The Scope of New York City (NYC) DOT Pilot [32]**

**Table 1 Deployment Components and Projects for NYC Pilot**

| | Category | NYCDOT – CV Application |
|---|---|---|
| 1 | V2I/I2V Safety | Speed Compliance |
| 2 | | Curve Speed Compliance |
| 3 | | Speed Compliance/Work Zone |
| 4 | | Red Light Violation Warning |
| 5 | | Oversize Vehicle Compliance |
| 6 | | Emergency Communications and Evacuation Information |
| 7 | V2V Safety | Forward Crash Warning (FCW) |
| 8 | | Emergency Electronics Brake Lights (EEBL) |
| 9 | | Blind Spot Warning (BSW) |
| 10 | | Lane Change Warning/Assist (LCA) |
| 11 | | Intersection Movement Assist (IMA) |
| 12 | | Vehicle Turning Right in Front of Bus Warning |
| 13 | V2I/I2V Pedestrian | Pedestrian in Signalized Crosswalk |
| 14 | | Mobile Accessible Pedestrian Signal System (PED-SIG) |
| 15 | Mobility | Intelligent Traffic Signal System (I-SIGCVDATA) |

**Table 2 Proposed CV Devices and Equipment - NYC**

| NYCDOT – Devices | Estimated Number |
|---|---|
| Roadside Unit (RSU) at Manhattan and Brooklyn Intersections and FDR Drive | 353 |
| Taxi Equipped with Aftermarket Safety Device (ASD)* | 5,850 |
| MTA Fleet Equipped with ASD* | 1,250 |
| UPS Truck Equipped with ASD* | 400 |
| NYCDOT Fleet Equipped with ASD* | 250 |
| DSNY Fleet Equipped with ASD* | 250 |
| Vulnerable Road User (Pedestrians/Bicyclists) Device | 100 |
| PED Detection System | 10 + 1 spare |
| Total Equipped Vehicles | 8,000 |

ii. Wyoming (WY) DOT Pilot

The focus at this pilot is adverse weather and freeway operations, aiming to reduce the number of blow-over incidents and adverse weather-related incidents in the corridor of deployment to increase safety and reduce non-recurring delays. The plan is to develop CV systems along the 402 miles of I-80 in Wyoming (Figure 5). Approximately 75 RSUs using DSRC will be deployed along the study routes. WYDOT will also equip around 400 fleet vehicles and commercial trucks with OBUs (150 will be heavy trucks who are regular users of I-80). Moreover, 100 WYDOT fleet vehicles, snowplows and highway patrol vehicles, will be equipped with weather sensors and on-board units. Tables 3 and 4 list the proposed applications and devices for this deployment.

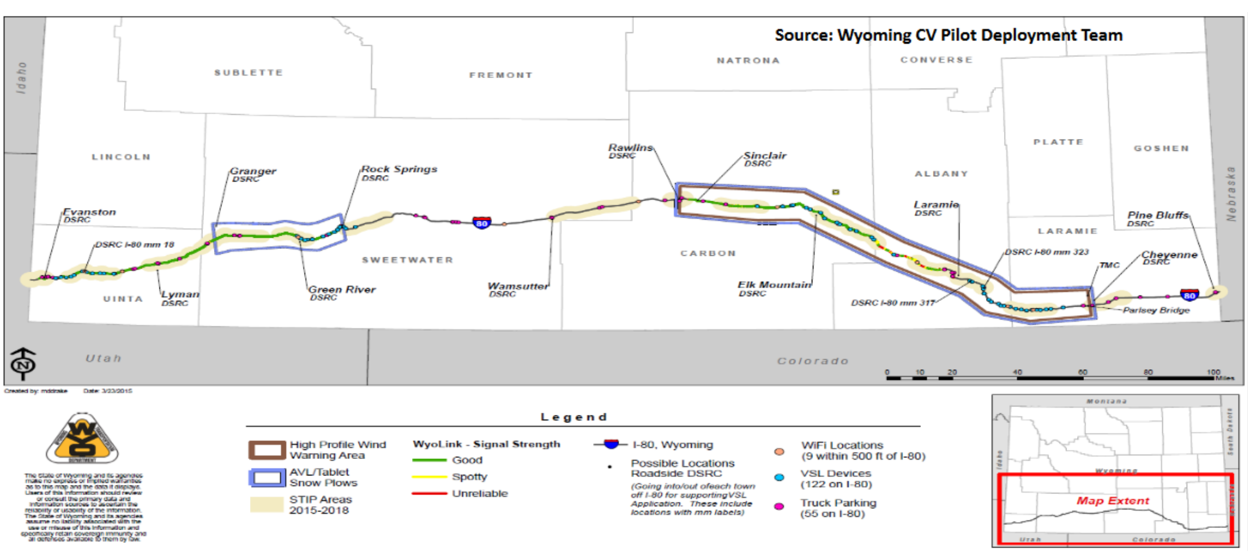



**Figure 5 Scope of Wyoming DOT Pilot**

The Tampa-Hillsborough Expressway Authority (THEA) project will be discussed in the next section under activities in Florida. This USDOT program requires the three winners to follow a similar implementation timeline and provide a set of deliverables according to ITS-JPO's guidelines. Therefore, all three projects have some similarities in the overall scope and project management.

**Table 3 Deployment Components and Projects for Wyoming Pilot**

| | Category | ICF/WYDOT – CV Application |
|---|---|---|
| 1 | V2V Safety | Forward Collision Warning (FCW) |
| 2 | V2I/I2V Safety | I2V Situational Awareness* |
| 3 | | Work Zone Warnings (WZW)* |
| 4 | | Spot Weather Impact Warning (SWIW)* |
| 5 | V2I and V2V Safety | Distress Notification (DN) |

**Table 4 Proposed CV Devices and Equipment - Wyoming**

| ICF/WYDOT – Devices | Estimated Number |
|---|---|
| Roadside Unit (RSU) | 75 |
| WYDOT Fleet Subsystem On-Board Unit (OBU) | 100 |
| Integrated Commercial Truck Subsystem OBU | 150 |
| Retrofit Vehicle Subsystem OBU | 25 |
| Basic Vehicle Subsystem OBU | 125 |
| Total Equipped Vehicles | 400 |

- *University-Driven Activities: Public, Private and University Partnerships*

In many global efforts, universities and academic institutions play an important role in developing testbeds and pilots. In some cases, universities lead the design, build and deployment phases. In such pilots, the university campus and its facilities are often part of testbed. This sub-section reviews these university-led testbeds and pilots.

i. Ohio State University: SMOOTH

Smart Mobile Operation: OSU Transportation Hub (SMOOTH) kicked off in December 2014 at the OSU main campus, Columbus, Ohio (Figure 6). The Ohio State University Center for Automotive Research has teamed up with CISCO, City of Columbus, General Electric (GE), Mid-Ohio Regional Planning Commission (MORPC) and Team ARIBO to address the first mile/last mile challenge. The project includes on demand CAVs to move passengers for the first mile to the bus stop and the last mile from the bus stop in west campus, and scheduled or on demand vehicles to move passengers through a closed loop within the OSU main campus roads and pedestrian areas. The vehicles are fully automated with V2V communication capabilities for convoy driving and V2I communication with smart LED Street and curb-side lighting infrastructure to switch them along the route. They will be equipped with vulnerable road user protection technology for pedestrian zones [34]. SMOOTH will keep track of vehicles and guide them and will receive information from smartphone applications to schedule and track the on-demand AVs. In March 2015, the project was sought to conclude and live demonstrations were scheduled in June 2015 and 2016.

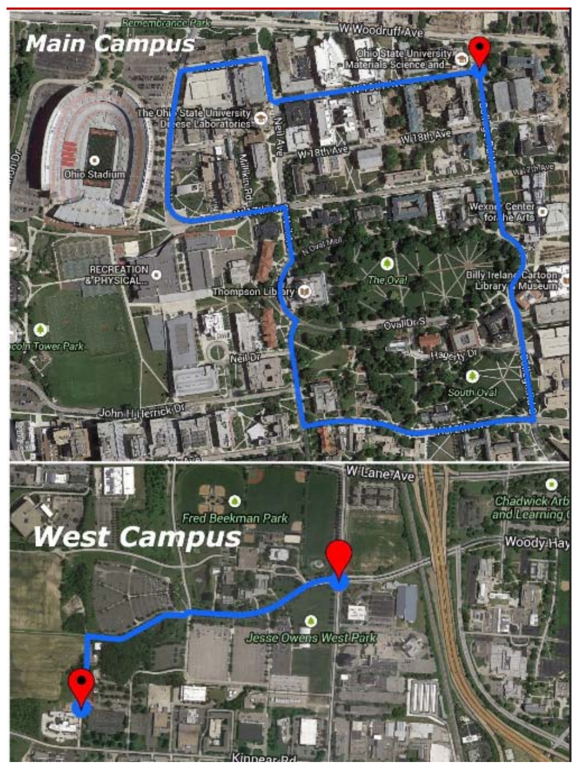



**Figure 6 SMOOTH**

ii. University of Michigan: M-City

Launched in July 2015, M-City is a 32-acre (13 ha) mock city and test-bed built for the testing of AVs located on the University of Michigan North Campus in Ann Arbor, Michigan [35]. The site has several common features of urban networks, including roadways, intersections, roundabouts, brick and gravel roads, a railroad crossing and parking spaces among others where visibility is impaired and with a maximum speed of 40 mph (Figure 7). Building facades and fake pedestrians can be changed for different tests.

**Figure 7 M-City, University of Michigan [35]**

It also features a model highway entrance ramp, a metal bridge and a tunnel – to test wireless signals and radar sensors penetration capability. M-City includes a fully autonomous, 15-passenger NAVYA electric shuttle to support research and provide self-guided tours of M-City. The facility has several stakeholders including auto manufacturers (Ford, General Motors, Honda, Nissan, Toyota), and solution providers (Delphi, Denso, Robert Bosch, Xerox, Verizon and Qualcomm).

iii. Carnegie Mellon University: Township and Pittsburgh Testbed

A partnership with CMU, Cranberry Township, the City of Pittsburgh, PennDOT, and SPC was formed to develop three testbeds in Pittsburgh. The CMU Cranberry Township and Pittsburgh Test Bed was established in 2015 covering 11 traffic signals in Cranberry Township and 24 traffic signals in Pittsburgh equipped with DSRC RSEs. The Baum-Centre Test Bed is another similar testbed on Baum Boulevard (state route) and Centre Avenue (city road) with 24 DSRC units. The PennDOT Ross Township Test Bed was launched in 2014 through an FHWA Accelerated Innovations Deployment (AID) grant. It features adaptive traffic control signals and DSRC, along SR 4003.

iv. Texas A&M: Connected Vehicle Test Bed at the Riverside Campus

Through an initiative started in 2014, this project aims to enhance safety and to overcome the limitations of today's camera-based systems. TTI's connected transportation initiative will include a transportation test-bed at Texas A&M University's Riverside Campus (RELLIS). Applications sought to deploy include work-zone applications (relay to motorists in-vehicle alerts of upcoming lane closures, queue warnings and other situations), smart pavement markings to support AV deployment, as well as sensing technologies to further enhance pavement-marking detection, and testing low-visibility conditions (namely, heavy rains, thick fog and low sunlight and glare). A set of equipment to be installed include RSUs for Basic Traffic Data Collection, Traveler Information Communications, Vehicle Driver Information Reception, as well as Vehicle OBU Situation Data Generation, Data Access Management, Data Collection and Aggregation, Object Discovery Registration and Lookup, Peer-to-Peer Data Exchange, Security Credential Management System Bootstrap, and TMC Traffic Information Dissemination. For further information readers may refer to the Texas A&M Transportation Technology Conference resources [36].

v. University of Alberta and British-Columbia: ACTIVE-AURORA

The ACTIVE-AURORA research circuit was formed in 2014 for testing and operationally evaluating emerging CV technologies, and applications and services for both urban real-time traffic management and freight operations. The project includes four test-beds and two laboratory test environments: ACTIVE (Alberta Cooperative Transportation Infrastructure and Vehicular Environment) representing the Edmonton test beds, and AURORA (AUtomotive test bed for Reconfigurable and Optimized Radio Access) representing the Vancouver test-beds. At both universities, "On-Campus Learning and Commercialization" laboratory test-bed facilities have been established to provide industry, researchers and students with facilities, in which they can create software applications, test hardware components and perform simulation, and data collection and analyses on the output obtained from the ACTIVE and AURORA test beds. On ACTIVE, three on-road test bed sites are located in the Edmonton area. The three test bed sites, which encompass both highways and arterials, include Whitemud Drive, Anthony Henday Drive, and 23rd Avenue. The British Columbia test-bed (AURORA) includes approximately 10 km along both two- and four-lane roadways within and near the UBC main campus, which aligns with the UBC "campus as a living lab" initiative. AURORA features wireless technologies such as LTE and 5.9 GHz.

- *Smart City Challenge Finalists*

In December 2015, USDOT launched the Smart City Challenge, by inviting mid-sized cities across the U.S. to develop ideas for an integrated, smart and data-driven transportation system to enhance the mobility of people and goods. A total of 78 applicant cities shared their challenges and ideas to tackle them. In the second phase, USDOT picked seven finalists which worked with the USDOT to further develop their ideas in the form of a technical memorandum. Finally, Columbus, OH was picked as the winner and was granted $50 million by the USDOT and Vulcan Inc. to implement their plan.

Although some of these proposals may not be implemented, they contain very interesting concepts and ideas. Therefore, in our review we briefly discuss these 78 proposals and the concepts by them.

i. An overview of the 78 SCC proposals

Among the common challenges that U.S. cities face, some of the most frequently mentioned are: the first-mile and last- mile service for transit users, shipment into and within a city, data collection and analysis, real-time feedback across systems, inefficient parking, carbon emissions, and traffic flow optimization on congested highways [37]. To address one or more of these challenges, several cities proposed more affordable and sustainable mode choices while improving the quality, service and reliability of public transportation, enhancing pedestrian/bicycle infrastructure, and better parking land-use. 44 out of 78 proposals suggested projects to test shared use AVs. Also in order to improve logistics and delivery operations, traffic signals with preemption for freight movements, dynamic applications to provide information on routes and parking to trucker drivers, automated low speed freight delivery, and AV trucks were mentioned in the proposals. 11 cities proposed smarter curb space management models (e.g., sensors and dynamic reservations among others) to speed up urban freight delivery.

Electric Vehicles (EV) have been an important component of the Smart City Challenge. Installing EV infrastructure, shared-use mobility options, converting public fleets and city buses to EVs, and detecting hotspots by monitoring air pollution are among the ideas proposed. 17 cities suggested inductive wireless charging in order to charge EVs and EV buses and trucks. Communication was the backbone of almost all proposals, with 53 cities proposing to implement DSRC. Also, most proposals emphasize data collection and analysis: 45 cities proposed the implementation of a central integrated transportation data analytics system, to help cities make better and faster decisions with limited resources. 9 cities proposed providing free public WiFi on public spaces and transportation. The seven finalists proposed approximately 65 unique strategies to improve jobs accessibility, training opportunities, reach under-developed areas, and ensure ubiquitous connectivity. Figure 8 provides an overview of the technology solutions proposed by the 78 cities.

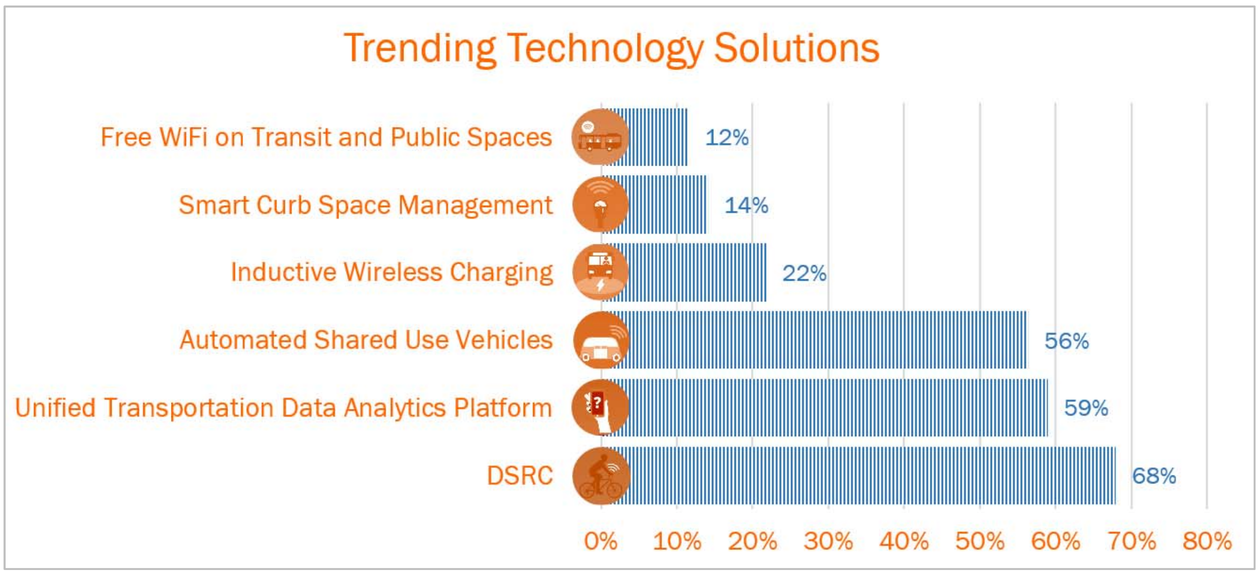



**Figure 8 Technology Proposed in SCC Vision Statement**

Generally, the focus of the proposals is on four general areas: CV, AV, parking and transit. Among all the ideas proposed, 41 cities proposed ideas for V2I and V2V connectivity (excluding pedestrians), 35 proposals directly considered employing CAVs, 32 cities addressed how one can convert current parking spaces to smart ones, and 26 proposals proposed transforming the current transit system into a smart one. The summary of technology trends is provided in Figure 9.

The remainder of this section provides additional information regarding the proposals of the seven finalists of this competition. Many of these plans may be implemented even if the respective cities where not successful in receiving funding under this program.

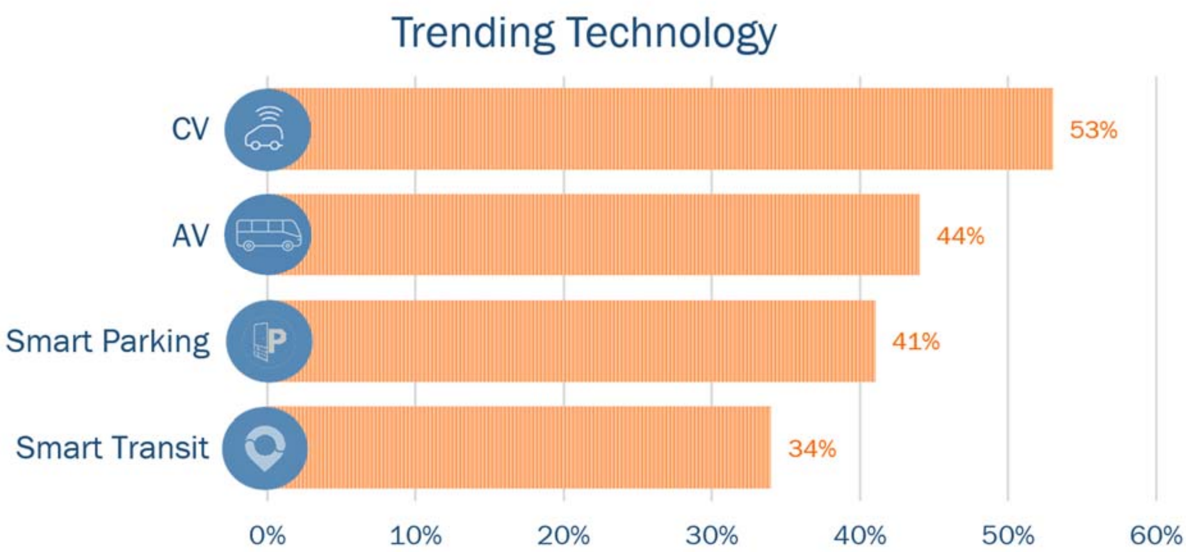



**Figure 9 Trending Technology Pilots Proposed by SCC Participants**

ii. Austin

The city is dedicated to providing safe, efficient, cost-effective and sustainable road-, bike- and walkways, and a transit system for the community [38]. The ultimate goal, as stated in the proposal, is to link underserved neighborhoods to economic opportunities and reduce the spread of poverty. Therefore, the overall plan for Austin was to develop a "Mobility Marketplace" to improve accessibility to mobility services for financially vulnerable users, older adults and disabled people. The city plans to employ ambassadors to collaborate with community organizations to educate them a out new technologies and mobility services and increase citizen involvement, particularly for those residing in underserved neighborhoods. Five major initiatives form the Austin smart city: automated and connected vehicles, EVs, sensor systems, travel access hubs and packaged mobility services.

iii. Columbus

The winner of SCC focused on infant mortality, with the goal to decrease it by 40%, and to reduce the health disparity gap by 50 percent by 2020 [39]. For this reason, Columbus indicated it will harness a new "central connected traffic signal and integrated transportation data system" and will build a set of applications to deliver advanced human services. Another plan is the integration of online doctor visit appointments with transit tracking systems to achieve automated and data driven rescheduling. These applications require a sophisticated multi-modal trip planning, a unified payment option for all modes, and cellphone apps to better serve persons with disabilities. The city has indicated it will establish a smart corridor connecting under-developed neighborhoods to jobs centers and services. The smart corridor will feature Bus Rapid Transit service by installing smart traffic signals, smart street lighting, real-time traveler information and payment, and free public Wi-Fi in vehicles and public places. Also, EVs and CAVs will be deployed to expand the BRT system.

iv. Denver

Denver targeted freight operations and aimed to make freight delivery more reliable, less air polluting, idling and noisy [40]. An integrated connected freight efficiency corridor with parking, staging areas and traffic information systems, as well as signal prioritization for freight form Denver's vision to achieve its goal.

v. Kansas City

Data and information flow is the backbone of this proposal [41]. The goal for this city is to advance their perception of urban travel to better relay and receive the information of the transportation decisions of citizens and transportation officials. Kansas City envisions extensive data collection and analysis on travel flow, traffic crashes, energy usage, and air pollution, residents' health and physical activities. The City will design an open data architecture, to allow for unlimited studies in transportation and urban systems operation, as well as other areas to empower citizens.

vi. Pittsburgh

Pollution is the focal point for Pittsburgh, and hence, the goal is to initiate EV conversion to decrease transportation emissions by 50% by 2030 [42]. Some of the projects proposed are smart street lighting, EV, and sustainable power generation for transportation. In order to reduce energy use, the city will convert up to 40,000 streetlights to LEDs. Also, these smart street lights are sensors equipped to monitor local air quality. A broad EV re-charging infrastructure is planned, along with the conversion of the city's public fleet to EVs.

vii. Portland

Ubiquitous transportation is the goal of the Portland proposal [43]. The goal is to provide access to new transportation options and comprehensive methods of making informed transportation choices to all communities, as citizens in underserved communities are more likely to miss out on new transportation technologies. Therefore, Portland envisions partnerships with community organizations to ensure that lowincome, disabled, aging, immigrant residents and other vulnerable citizens have access to transportation choices. It also considers involving residents through idea walls and canvas, supper chats, walking and van tours.

viii. San Francisco

Congestion, especially on the roadways linking to the downtown area, is the major challenge. The goal of the city is to increase the use of carpooling by regional commuters, to improve mobility and affordability and to mitigate congestion on roads and transit [44]. Some of the projects envisioned are developing dedicated connected regional carpool lanes and designate smart curb space for carpool pick-up/drop-off, apps for smartphones that facilitate instant carpool matching and for those who don't have access to cellphones, establishing carpool pickup plazas for carpool pick-up/drop-off. Also, the city considers connected infrastructure to collect and analyze data in order to track and improve the performance of carpool lanes.

Of these seven finalists, one was granted $50 million to pursue its plan, while four additional cities were awarded $6-11 million to deploy the projects they proposed. Portland and SF were awarded $11 million each to deploy smart traffic signal technology and to implement connected vehicle technologies as well as a pilot of a shared, electric, autonomous shuttle, respectively. Denver was given $6 million to deploy three project clusters: (1) to upgrade its TMC, (2) to build a CV network, and (3) to install automated pedestrian detection. Portland also will receive funding from USDOT to incorporate shared-use mobility into its current trip planning platform.

In summary, the following concepts were proposed and are being pursued by one or more of the proposers: shared data, dynamic routing for truck traffic, EV, on-demand delivery trucks, streets with dynamic markings, increasing of off-peak and overnight deliveries, affordable first mile/last mile, automated shuttles, multimodal transportation centers, and connected on-demand minibuses.

### 1.3. Activities and Deployments in Florida

Florida has been one of the most active states in promoting CAV implementation. A total of 6 cities from Florida submitted proposals for the SCC. Florida was the second state after Nevada to pass a bill allowing the operation of AVs on its highways. There are multiple pilot deployments and activities around the state. In this section we discuss existing pilots and testbeds in Florida, as well as the SCC proposals submitted by Florida cities.

- *Deployments and Pilot Activities*

i. Florida's Connected Vehicle Test Bed (Orlando)

The oldest CV initiative in Florida was launched in 2011 for the ITS World Congress as the Connected Vehicle Affiliated Testbed along I-4 in Orlando (Figure 10). FDOT developed the test-bed to find the best options to continuously and rapidly communicate information between the RSEs and the vehicles [45].

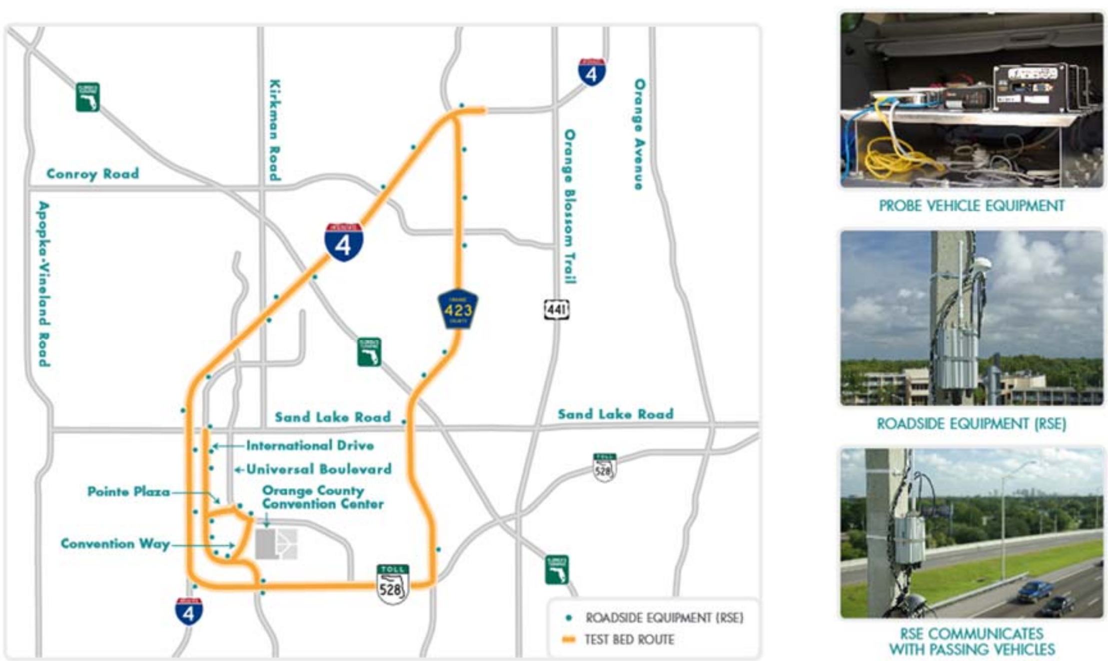



**Figure 10 Connected Vehicles Testbed- Orlando Scope**

The site features 29 radio RSU devices, which are connected to FDOT's existing 25 miles of fiber optic network. They collect information from the vehicles regarding their location and speed, and send basic safety messages (BSM) to the equipped vehicles via DSRC. Via the fiber optic network, the RSEs relay messages to/from Orlando's RTMC (FDOT's Regional Traffic Management Center), which is the hub of that network where traffic conditions are monitored 24/7. The vehicles are equipped with two-way OBE radio, a GPS-based Vehicle Awareness Device and a small computer that receives and displays information and BSM for RTMC. The testbed features a total of 11 RSEs on I-4, 7 on John Young Pkwy, 8 on International Dr., 2 on Universal Blvd, and 1 near the convention center. The RSEs provide V2I communication, data analytics, data transmission to SunGuide software, and can broadcast travel advisory messages. OBE equipment provides probe vehicle data messages, namely speed, trajectory, altitude, wiper status, airbag deployment and emissions among others, and displays traveler advisory messages, such as Amber Alert and crash and incident information. Currently the testbed is functional and the RTMC collects traffic data, namely speed and flow, from over 400 devices and 240 CCTV traffic cameras along thirty-three roadways. Road Rangers and the Florida Highway Patrol are also able to communicate with the RTMC.

ii. Tampa-Hillsborough Expressway Authority (THEA) Pilot

The third pilot project of the USDOT ITS-JPO CVPDP program is under-construction in Tampa. This project aims to leverage existing infrastructure and transform it to a smart and connected platform. It will develop a rich dataset to quantify safety and mobility efficiency and compare performance measures before and after CAV deployment [46]. The project launched in mid-September 2015 and Phases 2 and 3 are anticipated to conclude after November 2019. THEA plans the deployment of a variety of V2V and V2I apps in order to mitigate congestion, collisions, and also wrong way entry. THEA aims to employ CV technology to improve bus operations and pedestrian safety, and mitigate conflicts between transit, pedestrians, bicyclists and passenger cars at high density locations.

The Selmon Reversible Express Lanes (REL) is operated and maintained by THEA. 40 RSEs support V2I communication. The project employs DSRC to enable data and message transmissions among nearly 1,600 cars, 10 buses, 10 trolleys, and 500 pedestrians equipped with apps. THEA has partnered with The City of Tampa (COT), Florida Department of Transportation (FDOT) and Hillsborough Area Regional Transit (HART) to create a region-wide uniform CV platform that ensures interoperability and interagency collaboration [47]. With a grant of approximately $17 million, THEA envisions the deployment of three V2I and four V2V safety tests, three mobility tests, and one integrated data deployment as indicated in

Figure 11. Tables 5 and 6 list the applications to be deployed and the equipment envisioned for this project. Currently, the project is in design, with implementation and testing planned for May 2018.

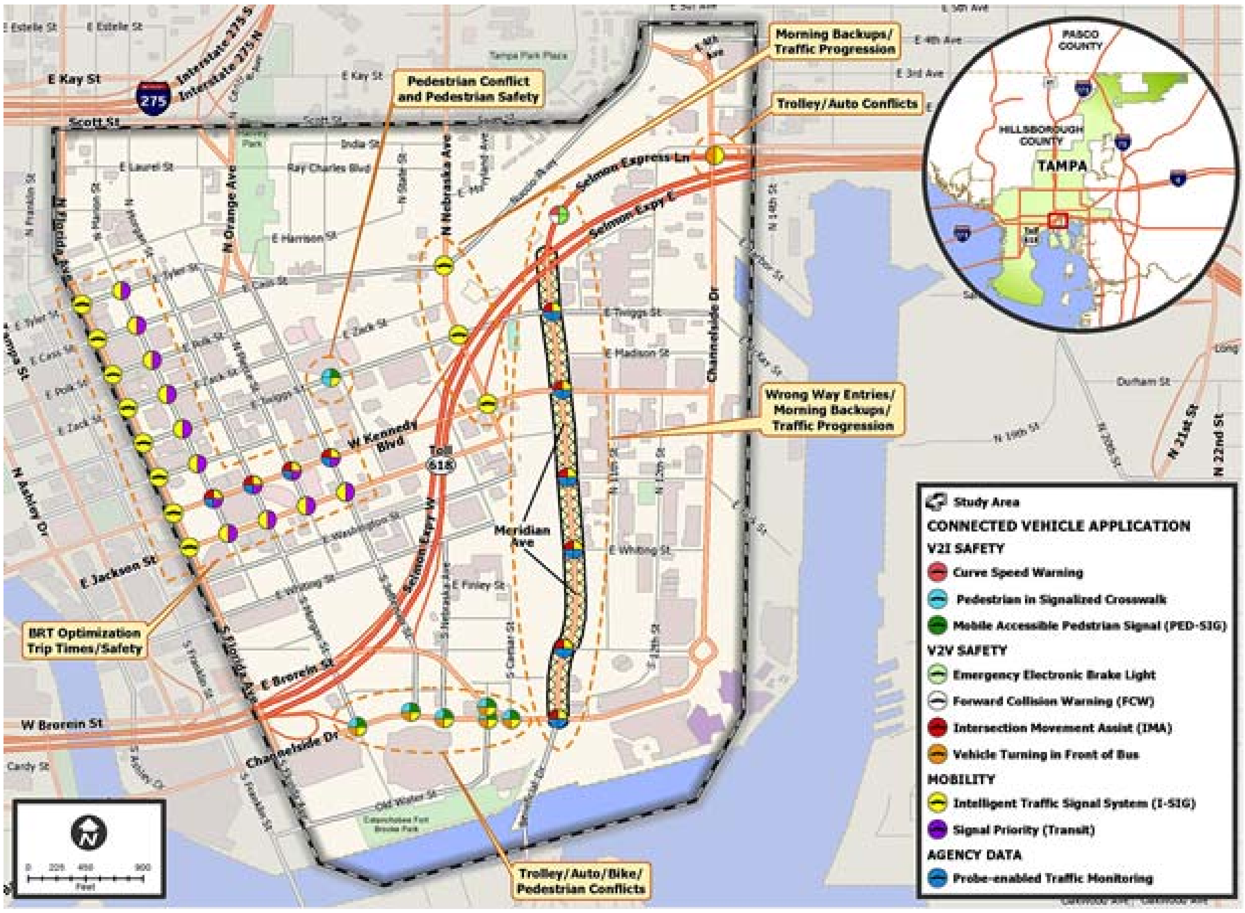



**Figure 11 The Scope of CVPDP Tampa [48]**

**Table 5 Deployment Components and Projects for Tampa Pilot**

| | Category | Tampa (THEA) – CV Application |
|---|---|---|
| 1 | V2I Safety | End of Ramp Deceleration Warning (ERDW) |
| 2 | | Pedestrian in Signalized Crosswalk Warning (PED-X) |
| 3 | | Wrong Way Entry (WWE) |
| 4 | V2V Safety | Emergency Electronic Brake Lights (EEBL) |
| 5 | | Forward Collision Warning (FCW) |
| 6 | | Intersection Movement Assist (IMA) |
| 7 | | Vehicle Turning Right in Front of a Transit Vehicle (VTRFTV) |
| 8 | Mobility | Mobile Accessible Pedestrian Signal System (PED-SIG) |
| 9 | | Intelligent Traffic Signal System (I-SIG) |
| 10 | | Transit Signal Priority (TSP) |
| 11 | Agency Data | Probe-enabled Data Monitoring (PeDM) |

**Table 6 Proposed CV Devices and Equipment- Tampa**

| Tampa (THEA) – Devices | Estimated Number |
|---|---|
| Roadside Unit (RSU) at Intersection | 40 |
| Vehicle Equipped with On-Board Unit (OBU) | 1,600 |
| Pedestrian Equipped with App in Smartphone | 500 |
| HART Transit Bus Equipped with OBU | 10 |
| TECO Line Street Car Equipped with OBU | 10 |
| Total Equipped Vehicles | 1,620 |

iii. Assessing Advanced Driver Assistance Systems (ADAS)

ADAS was a short-term pilot to determine if the MobilEye technology is capable of preventing avoidable traffic accidents. Deployment started in August 2014 with the installation of MobilEye's ADAS on approximately 50 vehicles, including light trucks, vans, and passenger cars from FDOT District 7, Hillsborough Area Regional Transit, Tampa Bay Area Regional Transit Agency, Pasco County Public Transportation, and the Pinellas Suncoast Transit Authority. ADAS includes (1) a forward-looking camera and an LED display to provide feedback as warnings in case of an anticipated forward collision, (2) lane departure alerts, (3) pedestrian/bicycle detection. However, these devices do not employ GPS modules or vehicle movement trackers. For effectiveness measurement, vehicles were equipped with GeoTab. For comparative purposes, another 50 vehicles were equipped with GeoTab only. Initial results by FDOT indicate that the system was successful in reducing the number of crashes [49].

iv. CAV/ITS Freight Applications

An initiative by the Florida Automated Vehicles (FAV) group was deployed in Miami in 2016 in order to increase safety and efficiency for freight operations. The overall objectives are to enhance trade and commerce for Florida by increasing AV adoption, and to deliver improved data and performance for stakeholders. The project includes a supply chain of three phases: measure, deploy and prioritize perishable-goods delivery. Each phase of the pilot project is sought to take between 6 months to one year. AV is capable of improving mobility efficiencies and safety along the highly repetitious freight routes of Miami International Airport (MIA). Phase one, currently underway, includes the deployment of CV to allow fleet operators and FDOT to analyze vehicle progression throughout corridors and detect bottlenecks occurring at traffic signals [49]. Phase two, currently under consideration, will connect the freight vehicles to RSE and traffic signals via the Miami-Dade TMC, while Phase three will ensure that during non-peak congestion hours traffic signal preemption will be granted to enhance delivery performance. Currently, preliminary measurement for public and private stakeholders, as well as identification of delivery routes are underway.

v. Central Florida AV Partnership Automated Vehicle Proving Ground

As discussed in the section on AV Proving-grounds in the U.S., one of the ten proving-grounds is under-construction in Central Florida to offer an opportunity for AV testing, knowledge transfer and oversee construction, as well as national and international certification for AV and tolling technologies. Started February 2017, the FDOT's Florida Turnpike Enterprise (FTE) is committed to construct a new transportation technology testing facility, entitled SunTrax. This testing site includes a 400-acre site adjacent to SR 540, and a 2.25-mile oval-shaped track located between Tampa and Orlando. The track will feature shelters, buildings, gantry structures, and a variety of RSE mounting equipment, particularly tolling equipment. The 200-acre infield of the track will be dedicated to fully-controlled CAV testing. The partnership envisioned several facilities, such as various pavement surfaces, learning laboratory, roundabouts, simulated city center, suburban and rural roadways, interconnected signalized intersections, and interchange ramps.

This partnership also includes several other projects, namely Interstate and Expressway Corridors (I-4, SR 528, and SR 540), City of Orlando Central Business District (LYNX, Bus Rapid Transit), NASA - Kennedy Space Center and the University of Central Florida (Transportation and Simulation Labs).

Currently, the design of the first phase has been completed featuring a controlled toll testing facility for AV and high-speed tolling [50].

- *Smart City Challenge Participants*

i. Jacksonville

The proposed projects include completing the city's fiber optic network, an Intelligent Traffic Signal System, installing Bluetooth travel-time origination and destination (BlueTOAD) traffic monitoring devices, app development (C2JAX) and integration of FDOT's 511, Waze and Transit Apps in C2JAX, Automatic Vehicle Location Optimization (AVL), Emergency Vehicle Preemption, Transit Signal Priority, Intelligent street and curb-side lighting fixtures, advanced video analytics, intelligent parking initiatives, dynamic wayfinding, an open data portal, and AV shuttles [51].

ii. Miami

Miami proposed 6 project clusters and a total of 32 deployable projects. Cluster one, on urban automation, includes AV friendly pump stations, an automated waste collection system, exclusive bus lanes, and red light running cameras. Cluster two (CVs) encompasses freeway and arterial connectivity, adaptive control/signal coordination, connected pedestrians, bicycles and public transportation, FHWA's new prototype for speed harmonization, real-time information on bridge openings and traffic signal preemptions. MobilEye will be deployed on public transportation vehicles expanding the current AVL tracking technology and web interface of the Trolley lines. Cluster three (Intelligent Sensor-Based Infrastructure) includes smart parking and garages, a public transit tracking and information system, multimodal system-wide traffic counts, travel time sensors, travel time sensors, environmental sensors and smart garbage collection [52].

Cluster four (User-Focused Mobility Services and Choices) is composed of Advanced traveler information systems, a city-wide transit tracking system, promoting and stream-lining the city's transit system, expanding the city's bike-sharing network, providing a safe and comfortable walking environment for short-range trips, building a smart parking infrastructure that minimizes unnecessary delays, integrating bridge opening and rail crossing information into the city's smart transportation network, "Mobility on Demand" functionality supporting car sharing services, expanding the city's water taxi services, accessibility of transit services, intersection holding areas, and the sidewalk network. Cluster five (Smart Grid, Roadway Electrification and EV's) is formed by three projects: (1) two-way communication technology, (2) the augmentation of EV recharge stations in downtown garages and (3) the dissemination to the public of information on their availability in real time. Cluster six (connected, involved citizens) focused on the use of digital decision-making tools, enhanced availability of open data and GIS, implementation of crowd sourcing platforms and strengthening and expanding neighborhood forums and other online meeting and social media platforms.

iii. Orlando

The City of Orlando proposed a variety of projects, including: adding electric-assist bikes to the bike share program, updating bike path and bike lane rules to allow bikes with electric motors and robot delivery, requiring preferred parking for alternative electric vehicles (EVs, scooters, etc.), EV charging stations for new development, smart parking, incentives to convert parking lots to other uses in tourist areas, reducing minimum parking requirements, creating neighborhood-based incentives for residents to install EV charging stations, requiring preferred parking for alternative electric vehicles, robot package delivery, creating satellite warehouses by leveraging existing uses, reserving strategic locations within parking garages for autonomous vehicles, installing solar panels on roofs of four garages and one surface lot in order to provide power to the EV charging stations and garage lighting, road diets to reclaim larger streetscape, redevelopment incentives along premium transit corridors, re-purposing city garages for car share, autonomous vehicle program for school pickup in areas not served by buses, underground utilities, smart infrastructure corridors in main streets, solar umbrellas, charging stations, tourist area as location for energy efficiency showcase, creating green spaces or tiny house development in under-used parking lots or abandoned car dealerships, partnering with Universal/Disney to adapt their crowd control tools to move people through autonomous vehicles, reviving the 2006 downtown transportation plan idea for a freight hub, but adapting for autonomous deliveries, robots and small scale storage of freight [53].

iv. St. Petersburg

Four main projects were envisioned in St. Petersburg’s proposal: (1) Aerial Cable Propelled Transit (CPT), (2) Parking and Event Management System in downtown using connected vehicle information, DMS signage, CCTV cameras and in-vehicle information systems, (3) Citywide “Wi-Fi” grid and all-new LED technology replacement and (4) Automated, On-Demand Low-Speed Vehicles/Smart Cars [54].

v. Tampa

The City of Tampa proposed 7 classes of projects with 4 projects under each category [55]:

Urban Automation

- Project 1: Automated vehicles on Reversible Express Lanes
- Project 2: Low-speed fully automated electric shuttles in downtown and at TIA
- Project 3: Automated marine and ground security vehicles at Port and TIA
- Project 4: Bus-on-Shoulder-System with Mobileye and active safety systems

Connected Vehicles

- Project 5: Additional applications leveraging THEA CV Pilot Deployment
- Project 6: Safety: Red light violation warning
- Project 7: Environment: Eco-approach and departure
- Project 8: RESCUME: Emergency Communications and Evacuation

Sensor-based Infrastructure

- Project 9: Road-side: weather, air quality, noise, traffic cameras, etc.
- Project 10: In-vehicle: position, velocity, weather, etc.
- Project 11: In-building: Indoor navigation beacons at Convention Center
- Project 12: Leveraging of USDOT's road weather products (Vehicle Data Translator, Motorist Advisory and Warnings, and Enhanced Maintenance Decision Support Systems)

Urban Analytics

- Project 13: Platform for data ingestion, processing, and decision-making support
- Project 14: Predictive analytics tools based on historical and current data
- Project 15: Goal driven capability build out
- Project 16: User-friendly and unified interface

Mobility

- Project 17: Integrated Mobility Platform for Tampa (IM-T) application
- Project 18: Solutions such as kiosks for vulnerable communities who cannot afford smart phones
- Project 19: Tampa senior center on-demand dynamic shuttle
- Project 20: Indoor navigation for improving accessibility to visually impaired

Delivery and Logistics

- Project 21: Data-driven, connected urban freight movement
- Project 22: App for Port to reduce check-in wait times
- Project 23: Freight-specific dynamic travel planning application
- Project 24: Sensor-enabled dynamic routing for trash collection

Smart grid and EV

- Project 25: Vehicle-to-grid and vehicle-to-home smart charging pilot
- Project 26: Infrastructure for EVs (static and dynamic charging)
- Project 27: Smart grid enabling intelligent infrastructure communication
- Project 28: Leverage of smart grid communication to automate traffic signals

### 1.4. Summary and discussion

Table 7 summarizes the findings of this section by indicting the main activities of the most significant testbed activities by type of category. The table lists the most significant testbeds nationally and internationally, and the rightmost part of the table indicates the types of activities underway or planned for each testbed. As shown, CV/DSRC and data analytics have been an integral part of the vast majority of testbeds and installations. The recently proposed activities tend to be more comprehensive than the earlier ones, including AVs and several additional components.

**Table 7 Review of International, National and Statewide CAV Activities**

| | | Project | Location | Scope | Start Date | Data Analytics | Smart Parking | Smart Transit | AV | CV (DSRC) | CV (Others) | Smart Signal | Smart Freight | EV platform | Shared Use | Smart Ped./Bike | Smart Curb Space |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Florida | Deployments | Florida's Connected Vehicle Test Bed | Orlando | 25 miles on I-4 / 400 RSU, 240 CCTV | 2011 | • | | | | • | | | | | | | |
| | | Assessing Advanced Driver Assistant Systems | FDOT District 7 | 100 cars equipped with MobilEye and GeoTab | 2014 | • | | | | | • | | | | | | |
| | | Tampa-Hillsborough Expressway Authority (THEA) | Tampa | 1,600 cars, 10 buses, 10 trolleys, 500 pedestrians | 2015 | • | | • | • | • | | • | | | | • | |
| | | AV/CV/ITS Freight Applications | Miami | Freight at Miami International Airport | 2016 | • | | | • | • | • | • | • | | | | |
| | | Central Florida AV Partnership | Central Florida | SunTrax / NASA-KSC / I-4, SR 528, and SR 540 | 2017 | • | | • | • | • | • | | | | • | | |
| | | University of Florida Advanced Tech. Campus Testbed | Gainesville | Campus-wide and Downtown | 2017 | • | • | • | • | • | • | • | | • | | • | • |
| | SCC Proposals | Connect to Jax | Jacksonville | City wide with a focus on Skyway, Downtown | 2016 | • | • | • | • | | • | • | | | | • | • |
| | | City of Miami | Miami | Airport, Dolphine Expr. And Downtown | 2016 | • | • | • | • | • | • | • | • | • | • | • | • |
| | | City of Orlando | Orlando | Urban, Tourist and Tech districts | 2016 | • | • | • | • | • | • | • | • | • | • | • | • |
| | | City of St. Petersburg | St. Petersburg | City-wide | 2016 | | • | • | • | | • | | | | | • | • |
| | | City of Tallahassee | Tallahassee | City-wide | 2016 | • | • | • | | | • | | | | | • | |
| | | Smart Tampa | Tampa | TIA, Selmon Expr., Downtown | 2016 | • | • | • | • | • | • | • | • | • | • | • | • |
| International | | Drive C2x | Italy and EU | SISCOGA, SAFER, SCORE@F, SIM, DITCM, COOP TS | 2011 | • | | | | • | • | • | | | | | |
| | | ACTIVE-AURORA research circuit | Alberta & BC, Canada | Alberta: three test bed sites /BC: 10 km along UBC | 2014 | • | | | | • | • | | • | | | | |
| | | AstaZero Proving Ground | Gotherburg, Sweden | 21.5 million sq. ft. / 3.5 mile highway | 2014 | • | | | | • | • | • | | | | | |
| | | Cooperative ITS Corridor: Rotterdam-Frankfurt-Vienna | North Europe | 800 miles / 4G / Netherland, Germany, Austria | 2015 | • | | | | • | • | | | | | | |
| | | National Intelligent CV testing Demonstration base | Shanghai, China | 38.6 sq. mi. along with two other research base | 2016 | | | | | • | • | | | | | | |
| | | Centre of Excellence Testing and Research of AVs (Cetran) | NTU, Singapore | 5 acre test circuit / roundabouts, slopes,sim. rainfall | 2017 | | | | • | • | | | | | | | |

Portfolio: Data Analytics through Smart Curb Space.

**Table 7 (Cont'd) Review of International, National and Statewide CAV Activities**

| | | Project | Location | Scope | Start Date | Portfolio: Data Analytics | Smart Parking | Smart Transit | AV | CV (DSRC) | CV (Others) | Smart Signal | Smart Freight | EV platform | Shared Use | Smart Ped./Bike | Smart Curb Space |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| National | CVPDP | Tampa-Hillsborough Expressway Authority (THEA) | Tampa, FL | 1,600 cars, 10 buses, 10 trolleys, 500 pedestrians | 2015 | • | | • | • | • | | • | | | | • | |
| | | Wyoming (WY) DOT Pilot | Wyoming, WY | 402 miles of I-80 / 400 Vehicle, 100 HDV / 75 RSU | 2015 | • | | | | • | | | • | | | | |
| | | NYCDOT CV Pilot Deployment | New York City, NY | 5800 cabs, 1250 buses, 400 fleet, and 500 vehicles | 2015 | • | | | | • | | • | | | | • | • |
| | Connected Vehicle Testbeds | Connected Vehicle Test Bed | Palo Alto, CA | 2-mile stretch / 11 Intersections | 2005 | • | | • | | • | | • | | | | | |
| | | Southeast Michigan Test Bed | Oakland CTY, MI | 125-mile / 50 RSEs / 9 vehicles | 2007 | | | | | • | • | | | | | | |
| | | Inform CVII NYSDOT LIE Test Bed | NYC, NY | 4 plow trucks / 31 Interstate RSEs / 8 Arterial | 2008 | • | | | | • | | | • | | | | |
| | | Denver E-470 Test / Denver Test Bed | Denver, CO | toll collection system on the E-470/ 85 RSEs | 2008 | | | | | • | | | | | | | |
| | | Turner-Fairbank Highway Research Center | Mclean, VA | Controlled facility including 3 testbeds | 2011 | • | | | | • | • | • | | | | | |
| | | The Northern Virginia Connected Vehicle Test (VCC,VAC) | Virginia, VA | 60 RSEs / I-66, 95 & 495, U.S. 29 and 50 / 12 Veh. | 2011 | | | | | • | | | | | | | |
| | | Florida's Connected Vehicle Test Bed | Orlando, FL | 25 miles on I-4 / 400 RSU, 240 CCTV | 2011 | • | | | | • | | | | | | | |
| | | MCDOT Test Bed: SMARTDrive | Anthem, AZ | 2.3 miles/11 Intersection, 6 Interchanges, 10 Freeway | 2012 | • | | | | • | • | • | | | | | |
| | | Minnesota Connected Vehicle Pilot Deployment Project | Minnesota, MN | Snow Plows and workzones across the state | 2015 | | | | | • | | | | | | | |
| | USDOT AV Proving Grounds | Thomas D. Larson Transportation Institute | Pittsburgh, PA | One-mile oval facility / dynamometer / DGPS base | 2017 | • | | | • | • | • | | • | | | | |
| | | Texas AV Proving Grounds Partnership | Texas, TX | Austin, Houston, Dallas/Arlington, San Antonio, El Paso | 2017 | • | | • | • | • | • | | • | • | • | • | • |
| | | Central Florida Automated Vehicle Partners | Central Florida, FL | SunTrax / NASA-KSC / I-4, SR 528, and SR 540 | 2017 | • | | • | • | • | • | | | | • | | |
| | | American Center for Mobility (ACM) Willow Run | Ypsilanti, MA | 2.5-mile test track with different traffic enviroments | 2017 | • | | | • | | • | • | | | | | |
| | | CCTA and GoMentum Station | Concord, CA | 5,000–acre station / 20 miles of paved roadway | 2017 | | | • | • | • | • | | | | • | | |
| | | San Diego Association of Governments | Chula Vista, CA | I-15 and South Bay Express Lanes / City of Chula Vista | 2017 | | | | • | | | | | | | | |
| | | Iowa City Area Development Group | Iowa City, IA | I-380 that connects Iowa City and Cedar Rapids | 2017 | | | | • | | | | | | | | |
| | | University of Wisconsin-Madison | Madison, WI | 400 acres of roadways /4-mile track/UW Main Campus | 2017 | • | | | • | • | • | • | | • | | • | |
| | | U.S. Army Aberdeen Test Center | Marylan, MD | Insufficient Inofrmation Available to Public | 2017 | | | | | | | | | | | | |
| | | North Carolina Turnpike Authority | North Carolina, NC | Insufficient Inofrmation Available to Public | 2017 | | | | | | | | | | | | |
| | University-Driven | SMOOTH | Ohio State Univ. | Main and West Campus | 2014 | • | | • | • | • | • | | | | | | |
| | | Township and Pittsburgh Test Bed | Carnegie Mellon Univ. | 3 Testbeds: Ross Township, - Baum-Centre, CMU | 2015 | | | | • | | | | | | | | |
| | | AACTVE | Univ. of Michigan | 5000 Veh. / 73 lane-miles / 45 street &12 freeway sites | 2015 | • | | | | • | | | | | | | |
| | | M-City | Univ. of Michigan | 32-arce Mock city | 2015 | • | | • | • | • | • | | | | | | |
| | | Campus Transportation Technology Initiative | Texas A&M Univ. | | 2017 | • | | • | • | • | • | | • | | | • | • |
| | | UW-Madison Automated Vehicle Proving Ground | UW-Madioson | 400 acres of roadways /4-mile track/UW Main Campus | 2017 | • | | | • | • | • | • | | • | | • | |
| | | University of Florida Advanced Tech. Campus Testbed | Univ. of Florida | Campus-wide and Downtown | 2017 | • | • | • | • | • | • | • | | • | | • | • |
| | SCC Finalists | Live from Austin, Vision for a 21st Century Mobility System | Ausin, TX | ABIA, IH-35, MOPAC, several US roads | 2016 | • | • | • | • | • | • | • | | • | • | • | • |
| | | Smart City, ColumbUS | Columbus, OH | CBD, OSU, Airport, Easton, Rickenbacker, Polaris | 2016 | • | • | • | • | • | • | • | • | • | • | • | |
| | | Beyond Traffic: Denver | Denver, CO | City-wide and Airport / Interstates | 2016 | • | | • | • | • | • | | | • | | | • |
| | | City of Kansas City | Kansas City, MO | Prospect Ave, Streetcar, I-70, freight park, CBD | 2016 | • | • | • | • | • | • | • | • | • | | • | • |
| | | City of Pittsburgh | Pittsburgh, PA | Smart Spine | 2016 | • | | | • | • | | • | • | • | | • | |
| | | Ubiquitous Mobility for Portland | Portland, OR | Columbia and Powell-Division Corridors | 2016 | • | | • | • | • | • | | | | | • | |
| | | City of San Franscisco Meeting the Smart City Challenge | San Francisco, CA | East San Francisco | 2016 | • | | • | • | • | • | • | • | • | • | • | • |

# 2. Automated and Connected Vehicles Testing Regulations

## 2.1. Automated Vehicles Testing Regulation: International

According to a report published on February 2015, a United Nations Economic Commission for Europe (UNECE) working party on Brakes and Running Gear (GRRF) discussed the first international regulatory steps concerning automated-driving under the auspices of World Forum on Harmonization of Vehicle Regulations (WP.29) [56] . For further information and a survey on international regulations, see [57].

## 2.2. Automated Vehicles Testing Regulation: The US

With the development of emerging technologies for autonomous vehicles, it is necessary for state and municipal governments to address the potential impacts of such vehicles on the highway system. Independent and governmental reports indicate an increasing number of states considering legislation related to autonomous vehicles. Several federal regulatory guidance and bills have been introduced on the operation and testing of AVs.

- *Federal Regulatory Guidance and Policy*

On May, 2013 NHTSA released a Preliminary Statement of Policy Concerning Automated Vehicles [58]. This statement was updated on January 2016, by the former U.S. Transportation Secretary Anthony Foxx in his announcement on the President's fiscal year 2017 budget proposal and policy guidance [59, 60]. Most recently, on September 2016, the U.S. Department of Transportation issued federal policy for automated vehicles [61]. The objective of this policy update is to facilitate every development and deployment of technologies with the potential to save lives. For this reason, in this policy NHTSA is required to (1) use all feasible tools and measures to determine the safety potential of new technologies, (2) eliminate obstacles that impede or postpone technology innovations from commercialization, (3) collaborate with governmental partners at all levels, industry, and other public and private stakeholders to develop or adopt new technologies. Along with the federal regulatory guidance and policy two federal bills, namely House of Representatives 3876 and 22, were introduced in 2015. HR 3876 requires *"the Government Accountability Office to make a publicly available report that assesses the organizational readiness of the DOT to address autonomous vehicle technology challenges, including consumer privacy protections* [62]*."* Furthermore, HR 22, has been enacted and chaptered on December 2015 [63]. Its focus is on fixing America's surface transportation (FAST Act), while Section 6025 directs GAO to assess the status of autonomous transportation technology policy developed by U.S. public entities.

On September 2016, the U.S. Department of Transportation published Federal Automated Vehicle Policy for the safe development of highly autonomous vehicles (HAVs) [64]. The draft is composed of four parts: (1) vehicle performance guidelines, (2) model state policy, (3) NHTSA’s current regulatory tools, (4) possible new regulatory actions helpful in ensuring the safe deployment of HAV, according to NHTSA. Portions of the policy report also apply to lower levels of automation, namely the driver-assistance systems already being deployed by auto manufacturers. The four components are as follows, according to the Federal Automated Vehicles Policy Overview fact sheet:

1. *Vehicle Performance Guidance for Automated Vehicles*: The guidance for manufacturers, developers and other organizations outlines a 15 point “Safety Assessment” for the safe design, development, testing and deployment of automated vehicles.
2. *Model State Policy:* This section presents a clear distinction between Federal and State responsibilities for regulation of HAVs, and suggests recommended policy areas for states to consider with the goal of generating a consistent national framework for the testing and deployment of highly automated vehicles.
3. *Current Regulatory Tools:* This discussion outlines DOT’s current regulatory tools that can be used to accelerate the safe development of HAVs, such as interpreting current rules to allow for greater flexibility in design and providing limited exemptions to allow for testing of nontraditional vehicle designs in a timelier fashion.
4. *Modern Regulatory Tools:* This discussion identifies potential new regulatory tools and statutory authorities that may aid the safe and efficient deployment of new lifesaving technologies.

This policy clarifies that states will retain their traditional responsibilities for vehicle licensing and registration, motor vehicle insurance, traffic laws and enforcement. Also, part two (model state policy) does not conflict with the states wishing to take action regarding use of AVs. The policy also includes a set of 15 top practices of the safe pre-deployment design, and development and testing of HAV’s prior to commercial sale or operation on state highways for AV manufacturers.

In March 2016, the John A. Volpe National Transportation Systems Center at the U.S. Department of Transportation published a report which identifies instances where the existing Federal Motor Vehicle Safety Standards (FMVSS) may pose challenges to the introduction of automated vehicles [65]. The core objective is to identify potential barriers and challenges for the certification of automated vehicles using existing FMVSS. This publication includes two reviews of the FMVSS: (1) a driver reference scan in order to identify the standards with an explicit/implicit reference to a human driver, (2) an automated vehicle concept scan in order to identify standards that may pose a challenge for a wide range of automated vehicle capabilities. The conclusion suggests that there are few barriers for automated vehicles to comply with FMVSS, if the vehicle is not substantially different from conventional vehicles. However, those that have significant differences from conventional vehicles, namely alternative cabin layouts, omission of manual controls among others, would be limited by the current FMVSS because many currently written standards are based on assumptions of conventional vehicle designs.

- *State House Bills and Policy*

States have been very active in introducing legislation on operation and testing of AVs. In 2011, Nevada was the first state to authorize the operation of AVs. In AB 511, Nevada authorized operation of AVs and a driver’s license endorsement for operators of these vehicles [66]. This bill defines “autonomous vehicle” and directs the Nevada DMV to adopt rules for license endorsement, testing and operation. By the end of the first half of 2012 only three states had introduced legislation; Nevada, Florida and California, with Florida being the least strict one [67]. By the end of that year, 3 other states introduced related legislation. In the following year another 6 states considered the use of AVs and in 2015 a total number of 16 states introduced legislation. In 2016 additional states introduced legislation and since last year this number has increased to 33 states. Since 2012, a total of 42 states (including D.C.) have considered legislation related to AVs (Figure 12). The remaining states either did not enact or chapter the legislation, or the bill was failed.

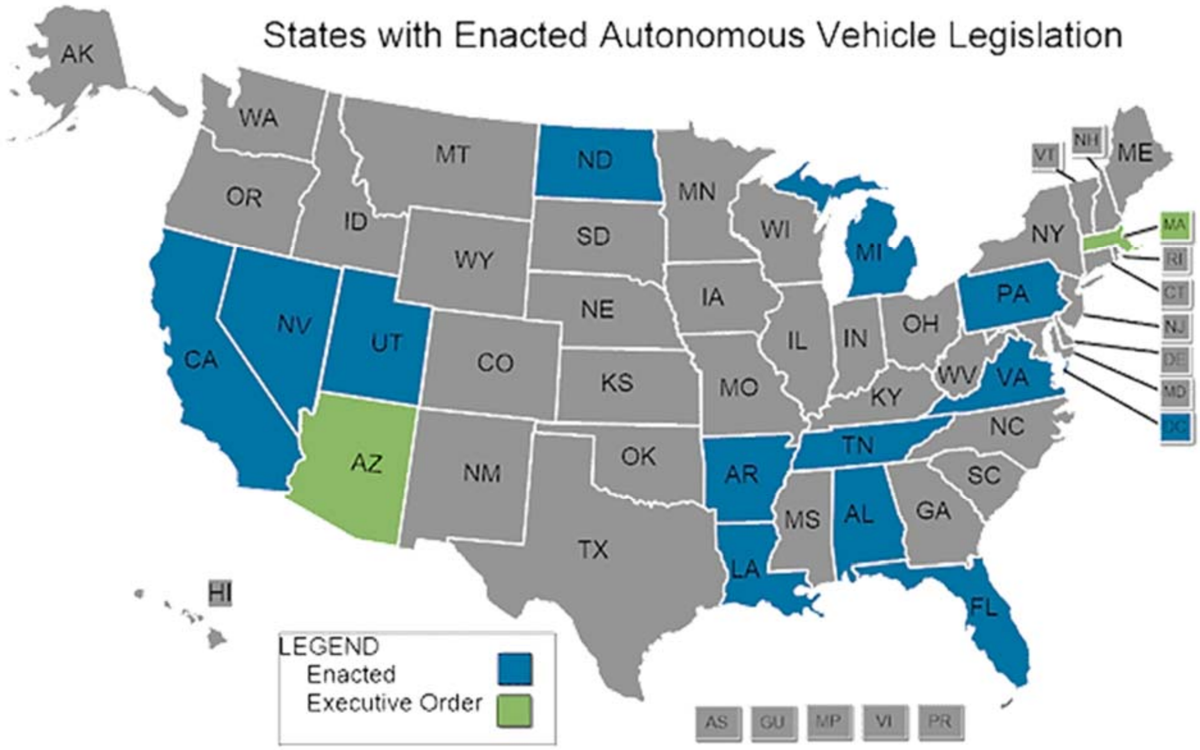



**Figure 12 Autonomous Vehicles-Self-Driving Vehicles Enacted Legislation, Available: NCSL.org [68] (Update: 5/1/2017)**

### 2.3. Automated Vehicles Testing Regulation: Florida

Florida has been one of the pioneers in considering legislation regarding highly automated vehicles (HAVs). The Florida Automated Vehicles (FAV) group has established numerous HAVs initiatives [69]. One of the connected vehicle testbeds was unveiled in Orlando along I-4 in 2011. In 2012 Florida passed House Bill 1399, sponsored by Senator Jeff Brandes, to facilitate testing and deployment of HAVs on Florida highways. Two sets of House Bills have been passed in 2012 and 2016, which declare the legislative intent of the state to promote the safe development, testing and operation of HAVs on state roads.

House Bill 1207, enacted and chaptered on April 16, 2012, defines "autonomous vehicle" and "autonomous technology" and declared the legal aim for a safe development, testing and operation of motor vehicles with autonomous technology on the state highways without any prohibition from the state and without any specific regulation on the testing and operation of autonomous technology in motor vehicles [70]. Florida's 2016 legislation (HB 7027) expanded the authorization on the operation of AVs on state highways and eliminated requirements related to the testing of AVs, such as the $5 million in insurance and the presence of a driver in the vehicle as long as an operator will be alerted in case of technology failure and will be able to stop the vehicle [71]. This bill, which was enacted and chaptered on April 4, 2016, requires AVs meet applicable federal safety standards and regulations [72].

In summary, Florida provides the maximum flexibility for those who are interested in testing their advanced technologies on public highways. An AV manufacturer is able to test their technology, as long as they are able to shut down the system remotely in emergency situations. From environmental, regulatory and technology perspective, the state of Florida is an ideal location for industry testing and research on CAVs.

## 3. Test-bed Activities from the Academic Research Perspective

University-based research has mostly focused on simulation of CAVs, development of algorithms and data management architecture, and CAV operations in various environments such as intersections and freeways. Traffic signal phasing and timing (SPaT) has also been a focal point of research in this area based on prioritizing the vehicles based on arrival sequence [73-75].

Li et al. [76] proposed a procedure to make integrated decisions on trajectory and signalization at an isolated intersection for an AV environment. Their approach entails receiving arrival information once the vehicles enter the communication range and their algorithm computes and relays the optimal trajectory to vehicles and signalization to RSU. The algorithm chooses among the trajectories with the lowest average travel time delay.

Bridgestone et al. [77] developed a micro indoor testbed for intelligent transportation systems and described the modular architecture of how they developed it. They developed the idea at the Ohio State University Control and Intelligent Transportation Research Laboratory [78-84].

There is a wealth of research on simulation of CAVs. Several articles address intersection and freeway traffic management in automated and connected environments. For example, Feng et al., formulated a multi-objective problem which re-designs adaptive signal control logic according to the input data from CVs, and employed VISSIM to compare the results to actuated systems under various scenarios [75]. Simulation is a commonly used tool for different aspects of AV and CV operations. Different research directions using simulation include, but are not limited to, autonomous reservation based intersection management [85], traffic signal control enhancement under vehicle-infrastructure integration systems [86], traffic signal dilemma zone warning systems [87], optimization of traffic flow through dynamic and individual speed advice (ODYSA) [88], controlling intersections with cooperative adaptive cruise control systems [89], traffic signal control for CVs and dynamic micro-simulation [90], autonomous vehicle merging on ramps with V2V [91], and autonomous vehicle merging on ramps without V2V communication [92].

## 4. Potential Industry Partners

To summarize industry initiatives, we assembled a list of companies that has been engaged in existing proposals and testbeds. The list was assembled through SCC proposals, ConOps, factsheets, and reports from different activities discussed in previous chapters. Industry partners are classified according to the product and service provided and features a brief description of the service/product. A point of contact is provided for each company when available. The list was supplemented by industry contacts provided by Regional Transit System (RTS) in Gainesville and the City of Gainesville. There are collaboration opportunities with a wide range of industrial sectors; autonomous and automated vehicles, advanced solution, hardware and software, IoT and consulting, and communication equipment providers.

## 5. Discussion and Conclusions

This memorandum summarizes the state-of-the-art of the CAV technologies pilots and activities. A comprehensive review on the literature examining the published literature on advanced technologies, as well as the ongoing research, testbeds across the State, US and internationally, industry state-of-the-art, federal policy and regulations was conducted.

Our literature review identified an extensive number of existing CAV activities around the globe. We have identified over 400 CAV activities, including testbed development, public road demonstrations, proving-grounds, pilots, public and private partnerships, pooled-fund research, etc. Among these the highest number of activities is located in Europe and North America (Figure 13). However, the nature, environment and setting of the CAV efforts differ widely.

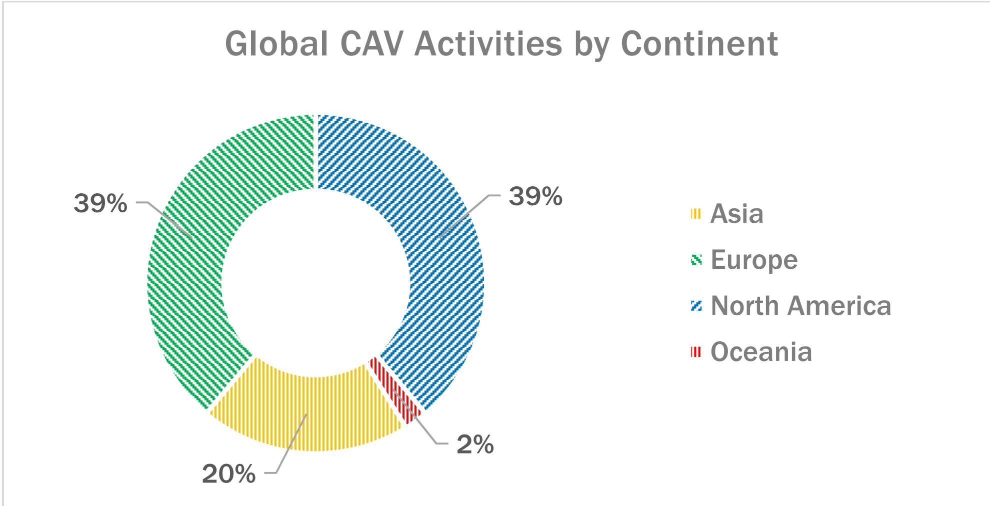



**Figure 13 Global CAV Activities**

The survey reveals that the European projects mainly focus on safety and crash avoidance through connectivity and advanced information transmission. Most of these efforts take place on public roads and are large in scope, which involve more than one country [93]. Almost all the reviewed European projects are implemented in EU countries with Germany being the CAV pioneer in terms of the number of deployments and pilot projects followed by Netherlands and Sweden.

Etrico-ITS Europe, Cooperative ITS Corridor, DRIVE C2X, HeERO, CVIS and MOBI.Europe are some of the most significant Europe-wide projects. Further information is available in [94]. All of these large-scale project aim to address transportation safety and mobility challenges through connectivity and wireless network. This approach has been constantly followed in Europe for the past 30 years.

Some European countries have also implemented national level projects. These projects seem to be more innovative than implementing ITS and connectivity applications, and have tapped on a variety of technologies, such as automated vehicles, sensor applications, etc. For instance, Germany is designing and implementing the V2X applications for automated driving under Automated Driving Applications & Technologies for Intelligent Vehicles (AdaptIVe) program [95]. Also, Germans initiated a project to provide the vehicles with internet connectivity in the Wolfsburg urban area. They initiated projects on automated vehicles under Highly Automated Vehicles for Intelligent Transport (HAVEit) in 2008, in which they focused on AVs and how other drivers interact with these vehicles [96]. This project was tested in the Volvo test track in Sweden with 6 AVs. One of the most notable projects in Germany is KONVOI, which employed Advanced Driver Assistance Systems for truck platooning, and Future Truck 2025, which developed a highway pilot system on trucks.

**Table 8 Continent-Wide Advanced Transportation Activities in Europe**

| | Project | Start Date | Description |
|---|---|---|---|
| Europe-Wide | European Road Transport Telematics Implementation Coordination Organization (ETRICO)-ITS Europe | 1992 | EU supported partnership with 27 completed ITS-**Connectivity** projects and 19 ongoing projects on safety, mobility and environment |
| | European project CVIS (Cooperative Vehicle-Infrastructure Systems) (FEHRL) | 2006 | EU-wide project composed of 60 partners to create a wireless network between vehicles and infrastructure (**V2I**) to increase safety and efficiency |
| | Driving Implementation and Evaluation of C2x Communication Technology (Drive C2x) | 2013 | **V2X** communication system in 7 European countries. Each country encompasses a cluster of projects. |
| | Cooperative ITS Corridor (Rotterdam - Frankfurt/Main - Vienna) | 2015 | 800 miles cross-national North-European ITS Corridor with work zone warning and probe vehicle data through **DSRC and Cellular** communication technologies |

Sweden has been one of the leading nations in the world which concentrated on different aspects of advanced transportation. Drive Me (Self-Driving Cars for Sustainable Mobility) was a project introduced by Volvo in 2014 to develop 100 autonomous vehicles on public roads in Gothenburg, Sweden. In the same year, Sweden opened a high-tech $70 million testbed, named AstaZero. The origin country of Vision-Zero [97] is extensively focused on safety through Sensor detection and shared data. Test Site Sweden (TSS), SAFER and SAFTRE are some of many activities on safety improvement in Sweden.

The French initiated Advanced Urban Mobility Platform (AUMP) in 2013 to address shared mobility and cab pool applications through technology. Same year they concentrated on low-speed automated vehicles in Automatisation Basse Vitesse (ABV) project. Italians introduced Intelligent Co-Operative System in Cars for Road Safety (I-WAY) project which focuses on car co-operate systems, and VisLab Intercontinental Autonomous Challenge in 2010, which was similar to DARPA Grand Challenge in the U.S. Dutch kicked off a similar competition as Grand Cooperative Driving Challenge in 2011, which required the participating teams to develop cooperative adaptive cruise control systems. Sensor-City was another project initiated in Assen, Netherland, which was a 3-years pilot on sensor-based mobility services to improve mobility through data collection from infrastructure and analysis. For further information on European activities, readers may refer to [13, 98].

In Asia and Oceania, Japan has almost half of all CAV projects in the continent (Figure 14). Most of the efforts in Japan are at the national level and focus on various aspects of ITS. Similar to the European projects, private sector tests and releases technology once the projects are deployed. '*Driving Safety Support Systems (DSSS), 'Smartway', 'Start ITS from Kanagawa, Yokohama (SKY)'* are among the most known Japanese CAV efforts. The majority of the projects in Japan revolve around safety through communication and common ITS applications. In fact, Japanese seem to be interested in V2X and common ITS and communication applications rather than autonomy and other advanced transportation activities. However, there are some projects that focus on the applications other than connectivity. For example, New Energy and Industrial Technology Development Organization (NEDO) introduced automated truck platooning system in 2008 with the use of a variety of sensors and communication modes. Also, in 2013 Nissan performed a public road autonomous vehicle testing in Kanagawa.

South Korea is the second largest nation for CAV initiatives in Asia/Oceania. Apart from safety and mobility ITS pilots, Koreans have embraced the idea of ubiquitous transportation and Smart City (U-City, for instance). They use a variety of applications, as well as universities' expertise, to transform urban areas into smart cities (e.g., Seoul, Busan, Jeju, Incheon-Songdo and Paju-Woonjeong) [99]. Along with U-City, National ITS 21 Plan is the largest ongoing project in South-Korea. It is fair to claim South-Korea from Asia, Sweden from Europe and the United State from America are the pioneer of CAV activities which target objectives beyond V2X connectivity.

China has been active in a wide variety of CAV activities, from controlled testbeds to public road demonstrations and pilots of different scales and scopes. *'Automated New Energy Vehicles Partnership', 'National Intelligent Connected Vehicle Testing Demonstration Base', 'GM & Shanghai Automotive Industry Cooperation (SAIC) Automated Vehicle Activities' and 'Star Wings Project'* are among the largest CAV activities in China. Among other Asian countries, Singapore has been investing on several controlled testbeds and public road CAV projects. *'I-Transport Systems', 'Automated Electric Vehicle Partnership', 'Singapore-MIT Alliance for Research and Technology (SMART)', 'One-North Public Roads Automated Vehicle Deployment'* are some of the funded and/or deployed projects. For further discussion readers may refer to [8].

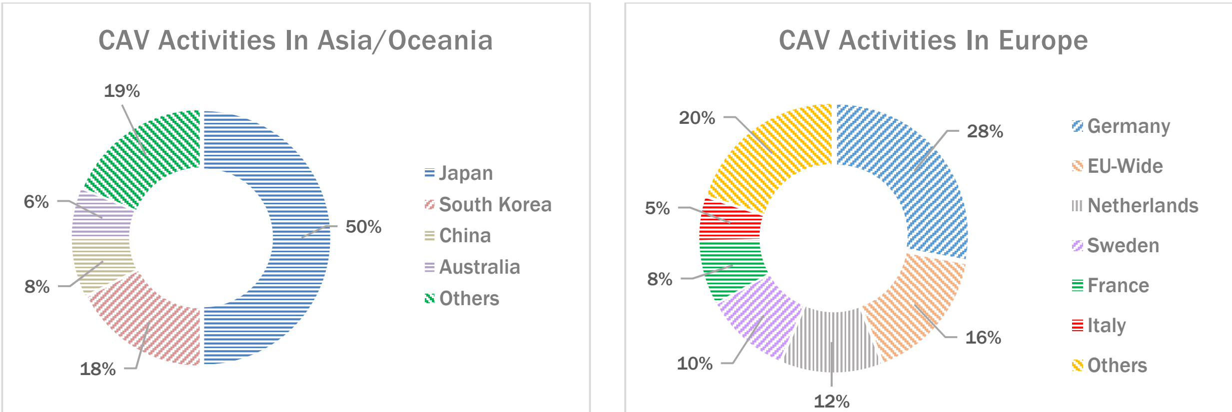



**Figure 14 CAV Activities in Asia/Oceania and Europe**

In summary, over 30 countries have been exploring CAV technologies. Some of the European and Japanese deployments and pilot projects have proven the capability of CAV in improving transportation systems. Activities in Europe typically involve large-scale coalitions of governments, as well as academia and industry. Japan has already deployed a CV network using cellular, infrared and DSRC communication. In addition to the activities discussed, Belgium, Spain, Italy, Finland, Norway, UK, Switzerland, Turkey and Israel in Europe, and also Qatar, United Arab Emirates and Iran from the middle-east have conducted CAV activities. Table 1 summarizes these efforts along with their location, features, start date and CAV technology components. In order to create this table, we developed a data-base of all activities and project components, then sorted them in terms of their frequency in different projects and selected the top 12 components. These 12 represent are in harmony with the USDOT's 13 elements of a smart city as discussed in Beyond Traffic 2045 [100] and covers the majority of various advanced transportation element, from CAV and EV to smart parking and freight.

Referring to the projects listed in Table 7, we conducted several technology trend analyses. Figure 15 summarizes significant milestones in CAV activities. As shown, 2011 and 2015 were important turning points in CAV research, partnership and activities. After 2011, there has been significant research and general interest in CAVs, while in 2015 several initiatives were introduced (the CVPDP was introduced, the FHWA deployment guideline was published, and the SCC was announced.) Therefore, in our trends analysis and in order to evaluate changes in technology trends over the course of time, we divide the time horizon into three sections: before 2011, between 2012 and 2015, and 2016 and after. Figure 16 depicts these trends for each major CAV technology category (see portfolio in Table 7).

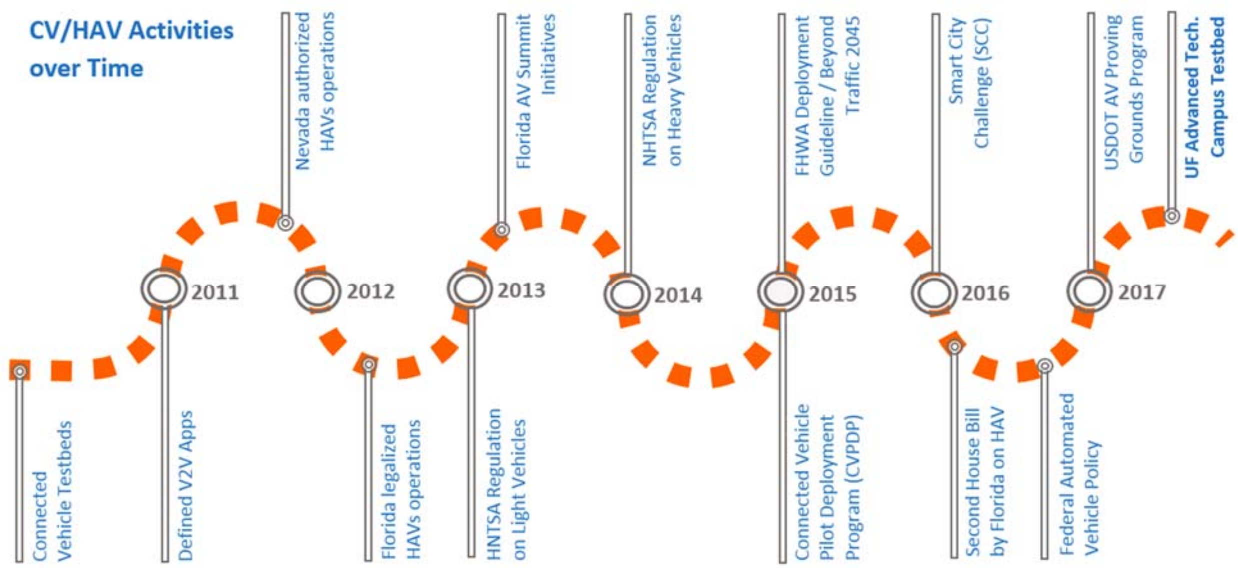
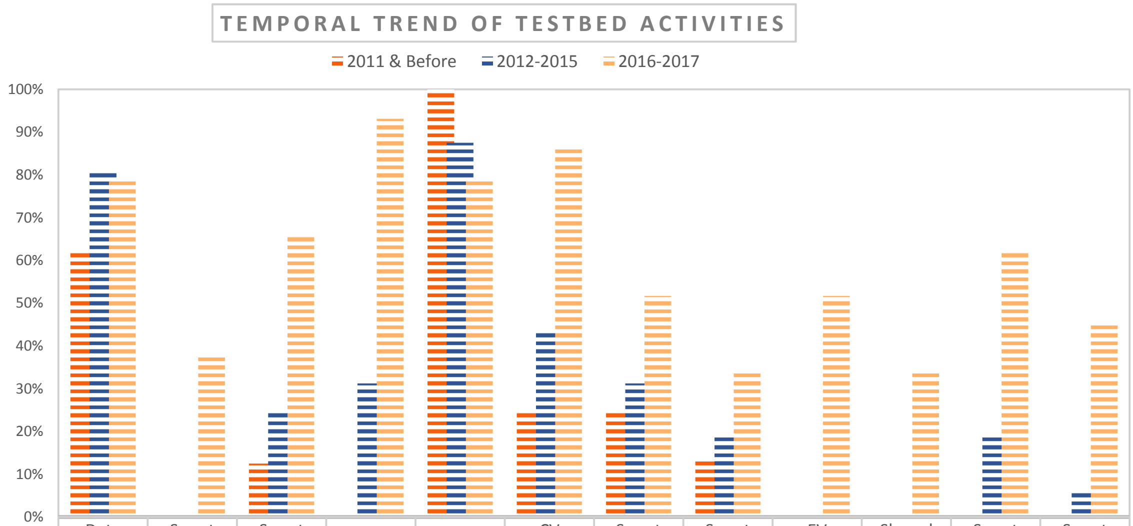



**Figure 15 Significant Milestones in CAV Activities**

Several interesting trends can be observed. The ideas of smart parking and initiatives, as well as shared use were never mentioned in the projects before 2016. Although EV technology is not too recent, the incorporation of EV platforms in the smart testbed projects was not discussed before 2016. Having pedestrians and bicyclists equipped and connected was only considered after 2012 and interest on this topic has increased rapidly in the past 1.5 years. Similar trends are observed for AV and smart curb space management, which have increased up to 5-fold in the past 1.5 years compared to the previous 4 years combined. In addition, highly automated vehicles (SAE level 4 and 5) is the most popular component of today's test-beds, and 93% of the testbed documents include it. Connectivity (other than DSRC), use of intelligent signals and focus on transit follow similar patterns.

On the other hand, the popularity of DSRC consideration has been reduced over time. In fact, DSRC used to be the only communication type discussed, while in the past 1.5 year, other types, most significantly cellular and Wi-Fi have gained more popularity. Although DSRC has a low latency time, is secure and reliable, it is limited in the amount of data it is able to relay. Also, the latency and security of other communication modes has been improving, which makes it possible to assume DSRC may someday in the near future be replaced by new generations of wireless technologies.




| | Data Analytics | Smart Parking | Smart Transit | AV | CV (DSRC) | CV (Others) | Smart Signal | Smart Freight | EV platform | Shared Use | Smart Ped./Bike | Smart Curb Space |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2011 & Before | 63% | 0% | 13% | 0% | 100% | 25% | 25% | 13% | 0% | 0% | 0% | 0% |
| 2012-2015 | 81% | 0% | 25% | 31% | 88% | 44% | 31% | 19% | 0% | 0% | 19% | 6% |
| 2016-2017 | 79% | 38% | 66% | 93% | 79% | 86% | 52% | 34% | 52% | 34% | 62% | 45% |

**Figure 16 Trends for Major CAV Technology Category**

# Appendix B: Research Peer Exchange 2017

FLORIDA DEPARTMENT OF TRANSPORTATION

FDOT

# RESEARCH PEER EXCHANGE 2017

## FINAL REPORT

[Prepared and submitted in accordance with 23 CFR 420.207(6)(b)]

FDOT Research Center
605 Suwannee Street, MS 30
Tallahassee, Florida 32399
April 25-27, 2017

## Acknowledgments

The Florida Department of Transportation Research Center wishes to express its great appreciation to those who joined us for our 2017 Research Peer Exchange. The three days of presentations, interactions, and brainstorming provided valuable insight into state DOT research roadmaps in the contexts of national agenda/activity and emerging technologies – how a program can work to be aware, agile, and relevant in this environment. The following report records the many ideas that came out of the peer exchange, which will provide a solid basis for a plan of action. Names and contact information for the principal discussants is provided in Chapter VII of the report.

Pictured above:

# Table of Contents

# List of Acronyms

| | |
|---|---|
| AASHTO | American Association of State Highway Transportation Officials |
| AV | Automated vehicle |
| AVAIL | Albany Visualization and Informatics Lab, an initiative in the Lewis Mumford Center at the University at Albany, State University of New York |
| Caltrans | California Department of Transportation |
| CV | Connected vehicle |
| DOT | Department of Transportation |
| DRISI | Division of Research, Innovation, and System Information, a division of Caltrans |
| EAR | Exploratory Advanced Research, an FHWA program |
| FDOT | Florida Department of Transportation |
| FHWA | Federal Highway Administration |
| GDOT | Georgia Department of Transportation |
| NCHRP | National Cooperative Highway Research Program |
| NDS | Naturalistic Driving Survey, a project of SHRP 2 |
| RAC | Research Advisory Committee, an AASHTO committee |
| RFP | Request for Proposal |
| ROADS | Reliable Open Accurate Data Sharing, an FDOT project |
| SCOR | Standing Committee on Research, an AASHTO committee |
| SHRP 2 | Second Strategic Research Highway Program, authorized in 2009 |
| TPF | Transportation Pooled Funds, an FHWA mechanism for funding multistate research |
| TRB | Transportation Research Board |
| TSM&O | Transportation Systems Management & Operations |
| UAS | Unmanned aerial systems |
| UF | University of Florida |
| UFTI | University of Florida Transportation Institute |

# I. Introduction – Welcome, Overview, and Objectives

The FDOT Research Program receives approximately $14 million a year to support its annual research program, which includes pooled fund and cooperative research. Most research is performed by state universities. The Research Center's website, http://www.fdot.gov/research/, includes final reports, summaries of final reports, *Research Showcase* magazine, and other information. The Technology Transfer (T2) program for the state is administered by the University of Florida.

23 CFR Part 420, Subpart B, contains four provisions that each state must meet to be eligible for Federal Highway Administration (FHWA) planning and research funds for its research, development, and technology transfer (RD&T) activities. One requirement is to conduct peer exchanges that consider for improvement the state's RD&T management process or some aspect of the research program and to be willing to participate in peer exchanges held by other states' programs. This report documents the Florida Department of Transportation's peer exchange held on April 25–27, 2017, in partial fulfillment of these requirements.

Members of this Peer Exchange team included

Steve Andrle – Transportation Research Board (TRB)

Ray Derr – National Cooperative Highway Research Program (NCHRP)

Darryll Dockstader – FDOT Research Center

Dr. Lily Elefteriadou – University of Florida

King Gee – American Association of State Highway Transportation Officials (AASHTO)

Joe Horton – Caltrans

David Jared – Georgia DOT

David Kuehn – FHWA Exploratory Advanced Research (EAR) Program

Dr. Catherine T. Lawson – University of Albany

James Lou – IBM

Mark Norman – TRB

Dr. Christopher Poe – Texas A&M Transportation Institute

David Sherman – FDOT Research Center

Sue Sillick – Montana DOT

Other participants observing the exchange included

April Blackburn – FDOT

Tom Byron – FDOT

Ed Hutchinson – FDOT

John Krause – FDOT

Aschkan Omidvar – University of Florida

Teresa Parker – FHWA

Raj V. Ponnaluri – FDOT

Jeri Shell – University of Florida

Brent Shore – FDOT

Jessica VanDenBogaert – FDOT

Each of FDOT's peer exchanges has been substantially different in composition and theme. The first (1997) focused on overall research program management; the second (2002) on opportunities for enhancing the Research Center's relationships with FDOT project managers and universities; the third (2007) on strategic project visioning; and the fourth (2013) on implementation and performance measurement.

State DOT research programs are applied research programs, historically focused on materials and structures. In the last several years, the pace and nature of FDOT's research program have evolved. Increased emphasis on implementation and performance, along with accelerating technology cycles, have placed greater demands on the program to innovate, partner, monitor sometimes hard-to-find or mountainous amounts of relevant activity, and implement and measure outcomes. The theme of this fifth peer exchange was to discuss state DOT research roadmaps in the contexts of national agenda/activity and emerging technologies—to explore how a program can work to be aware, agile, and relevant in this environment.

The report follows the format of the panel and working sessions for the first two days of the exchange (the agenda is presented in appendix A). Three panel sessions were held on day one, focusing on national activity, university and industry activity, and state DOT activity, respectively. The afternoon working session focused on the concept of a transportation research roadmap. The goal of the first half of day two was to workshop and synthesize the ideas generated from a presentation on the FDOT ROADS (Reliable Open Accurate Data Sharing) initiative and its implications for research data needs and data creation. The afternoon of day two was devoted to emerging technologies, typified by, but not limited to, automated and connected vehicle issues, and, in the context of the previous sessions, with the goal of developing recommendations for program improvement. Exchange presentations may be found in appendices B and C.

# II. National, Industry and University, and State DOT Convergence

## 1. Participant Presentations on Respective Discourse Concerning Emerging Technologies

Participants delivered presentations discussing research roadmaps, strategic process, emerging technologies, and data. The presentations were delivered across three panel sessions moderated by Steve Andrle and Darryll Dockstader. The following is a list of presentation titles and descriptions in order of delivery. PowerPoint slides for each presentation appear in appendix C.

### Panel 1 – The National Picture

Moderator – Steve Andrle

#### King Gee – AASHTO

***Presentation title: "Strategic Research in Context"***

Although transportation infrastructure is often considered slow changing, the reality is that there are forces within the transportation sector, outside the transportation sector, within a state, and nationwide that are poised to transform traditional paradigms. Strategic research must anticipate and support an agency's ability to manage and address those changes. The presentation briefly examined these forces and noted some success factors.

#### Ray Derr – NCHRP

***Presentation title: "NCHRP's Research Roadmap Experiences"***

Derr discussed NCHRP's experience with roadmapping for their research efforts, including SHRP2, Connected Vehicles/Automated Vehicles, and Transformational Technologies.

#### David Kuehn – FHWA EAR

***Presentation title: "A Map is to Research as Directions are to…"***

Kuehn discussed purposes, approaches, and uses of research roadmaps.

#### Mark Norman – TRB

***Presentation title: "Transformational Technologies – Transforming Research"***

Norman discussed potential impacts of transformational technologies on our transportation goals, the range of prospective positive and negative outcomes, the role of research in leading us to positive outcomes, and how our approaches to research itself may have to change in an era of transformational technologies.

## Panel 2 – Universities and Industry

Moderator – Steve Andrle

#### Dr. Christopher Poe – Texas A&M Transportation Institute

***Presentation title: "Bridging the Gap to Deployment"***

Poe discussed the needs of, and approaches to, research and testing of automated and connected vehicle technologies. He highlighted work from both Texas and Florida on automated vehicle proving grounds and the importance of partnerships for pilots and early deployments.

#### Dr. Catherine T. Lawson – University of Albany

***Presentation title: "The Road to the Future is Paved with Data"***

While transportation professionals have a long history of using data, new techniques and data sources are creating amazing opportunities and daunting challenges. New York State DOT has taken on the challenge by utilizing data science approaches to meet their data needs (e.g., use of NPMRDS to develop route-level tool suites). Universities have a key role in assisting transportation agencies in advancing their understanding of how best to navigate into the future.

#### Dr. Lily Elefteriadou – University of Florida

***Presentation title: "Developing a Transportation Testbed in Gainesville, Florida: From Concept to Implementation"***

Elefteriadou provided background and motivation for the development of this testbed, along with the overall concept and plans for implementation. She also discussed ongoing research at UF on autonomous/connected vehicles. The presentation closed with thoughts on the essential elements for successful implementation.

#### James Lou – IBM

***Presentation title: "Transforming Transportation Management with Cognitive ITS Infrastructure"***

## Panel 3 – State DOTs

Moderator – Darryll Dockstader

**David Jared – Georgia DOT**

***Presentation title: "Strategic Research at Georgia DOT"***

Jared provided an overview of GDOT's entire research program, emphasizing development of research aligned with GDOT strategic goals and the structure supporting such development. Some limited discussion of research roadmaps was included.

**Joe Horton – Caltrans**

***Presentation title: "The Caltrans Research Process"***

The presentation discussed the research operations of the Caltrans Division of Research, Innovation, and System Information (DRISI). The presentation covered the mission of DRISI, its research services, governance, and research development. Special attention was given to the areas of research roadmaps, research prioritization, and the handling of emerging technologies.

**Sue Sillick – Montana DOT**

***Presentation title: "Research Roadmaps: Communication, Coordination, and Collaboration"***

The presentation focused on the MDT (Montana Department of Transportation) solicitation, prioritization and selection process as well as the coordination and collaboration needed to overcome barriers, making sure the right "players" are involved both nationally and at the state level. Additionally, tools and mechanisms were discussed.

# III. Concept of Transportation Research Roadmaps

Darryll Dockstader led an in-depth discussion on the concept of a transportation research roadmap, during which participants discussed opportunities and desired outcomes. Key points of this discussion included:

Distinguishing between categories (below), which are thematic, and goals, which have direction and measurable purpose

Safety

Mobility

Tech transfer

Information

Equity

Sustainability

Economic development

Determining the goals FDOT will pursue

Ideas on collaboration including semiannual meetings to revisit transformational technologies issues

Meetings to consist of a group of 20-30

Standing groups could be a challenge since it doesn't fit traditional models of procurement.

Discussion on how big data is a complementing, vital component

# IV. Data and Research

April Blackburn, Chief of Transportation Technology at FDOT, delivered a presentation on the FDOT ROADS initiative which was developed to improve data reliability and simplify data sharing across FDOT, which is vital to decision-making.

The participants actively discussed issues raised within and by this presentation, including the following:

Communicating throughout the data-gathering process is key to ensure consistent submission of data to allow FDOT to set up mechanisms to best share data among various users.

Leveraging of expertise to reduce duplication and increase accuracy of data being collected

Collaborating across multiple disciplines in an effort to understand data needs and develop software

Exploring the initiative’s three vital components:

Leveraging available research

Requesting additional research

Collaborating

Engaging with industry

# V. Emerging Technologies

David Sherman, Research Performance Coordinator for the FDOT Research Center, delivered a presentation highlighting various test beds and initiatives ongoing in Florida.

Following this presentation, Dr. Raj Ponnaluri, State Arterial Management Systems Engineer with FDOT, led a discussion on Transportation Systems Management & Operations (TSM&O) emerging technologies within the Traffic Engineering & Operations Office.

These presentations stimulated a discussion among attendees demonstrating a consensus on the importance of having strong partnerships, including engagement with industry, university, and DOT teams. Collaboration is vital to gain objectivity as well as validation and replication.

# VI. Conclusions

This peer exchange benefited from a vibrant team that generated a great deal of mature consideration of the issues. The various perspectives of the state agency, federal, academic, and industry participants made for valuable discussion.

## 1. Participant Takeaways

### Steve Andrle – TRB

#### No Brainers

1. Align research and field test program with Florida DOT goals and objectives.

2. Continue developing the ROADS data management program.

#### Ideas

3. Conduct research on "cognitive architecture" and data platforms as recommended by James Lou (IBM) and Catherine T. Lawson (University at Albany).

4. Hire or gain the capability of a data scientist to help structure DOT data.

5. Spend some time and money planning for ingesting and using data from research and field tests. This is a subset of number 4. Look at APIs, open source programming, and other new ways to connect data and users. The data platforms or at least a data framework for research needs to be established.

6. Explore the Capability Maturity Model for planning progress. See SHRP 2 R06 report. Andrle will supply a copy, and it is also available on the TRB website under data and resources (see below).

7. Develop a partnership strategy to capitalize on the test beds and proving grounds in Florida. Take advantage of Florida's favorable laws on operating automated vehicles. Communicate this capability.

8. Set aside funding for selective implementation of research results. This may mean taking a project from the field test stage to demonstration.

9. Investigate "automated reporting" of results from Florida's nine research universities, four test beds, and private AV deployment sites (e.g., Babcock Ranch). This can start with simple

progress reports and move toward sharing data. Link to others who are (or should be) reporting on the ten national proving grounds, Smart Cities winner and applicants, the National Connected Vehicle Test Bed, and TRB's forum on Preparing for Automated Vehicles.

***Capability Maturity Model*** – This stepwise model can be combined with steps that need to be taken to achieve each level to form a matrix for future actions.

**Levels of Maturity**

1. Initial – Disorganized; Work characterized by individual effort needs champions to progress.
2. Repeatable – Processes are documented and repeatable.
3. Defined – Organization has adopted the process and developed standards.
4. Managed – The organization monitors and controls.
5. Optimized – Constant improvement and feedback.

## Ray Derr – NCHRP

**Takeaways for my work**

1. The system for ranking NCHRP problem statements has been embellished over the years but remains basically the same. Elements of the California Research Prioritization Methodology might be useful in reshaping it, particularly in better aligning the program with AASHTO's Strategic Plan.
2. The AASHTO Standing Committee on Research has asked AASHTO committees to develop research roadmaps. The examples provided during the peer exchange could be useful models.
3. Some of Derr's new projects touch upon the data science issues discussed, and he will be better equipped to incorporate them into the panel and scope of work. Derr thinks the Automated Traffic Signal Performance Measures website hosted by the Utah DOT (http://udottraffic.utah.gov/atspm) represents a good model for getting started on open data platforms that facilitate data analytics.

Florida DOT is interested in a broad range of emerging topics, from automated vehicles to bridge sensor systems. A critical need for any of these topics is to obtain a good understanding of what has been learned, either from other research efforts (public sector and private sector) and other deployment efforts. For some problems or issues identified by FDOT staff, a quick literature review would suffice, particularly if it identifies a viable solution. For others, identifying experts from other states and bringing them in for a workshop could be effective. FDOT may decide that some issues warrant a sustained research effort that would benefit from developing a research roadmap, and several examples were presented. For emerging technologies, the rapidly changing environment reduces the viability of a long term plan, and the DOT may be best served by shorter-term, more agile approach. These efforts would benefit from input from a wide range of stakeholders beyond FDOT, including the private sector, academia, and local agencies.

For the testbed being developed through the University of Florida, a diverse oversight group would be useful in setting priorities for activities to be undertaken. Some of these should aim to replicate or validate similar efforts conducted at other facilities in the United States and internationally. Establishing ongoing communications channels with the other testbeds would be valuable in coordinating research efforts and disseminating information and results. The NCHRP has some projects getting underway that could help with these coordination efforts.

## Dr. Lily Elefteriadou, University of Florida

1. For the testbed it is important to schedule 6-month reviews with stakeholders (a "Transportation Innovation Forum"?). One of those could be scheduled in conjunction with the annual FAV conference. This review should discuss success stories/performance measurement, other developments around the country and internationally, tech transfer opportunities, decisions on new research, and industry partnerships.

2. The testbed plan should consider both a bottom down and a top up approach. It should consider the overall goals of FDOT (for example, Safety, Mobility, Information/Decision making, Sustainability (including maintenance needs), Equity, Tech transfer, Economic development), and also the availability of new technology and opportunities that can be pursued provided they meet one of the main goals.

3. Projects can be categorized into "families" and frequent meetings should be scheduled with the researchers and stakeholders of each such family to ensure coordination.

4. We should explore collaboration opportunities with the TTI testbed. One item discussed was specifically related to developing a joint RFI for industry.

5. Learned a lot about data analytics and visualization, and we are planning a workshop in early fall, to bring in researchers and practitioners that work in these areas to discuss different approaches and implementations for consideration in our data analytics work for the testbed.

## King Gee – AASHTO

### Key Ideas/"Take-Aways"

A "Strategic Road Map" seems a bit contradictory in that being strategic necessarily means one may not want the level of detail in it that a "route map" has to have to guide the way.

"Strategic" implies "direction" – even though the destination may be unclear today, it is still essential to have a general sense of the way forward, which will be clearer as the journey progresses.

Strategic goals need to be "goals" and not general topic areas, e.g., "safety" is a subject area, and a safety goal might be "reduce traffic fatalities."

When thinking strategically in the evolving transportation space, we need to think of it as a system (systems thinking) by seeing the infrastructure, the vehicle, and the driver/passenger as a whole. Previously, decisions in one area were "silo-ed," not affecting the other two.

The innovations and innovative thinking of academia and industry need to be leveraged and unleashed from traditional limits.

This new perspective will be challenging and may require that research contract agreements include provisions to pivot as new information and advances come to light.

The new transportation space will bring new business models with old and new partners where FDOT needs to consider its negotiating position strengths to get the best terms for itself and the citizens of Florida.

A key strategic consideration for FDOT is where it wants to be in, say, 30 years, and what role(s) it wants to be positioned for within Florida and nationally.

The illustrations provided by FDOT's Transportation Technology initiative and the TSM&O strategic plan are great examples of proactive strategic direction taken by FDOT supported by specific and concrete actions,

Research can help answer the "where" and "roles" for FDOT and provide options for actions to support its journey forward,

Regarding the emerging areas of CVs and AVs and the UF testbed, FDOT should set some general direction and eventually define some specific functions and desired research answers to be served by the testbed for Florida's aspirations.

Given the emerging nature of this space, a tremendous service would be provided by initiating a forum for testbed managers from around the country to meet periodically:

To share trends and progress seen at their respective testbeds

To identify areas for collaboration and coordination

To articulate and reach consensus on gaps that need to be filled with research

To present a single point of contact for peer institutions from abroad.

Ultimately, a key premise should be that emerging technology and potentially transformative technology should be positioned to serve transportation goals and not merely be advanced because they are new and “shiny.”

Unintended consequences may occur, and research should identify the breadth of unintended consequences that may be unwanted and should note early signs of such consequences emerging so that policy steps may be taken to mitigate negative impacts.

## Joe Horton – Caltrans

### Caltrans FL Peer Exchange Take-Aways

1. Caltrans wants to improve the implementation and communication of research. The FDOT Research Coordinator position is an intriguing idea that we may incorporate into our business practices.

2. FHWA gave a presentation on research roadmaps that will help Caltrans refine our processes. Differentiating between a landscape roadmap that helps you decide where to go versus a route-style research roadmap that lays out the process to get to the results.

3. Learning about the FL testbeds was helpful. It provides opportunities to collaborate on CAV research.

4. Caltrans is interested in the FDOT IT Strategic Management Plan. We would like to learn from their experience and successes.

5. Learning about the changes to the AASHTO restructuring process was useful. We did not realize that the restructuring of RAC and SCOR will lead to a CEO-led Research and Innovation committee. This will change the current AASHTO RAC process. The various state DOTs need to comment on the reorganization so that the activities and research in the national arena continue to progress.

6. DOTs need to work more closely with industry on CAV issues. The IBM assertion that "cognitive" technology will be a key technology that will bring information together to the driver is one take-away that DOTs may find useful for industry.

7. Montana DOT developed a crosswalk that ties the old AASHTO structure to the new AASHTO structure, along with the assorted TRB committees. Caltrans is currently adjusting who will attend

AASHTO as the main representatives for Caltrans. The crosswalk will provide vital information to ensure Caltrans has the right people participating in the most important AASHTO committees.

#### Observations

1. The FDOT plan to develop a test bed through the AID process is a great decision. This will help ensure that FDOT is involved with the development of CAV solutions so that DOTs are ready for the large scale use of CAV. More states need to join in this effort.

2. I applaud the effort by FDOT to develop new tools to assist in the planning and development of needed research to support their efforts in dealing with transformational technologies, such as CAVs.

### David Jared – Georgia DOT

#### Top Three Take-Homes

1. Research roadmaps can be subdivided into "landscape" maps (where to go) and "route" maps (how to get there). (FHWA)

2. Roadmaps may be incorporated into the existing GDOT research initiation process. (Caltrans)

3. For research on transformational technologies, consider parallel tasking, scenario planning, and open calls for ideas. (TRB)

#### Day 1 Take-Homes

1. AASHTO

State DOTs are 52 "laboratories" but are shifting from data collection/provision to data purchasing.

Policy research quality is often subpar.

2. TRB

a. Roadmap considerations: awareness, agility, relevance

3. State University of New York (Albany)

a. Data should be viewed as an "agile" asset.

b. Concept of a "data scientist" should be explored to guide data asset management.

c. Web-based dashboards should be considered for data dissemination.

4. IBM

a. Data should be considered as a "natural resource" for the 21st century.

b. Utilize private research findings to extent possible: they can save time.

5. Caltrans

a. Research ideas come bottom-up; guidance top-down (confirms current GDOT model).

6. University of Florida

a. Factors to consider in roadmaps: safety, mobility, providing information, technology transfer, economic development, equity, sustainability.

**Day 2 Take-Homes**

1. Florida DOT

a. Data governance shouldn't be viewed as scary but as expeditious.

b. Good data inventory can prevent unnecessary data purchases.

c. Identify relationship between GDOT-IT and Office of Transportation Data (how could they implement data governance policy?).

2. TRB

a. Review national concrete research roadmap; adaptable to other pavement research?

b. Consider more performance-based research, focused on outcomes rather than processes.

## David Kuehn – FHWA EAR

1. From King Gee: We are entering a unique time in highway transportation research with raised public awareness and interest created by advances in vehicle automation.

2. On Roadmaps

a. It can be difficult obtaining and maintaining situational awareness in rapidly advancing areas of research. Many organizations are conducting scans. There is limited sharing of the scanning within or across organizations, which can result in unnecessary duplication.

b. State DOT and NCHRP research mostly focuses on discrete projects, not programs. Projects often are bottom-up with limited strategic focus.

c. Transportation Pooled Fund studies can provide a management scheme for research on a topic beyond the fixed period of performance and work scope of a project.

d. Agencies are seeking methods to increase flexibility in research procurement in response to rapidly changing environments.

3. Communication of Roadmaps

a. Some roadmaps are prospective, and others retrospective (describe a bundle of projects that came from the ground up). Both can aid in communication.

b. Communication can aid with cross-cutting issues, e.g., research on when to grout tendons involves structures, materials, and construction areas.

4. Regarding research program management, Caltrans conducts initial stage investigations that often result in identifying solutions developed by others, saving the need for what could be unnecessary duplication of research.

5. Data can be valuable assets resulting from research.

a. Research programs may benefit by considering data value, lifecycle, and possible re-uses earlier.

b. It can be difficult to transition data or software developed under research into program tools and data analytics. Coordination with Acquisition and IT are necessary.

6. There is a benefit to strengthening the link between research and policy. Research road maps may not encompass the use of results for policy development or policy change.

7. There is increasing interest in moving research to pilot deployments in the area of connected and automated vehicles.

a. These activities engage local agencies and universities. There are test bed coalitions in Florida and Texas.

b. There are questions on how and when to engage industry.

## Dr. Catherine T. Lawson, University at Albany

### Vision

Research catchment – Consider the concept of a "research catchment" rather than using the term research roadmap or research route map. A research catchment would suggest research could be informed by like-kind research activities that validate and/or compliment research efforts. FDOT should consider capturing data production flows using Application Programming Interfaces (APIs) that could to be accessed using a web-based platform designed to ensure agile access and analytics on the fly.

### Approach

Coordinate test-beds locally, nationally, and internationally to allow for confirmation/validation of test-bed outputs and approaches and rapid identification of next steps (review literature review to identify elements already tested or underway).

Expand science behind scenario planning to reflect experimental design structure.

Develop clear direction for dealing with industry partners to make sure DOT research is benefiting equally with private sector.

## James Lou, IBM

Public and private sectors, including academia, should work together on using latest technologies such as IoT, Cloud, Cognitive AI, and Analytics, for ITS deployment. Regular exchange is necessary to synch up on progress.

A procurement process different from civil infrastructure projects are necessary for ITS and technology projects. The new process will allow technologies to be adopted more rapidly and bring faster benefits (e.g. congestion relief) to the travelling public.

Research on a cognitive IT architecture for transportation is necessary in light of Big Data, connected vehicles, and Cloud computing. The IT platform includes Cloud infrastructure, Data Analytics, and Cognitive AI Machine Learning. The platform supports multiple ITS applications and serves as the basis for future innovation.

## Mark Norman – TRB

Florida DOT, Texas, California, Montana, and Georgia, and other states are already pursuing innovative approaches to research

Florida DOT is already pursuing more than a dozen research projects on connected/automated vehicles.

California DOT has considerable experience with research roadmaps.

TxDOT Innovate Research Program (no RFPs or problem statements)

Georgia DOT annual implementation reports

Several states are establishing lead implementation manager positions.

On the other hand, states are also facing some of the same barriers.

State RFPs for ITS projects still use technologies that are 10-15 years old. Most projects do not incorporate latest technologies such as Cloud, Big Data, IoT, and Cognitive Computing. The result is that outdated systems are designed and implemented which deliver reduced benefits to the traveling public. DOTs should consider adopting a suitable procurement method for ITS technology projects that differ from traditional civil infrastructure projects.

Concept of a research roadmap

Needs to track with DOT's overall mission and goals

Idea of a dynamic/living research roadmap has value.

Standing group that meets at least on a regular basis could also have value.

Standing contracts for quick response answers could have value.

However, all of these would mean some change from the ways we have historically done business.

As in any change, support from top management would be key.

Potential Impacts on our traditional research processes

Redefining our definition of a research "project"

Accomplish tasks in parallel rather than in series, and bring together at the end.

Consider need to rely more on scenario planning for some topics.

Focus RFPs on outcomes rather than processes.

Enhance agility/flexibility for researchers and staff.

Reduce administrative burdens.

Leverage demos and field tests.

Look to other sectors for good models.

Florida DOT's challenges in addressing research in transformation technologies are not unique.

Other states are facing similar challenges and questions:

What are the issues in this area that can be addressed by research?

What research is already underway or planned by others?

How can state DOTs keep abreast of all that is happening?

What "niches" can/should individual states focus on as part of their own research programs?

What opportunities exist or should be created to enable states to collaborate on researching common issues and for "replicating" research results where desirable?

How might some of our traditional research processes need to change in this age of transformational technologies?

Other state DOTs would benefit from a discussion of issues addressed during this peer exchange.

AASHTO RAC/TRB State Reps meeting(s) would be a good venue to expand this dialogue.

## Teresa Parker – FHWA

Aligns with FAST-ACT and new future highway funding legislation

Communication, collaboration, and coordination are extremely important for engaging the public and stakeholders early on in the initiation of potential research projects.

Emerging Research Projects: Ask the right questions which will aid in reducing time/money.

On-going feedback on what's happening from a national/state/university/private sector/international perspective to not reinvent the wheel but to replicate the processes to fit what the state needs

Possibility to leverage other funding sources for emerging research projects with others

Data seems to be a big factor in how, what, where, and who can strategically utilize the data.

Establish a network to keep open dialogue and communication with the peer exchange stakeholders from both past and present.

Tap into other career discipline areas that you may not even think to consider when defining a purpose and need.

### Sue Sillick – Montana DOT

Investigate developing data plans for research projects.

Incorporate data considerations upfront at the beginning of each project. Identify others who may be able to benefit from project data, and develop it in a manner to facilitate its use.

Contact John Krause to learn about demonstration UAS projects.

Remember governance is not scary; it helps us go fast.

Share FDOT IT strategic plan presentation with MDT staff.

Share AASHTO-TRB committee's crosswalk with Joe.

Share Peer Exchange presentations and report with WTI.

## 2. Research Center Action Plan

As a result of the in-depth discussion throughout the peer exchange, FDOT identified the following items that will be vetted and prioritized in coordination with executive leadership to identify top priorities for action. The list below comprises actions ongoing as well as items for future consideration and development. These will be managed through annual review and reporting.

### Initial Action Plan Items

Consider potential additional project vetting across functional areas against identified key strategic criteria (Horton).

Consider additional ways to create project cohorts or families.

Consider potential for standing subject matter teams (cross-functional, potentially cross-sector, national). Formalize approach and possibly provide additional, e.g., consultant or university support to manage (Norman et al.).

Consider potential for open RFI through UF for campus test bed to attract test bed users (Kuehn, Poe).

Consider more effective monitoring of test bed areas vis-à-vis national groups (e.g., CV TPF).

Consider how to expedite project data sharing (real- and near-real-time).

Guidance (top-down) and project (bottom-up) coordination sharing with leadership and functional areas

Annual implementation report

Revisit organizational process and language used in implementing potential changes.

### Future Action Plan Items to Be Considered and Developed

Consider process to effectively and actively manage whatever version of a “roadmap” is considered (Andrle).

Consider development of key area/focus topics for open call for research ideas/projects (Kuehn).

Consider how to craft a portfolio of case projects or partner for distributed replication projects at different test beds (Sillick).

Six-month emerging technology coordination/information sharing meeting

Topic scouting (maturation of technology) to share with functional areas/leadership to coordinate strategic goals and research portfolio

Advisory committees in research project selection

Consider how implementation of solutions can be leveraged to expedite process.

Immersive research/research catchment – real-time awareness

Staff assignments for monitoring current event issues in selected areas.

Expand the science behind scenario planning for potential integration into research projects.

Develop clear direction for working with industry partners to effectively leverage and understand respective benefits.

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# Appendix A – FDOT 2017 Research Peer Exchange: Agenda

## Monday, April 24

| | | |
|---|---|---|
| — | Travel Day | |

## Tuesday, April 25

## Morning Schedule – Auditorium

| | | |
|---|---|---|
| 8:00 am | Introduction – State DOT Research Roadmaps in the Contexts of National Agenda/Activity and Emerging Technologies | Darryll Dockstader |
| 8:30 am | Panel 1 – The National Picture<br>8:30 King Gee, AASHTO<br>8:45 Ray Derr, NCHRP<br>9:00 David Kuehn, FHWA EAR<br>9:15 Mark Norman, TRB<br>9:30 Q&A | Moderator: Steve Andrle |
| 9:45 am | Break | |
| 10:00 am | Panel 2 – Universities and Industry<br>10:00 Dr. Christopher Poe, Texas A&M Transportation Institute<br>10:15 Dr. Catherine T. Lawson, University at Albany<br>10:30 Dr. Lily Elefteriadou, University of Florida<br>10:45 James Lou, IBM<br>11:00 Q&A | Moderator: Steve Andrle |
| 11:15 am | Break | |

| | | |
|---|---|---|
| 11:30 am | Panel 3 – State DOTs<br>11:30 David Jared, Georgia DOT<br>11:45 Joe Horton, Caltrans<br>12:00 Sue Sillick, Montana DOT<br>12:15 Q&A | Moderator: Darryll<br>Dockstader |
| 12:30 pm | Lunch | |

## Afternoon Schedule – 336

| | | |
|---|---|---|
| 1:30 pm | Concept of a Research Roadmap | |
| 2:30 pm | Tour of Cascades Park | |
| 3:15 pm | Concept of a Research Roadmap – Discussion (continued) | |
| 5:00 pm | Dinner | |

## Wednesday, April 26

## Morning Schedule – 336

| | | |
|---|---|---|
| 8:00 am | Recap | |
| 8:30 am | ROADS – FDOT's Process – April Blackburn | |
| 9:00 am | And What of Data and Research?<br>Data and Decision-making<br>Data and Performance Analysis<br>Data and Production<br>Data Security | |
| 10:00 am | Break | |
| 10:15 am | Data and Research, Research and Data (continued) – David Sherman, Raj Ponnaluri | |
| 12:00 pm | Lunch | |

## Afternoon Schedule – 336

| | | |
|---|---|---|
| 1:30 pm | Emerging Technologies<br>What do we mean by emerging technologies<br>CAV Projects<br>UF Campus Testbed | |
| 3:30 pm | Break | |
| 3:45 pm | Emerging Technologies (continued) | |

| | |
|---|---|
| 5:00 pm | Adjourn |

**Thursday, April 27**

| | | |
|---|---|---|
| 8:00–11:00 am | Recap, report preparation, and wrap-up | |
| 11:00 am - 12:00 pm | Report out to Brian Blanchard, FDOT Assistant Secretary | |

# Appendix B – Opening Presentation

## Darryll Dockstader – Opening Presentation

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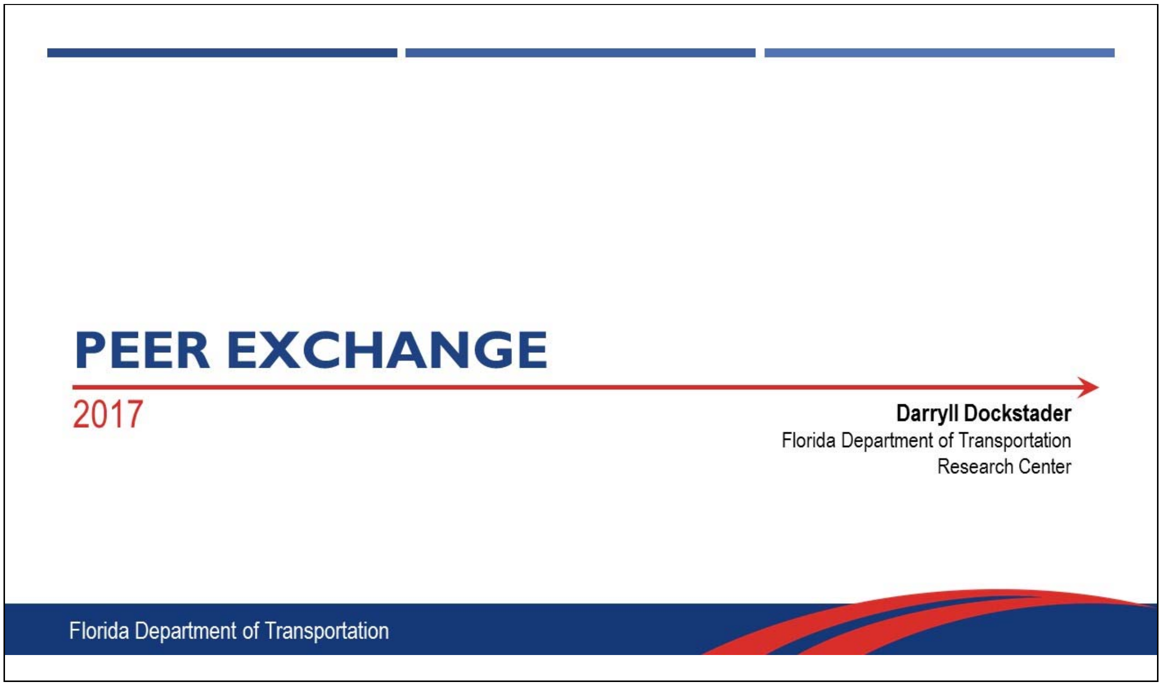


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**Dockstader, continued**

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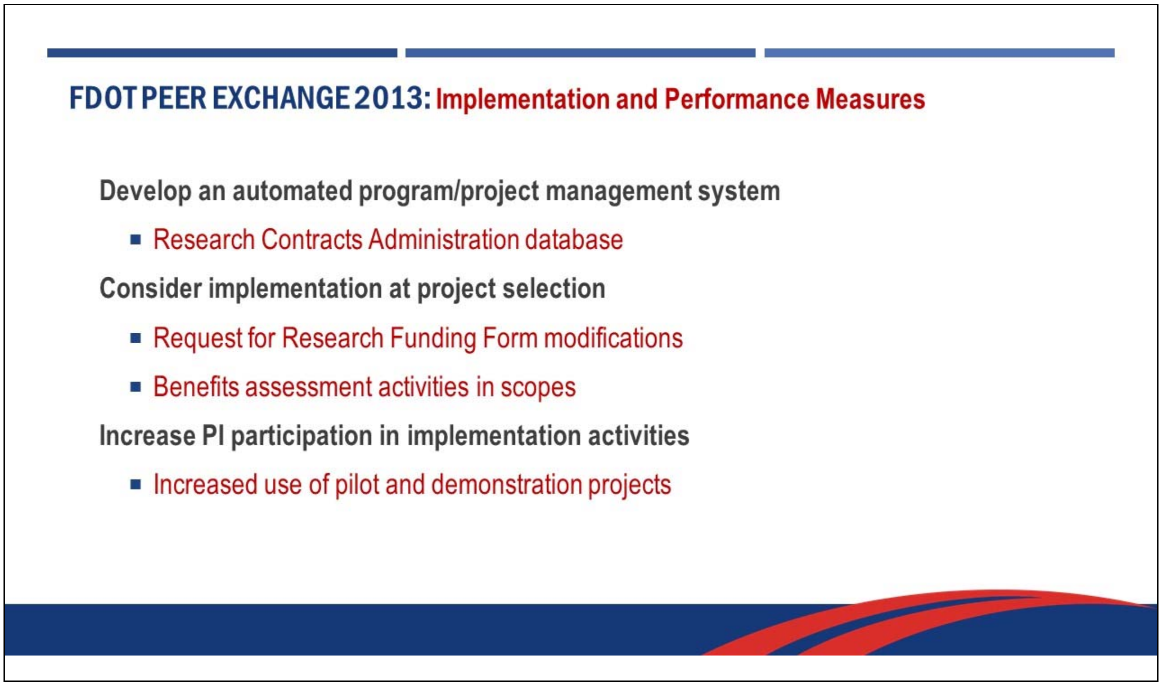


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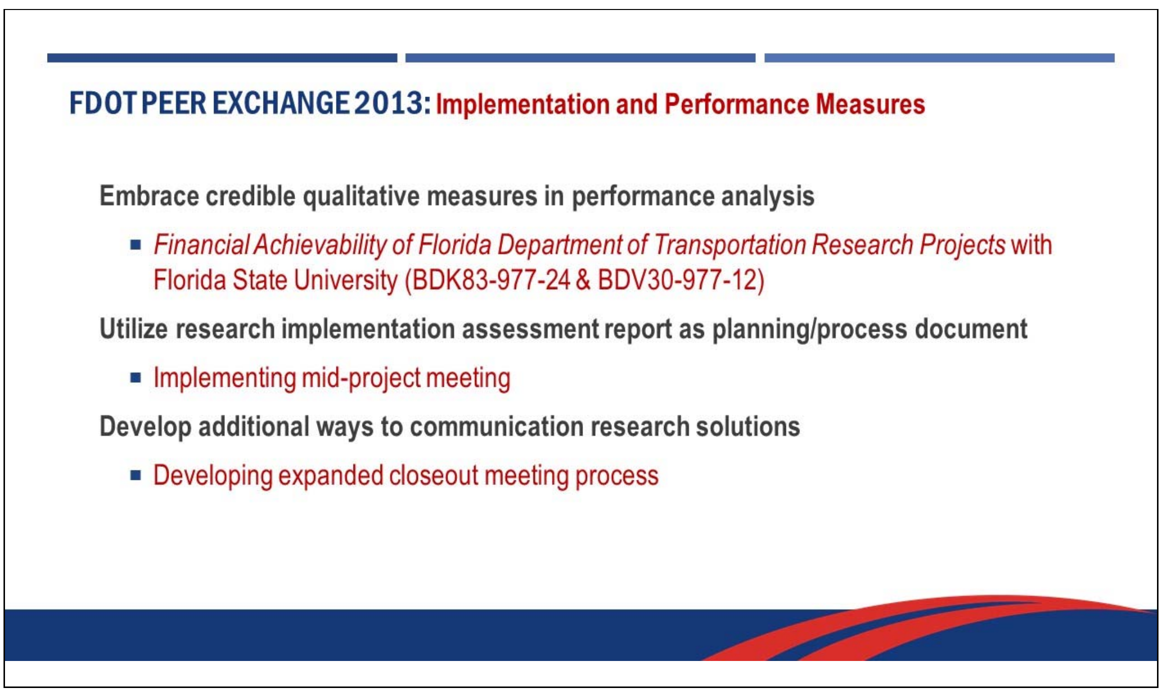

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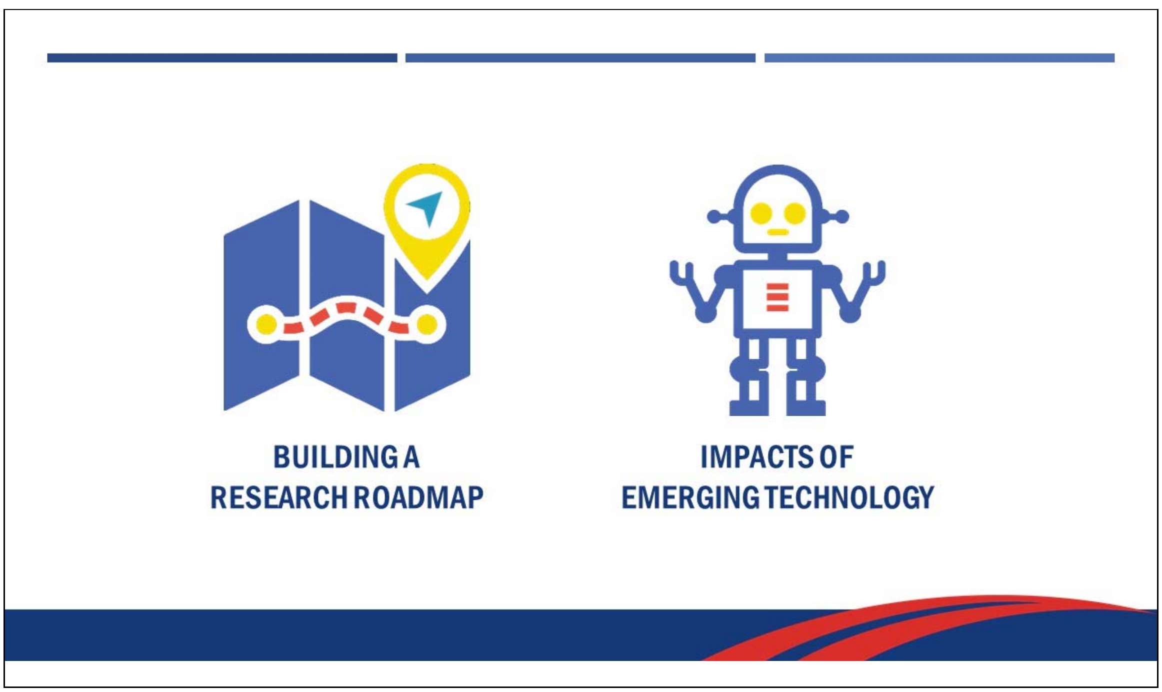

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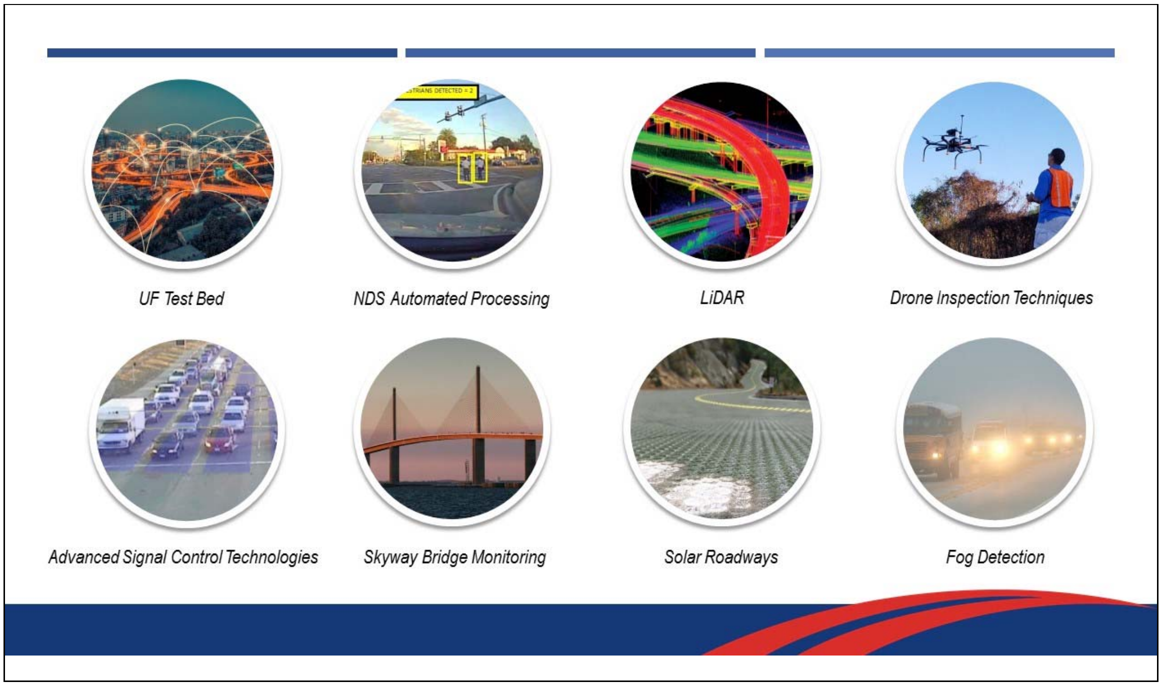


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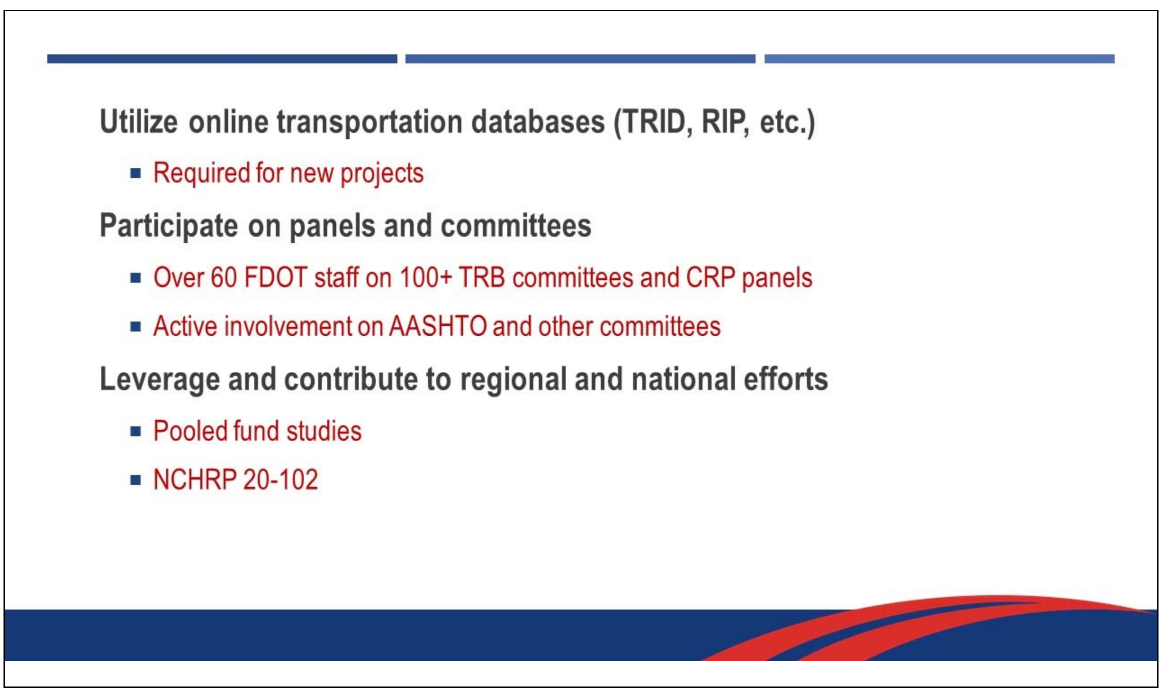

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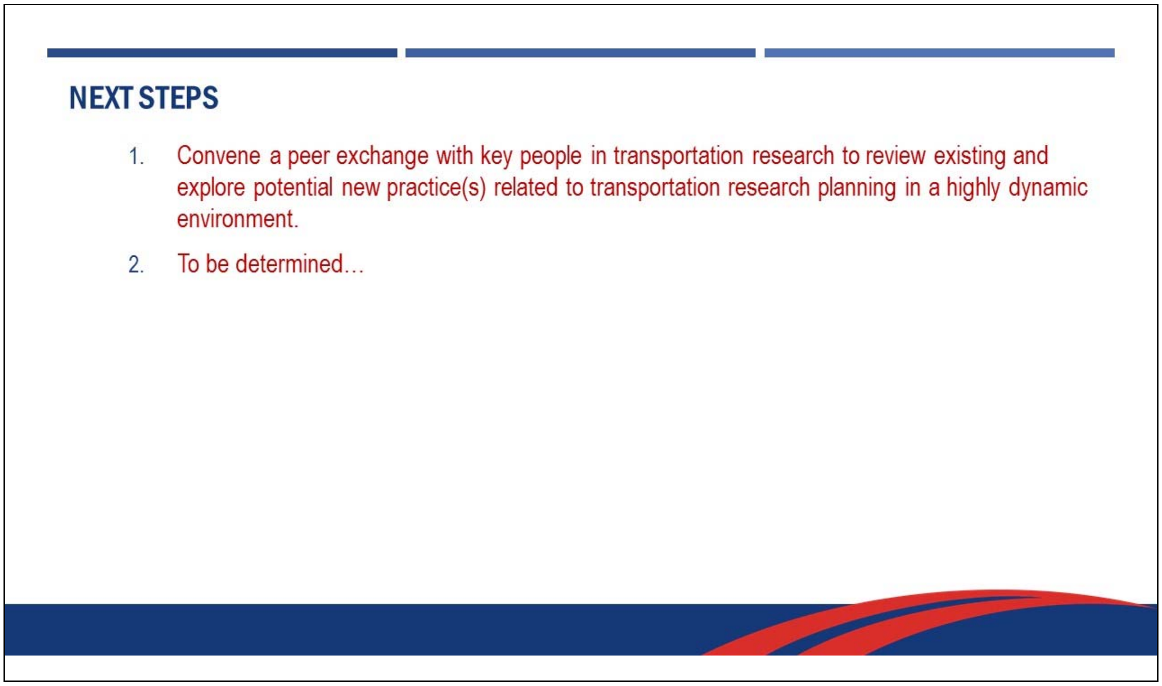

# Appendix C – Panel Presentations

## King Gee – AASHTO

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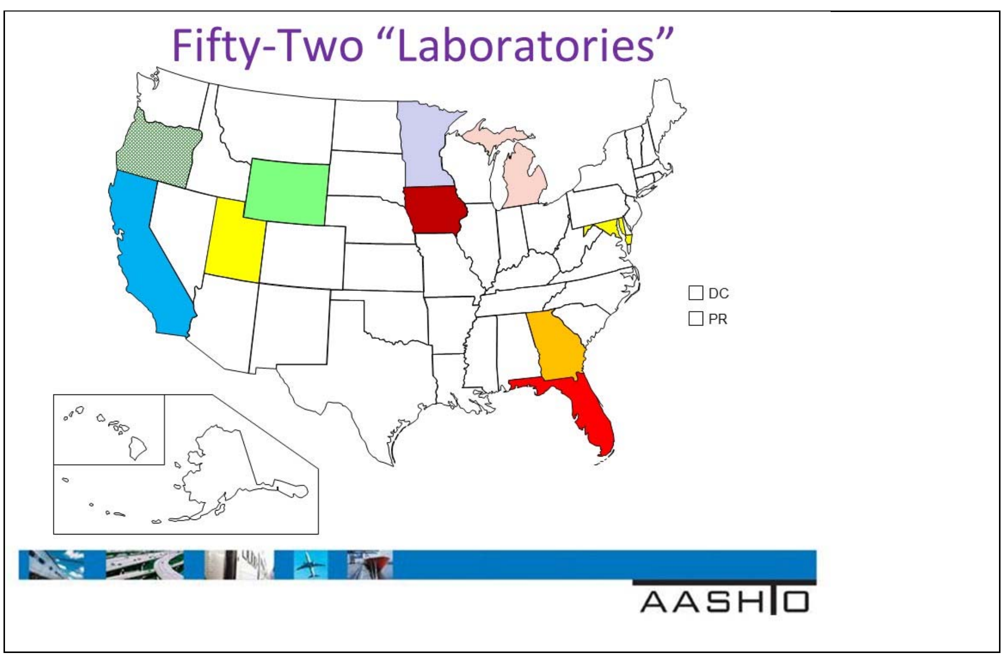

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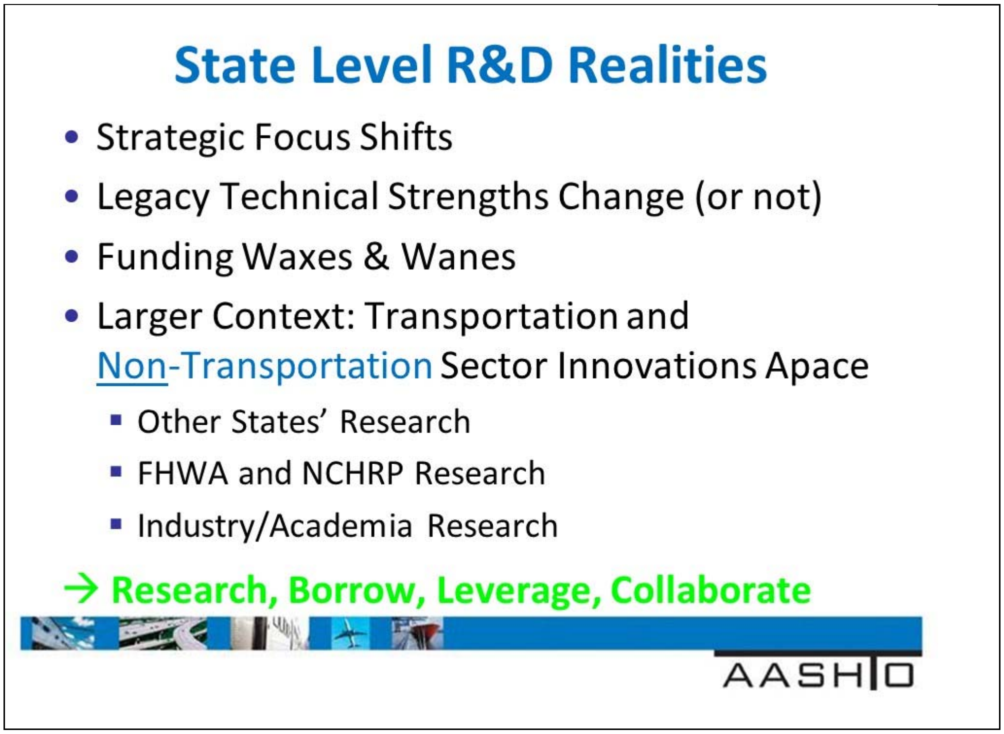


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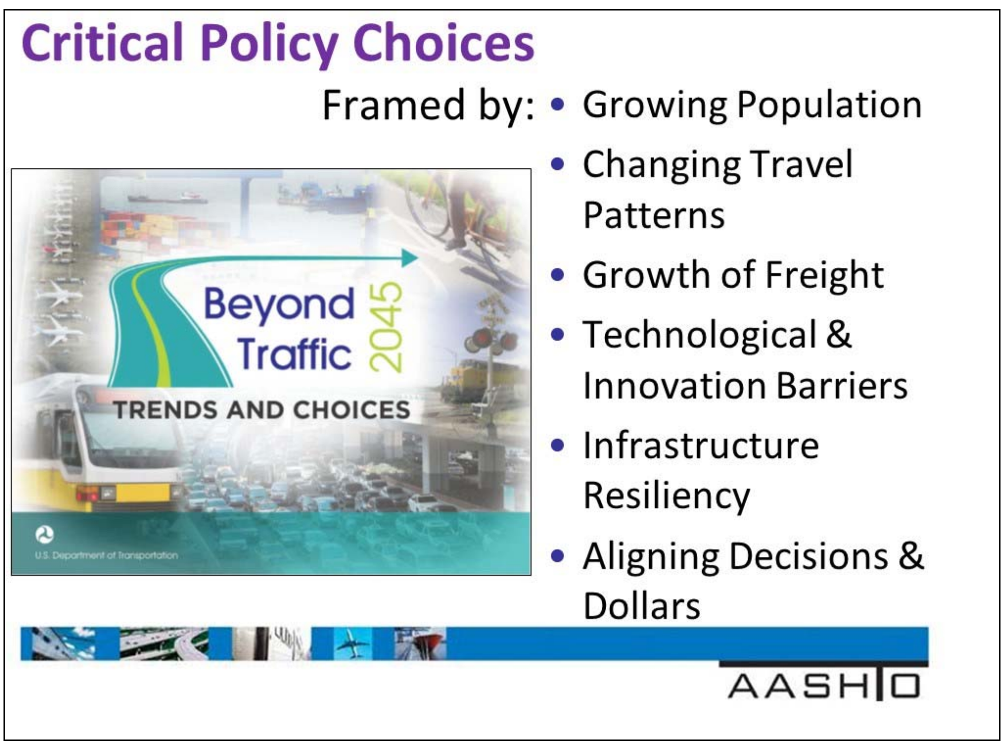

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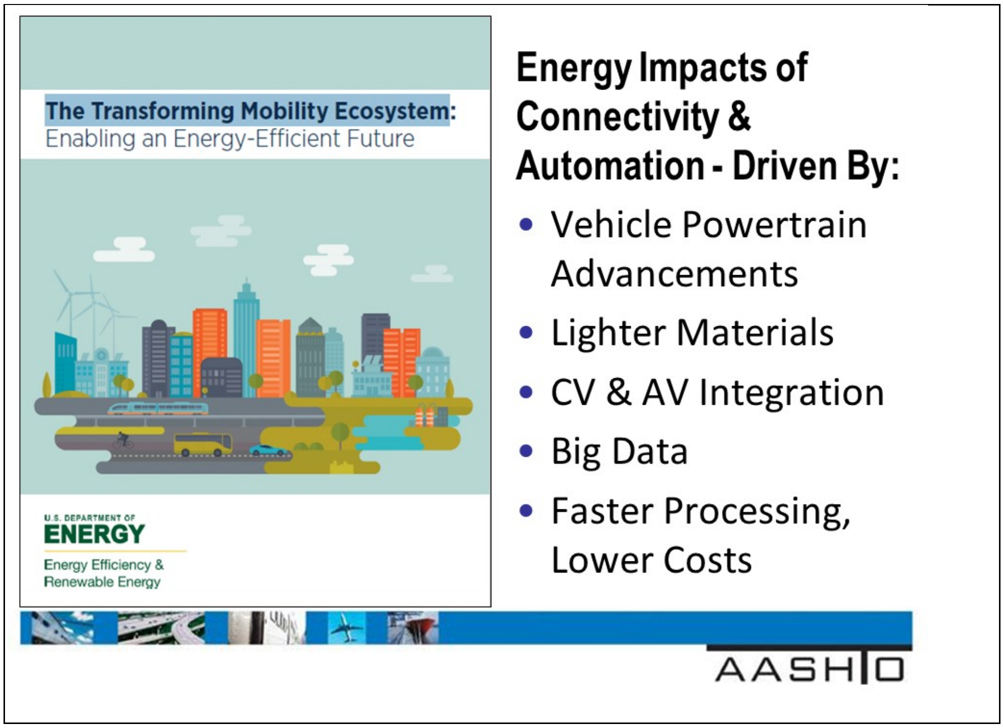


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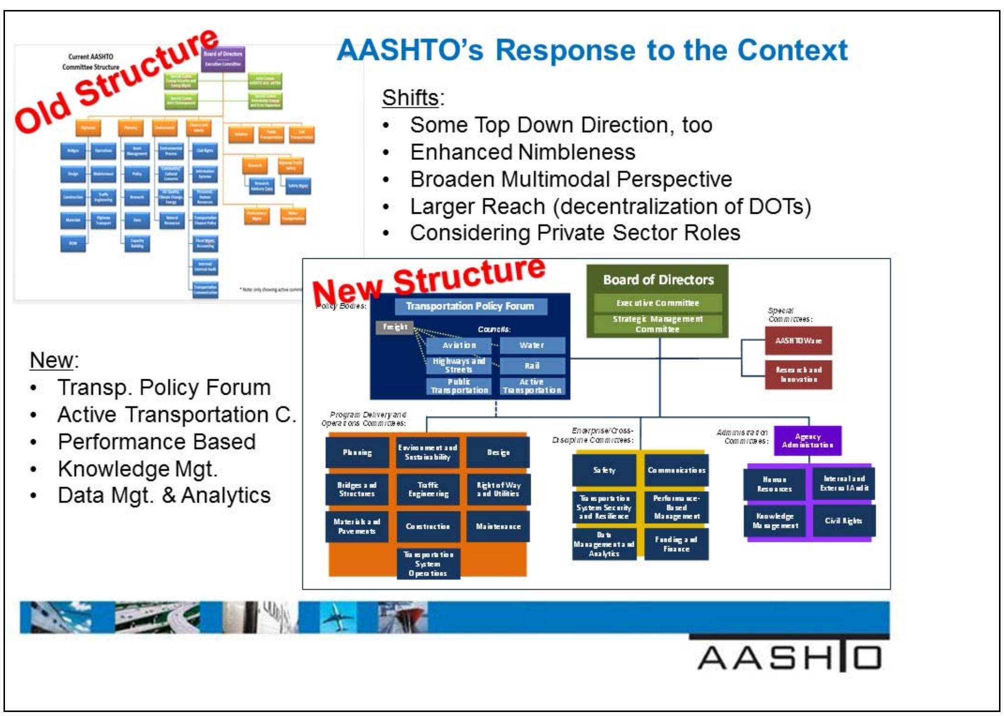

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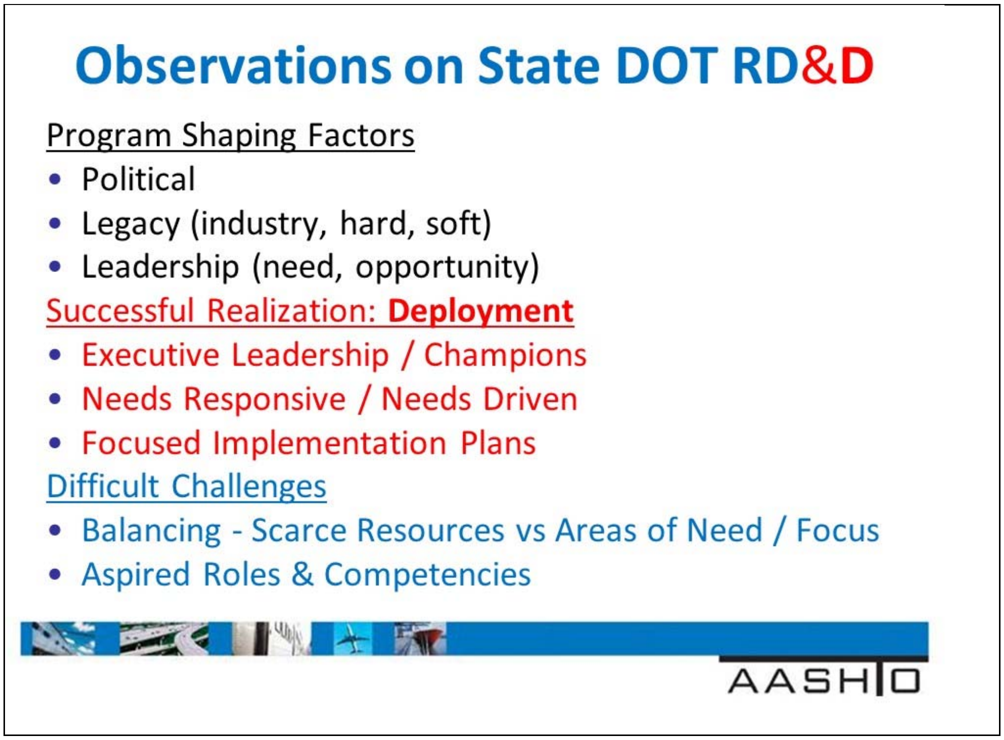


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## Ray Derr – NCHRP

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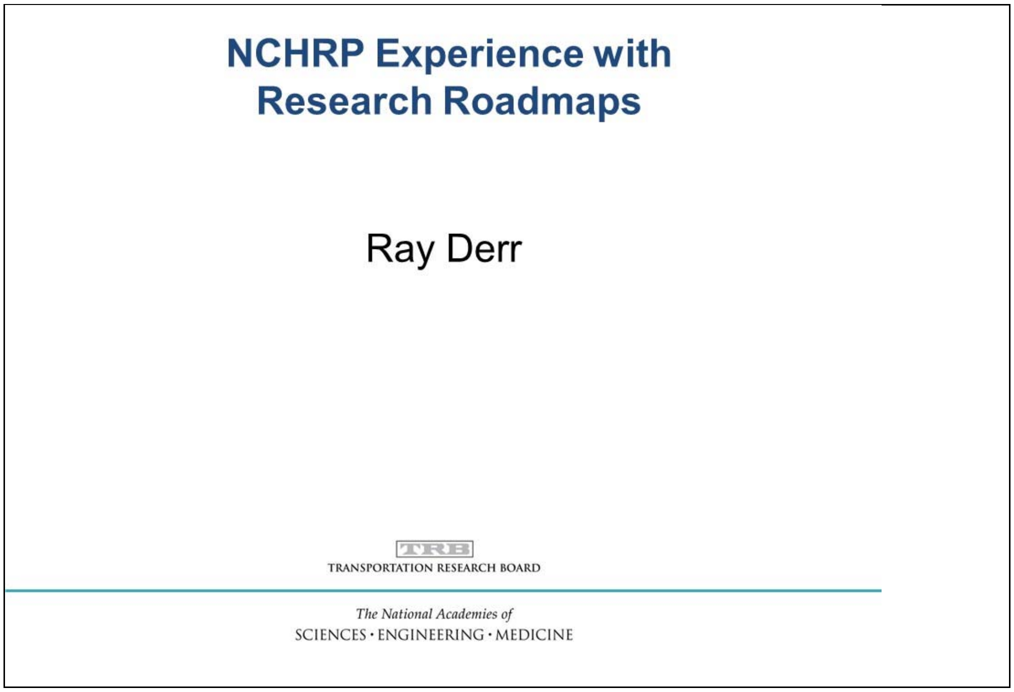


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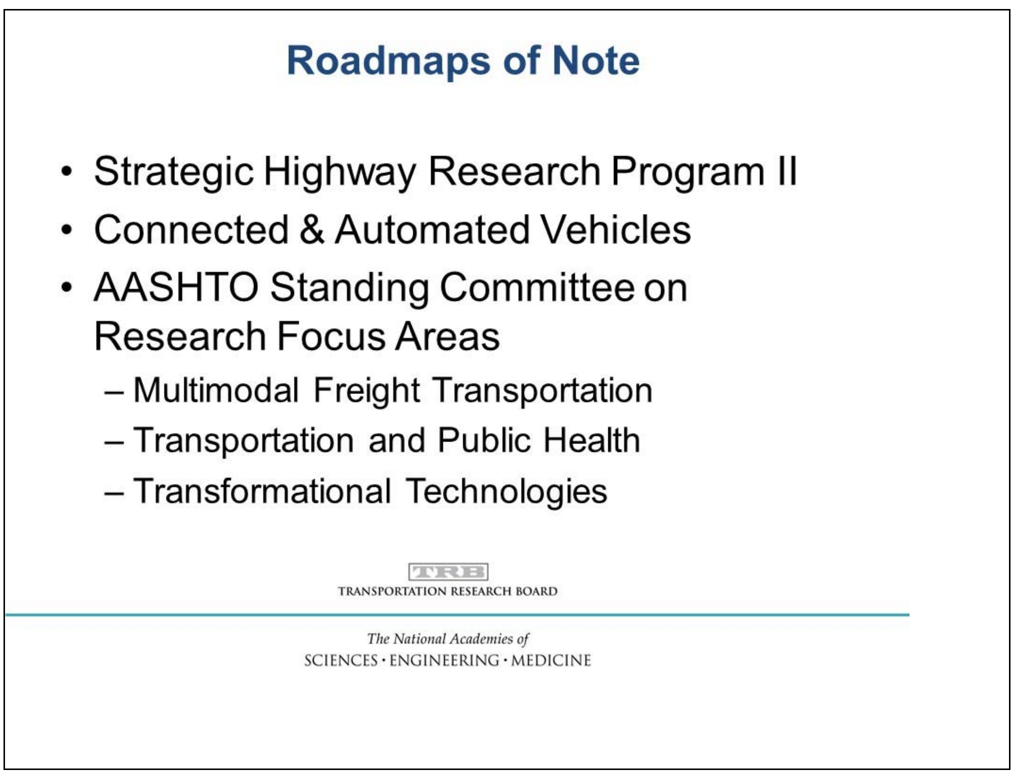

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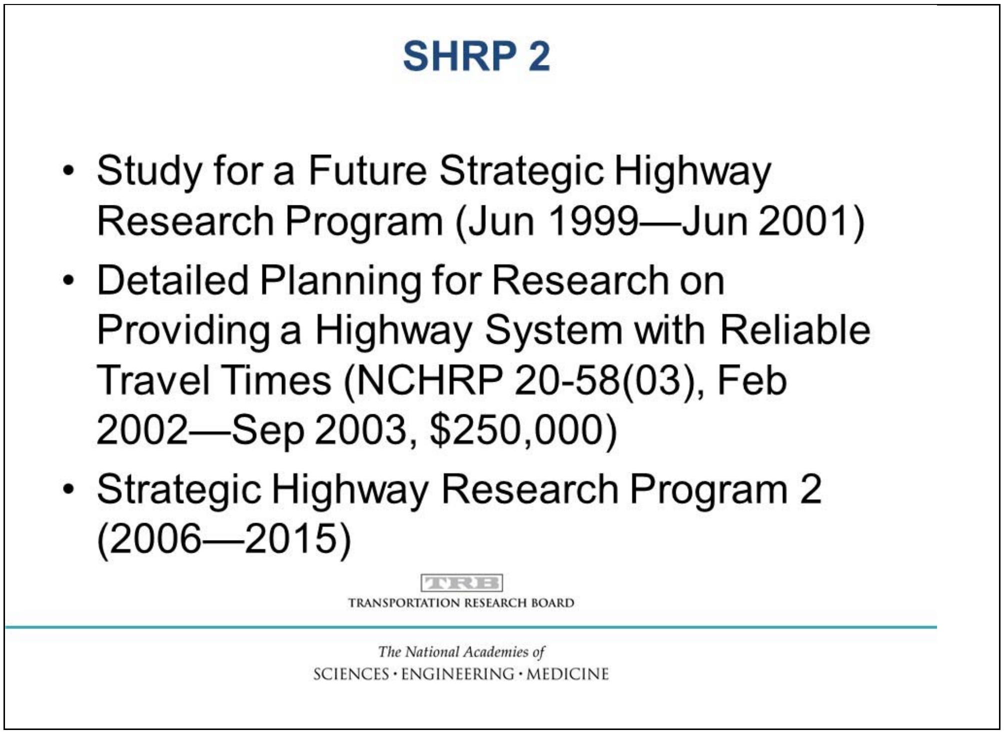


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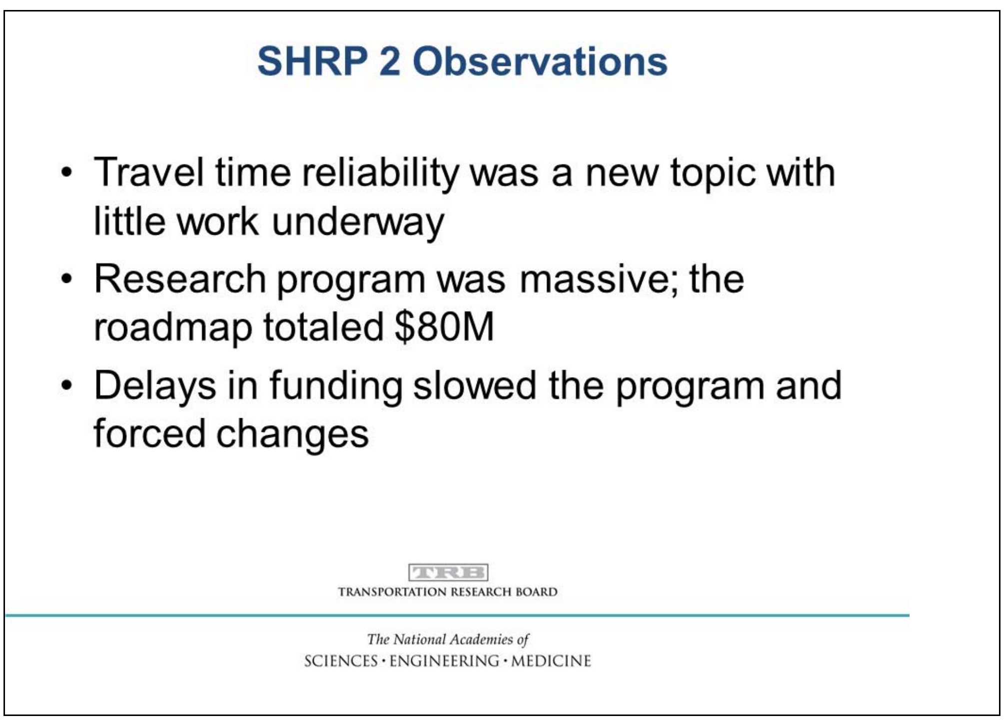

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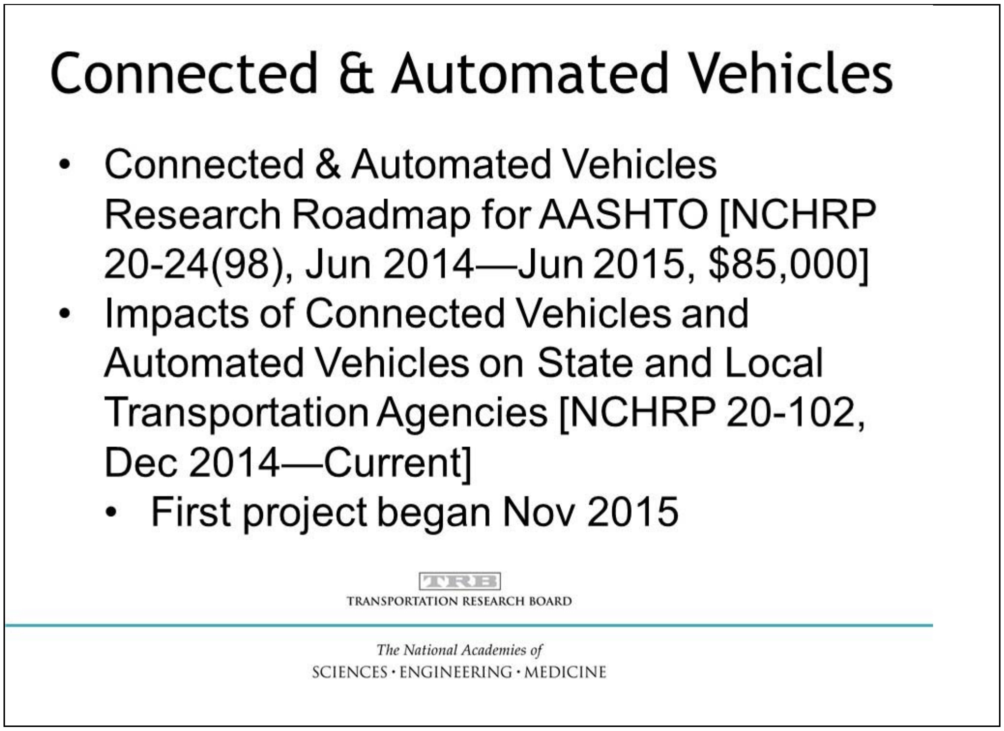


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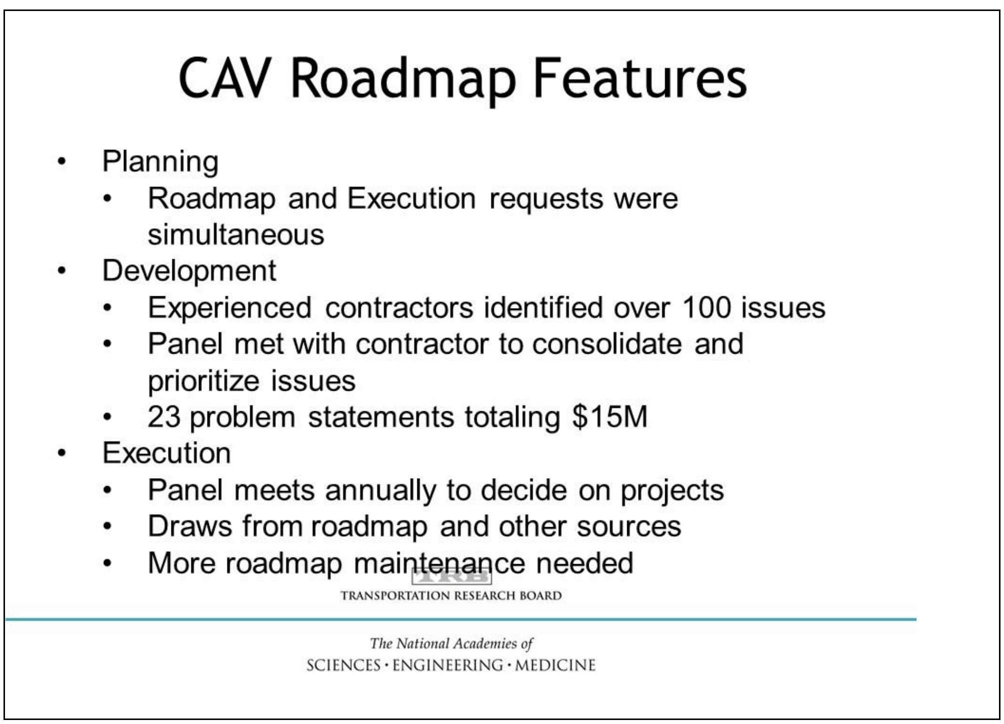

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## Transformational Technologies

- Research Roadmap for Transformational Technologies (Other than CV/AV) [NCHRP 20-113, $250k]
  - Support for TRB Symposium [$130k]
- TRB Partners in Research Symposium: Transformational Technologies in Transportation [Oct 30-Nov 1, 2016]
- Three projects approved in Feb 2017 and Mar 2017

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*Slide 8*

## Transformational Tech. Features

- Planning
  - Symposium planning was extensive
  - Contractor identified participants and developed resources
- Symposium
  - Focused on how public policy objectives can be met through technology initiatives
  - Topical break-out groups to identify issues
  - Three themes
    - Private-sector, public-sector, and academia working together is vital
    - Planning horizons are very different
    - Processes need to change for public sector to keep pace
  - Three problem statements developed
- Execution
  - Process for dialogue still being developed

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**Derr, concluded**

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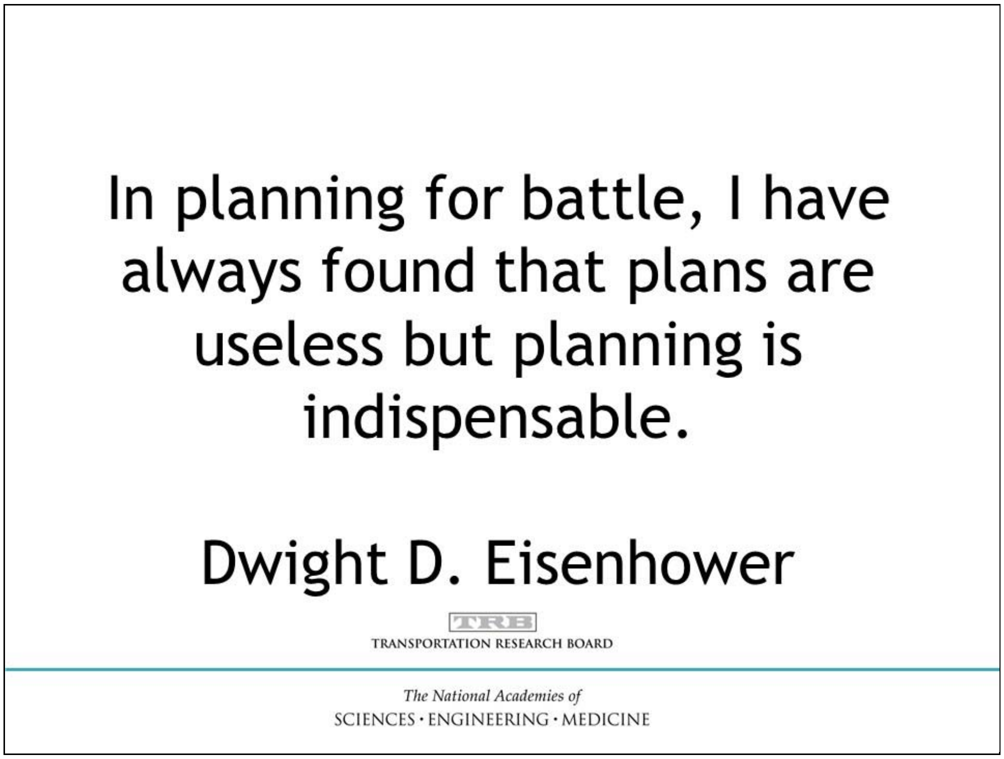

## David Kuehn – FHWA EAR

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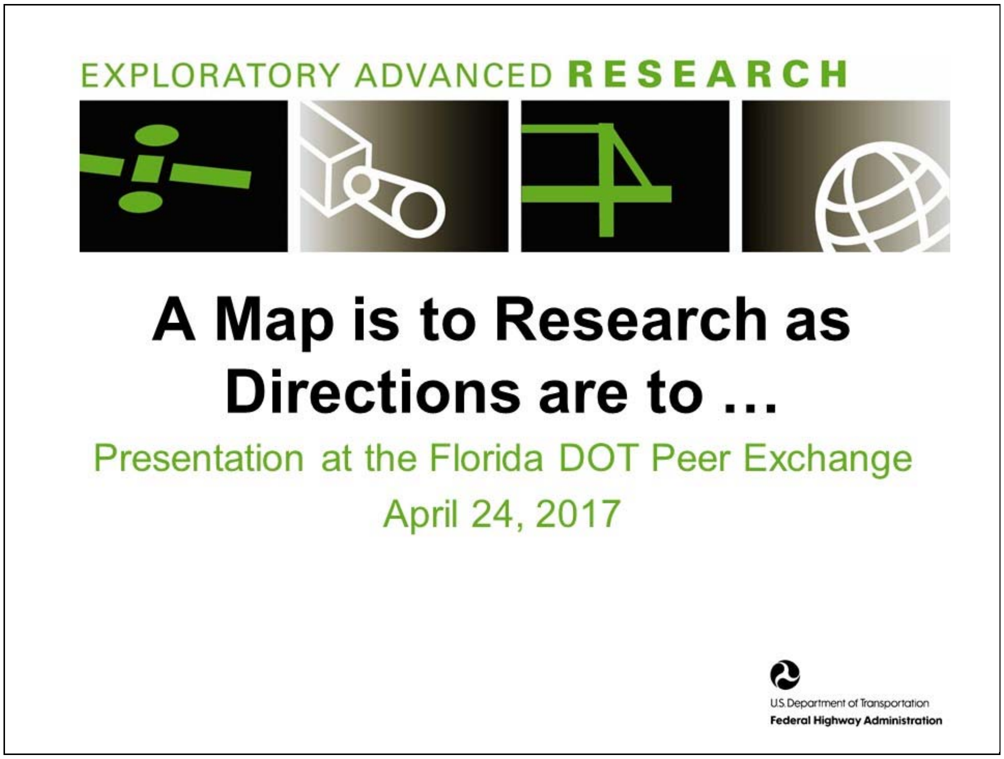


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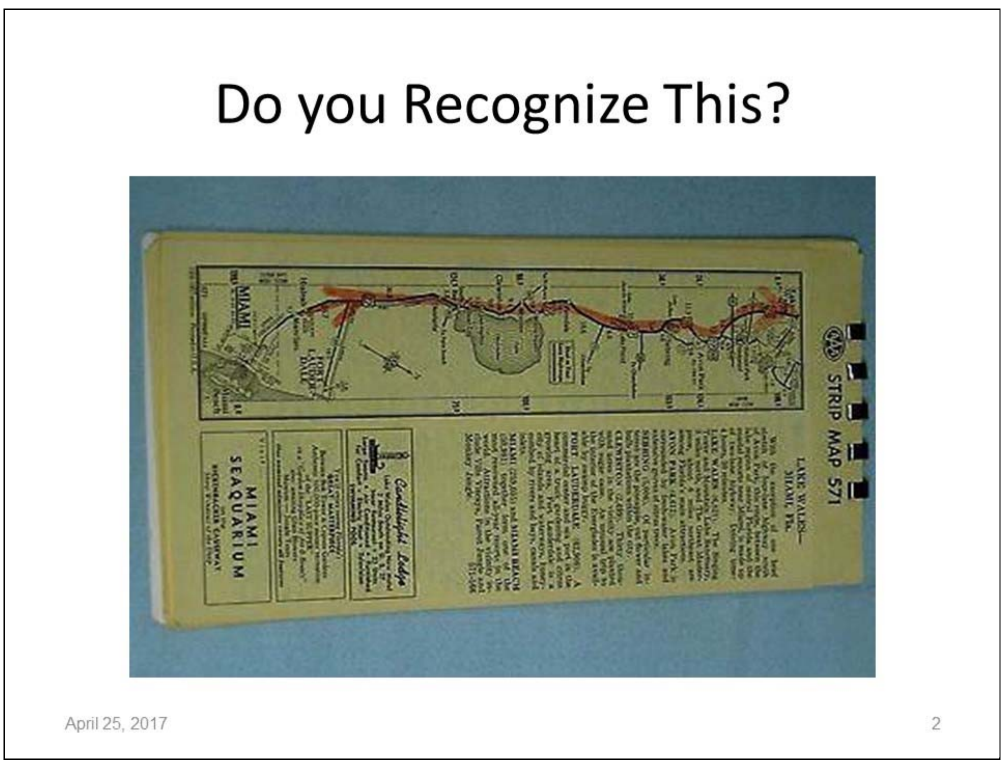

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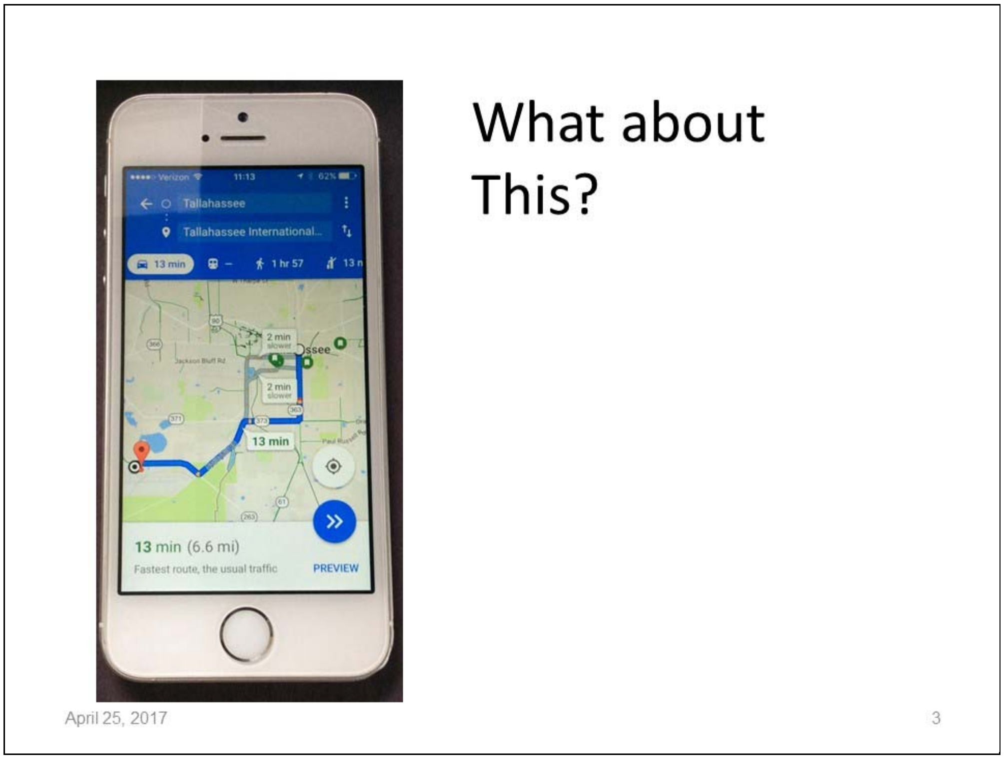


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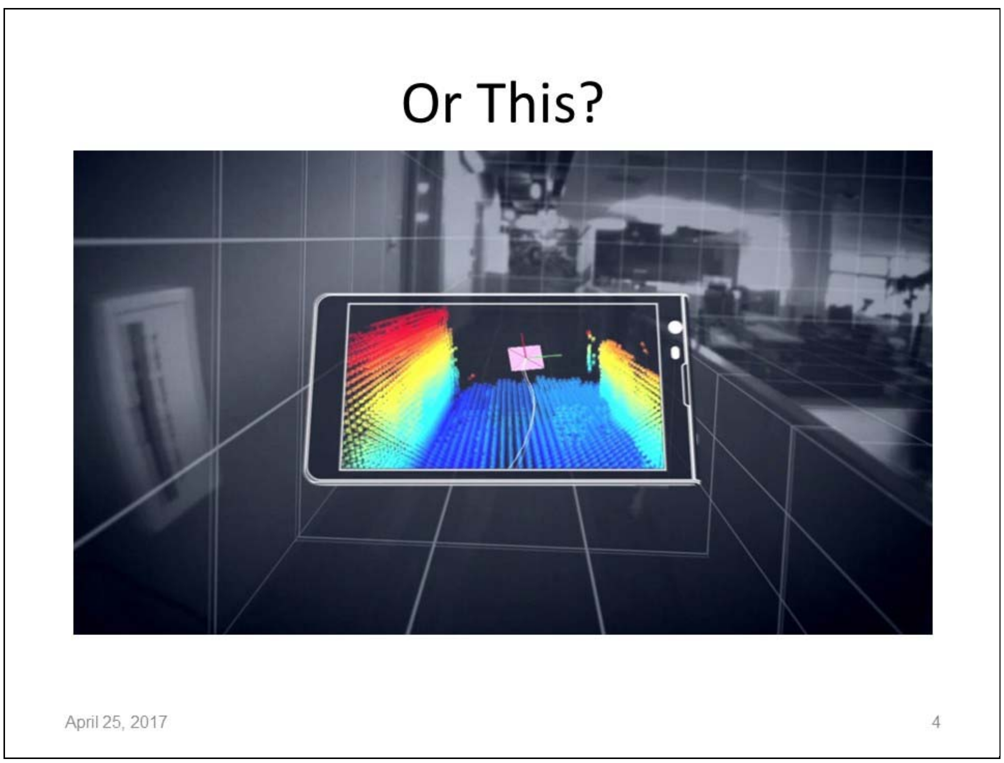

**Kuehn, continued**

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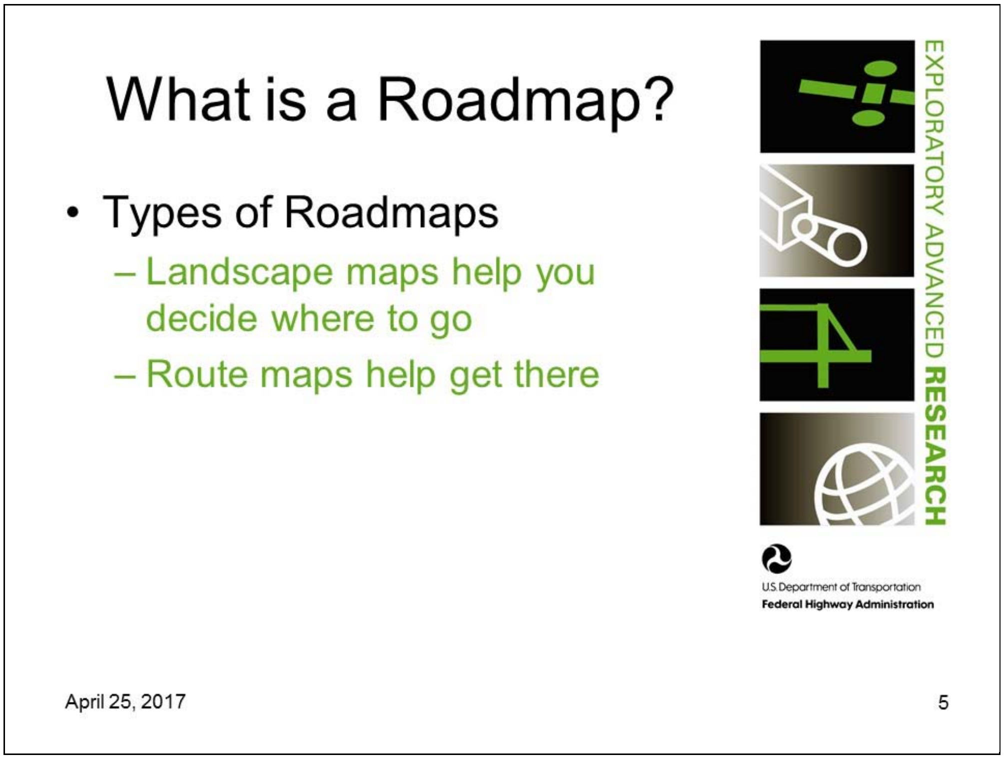


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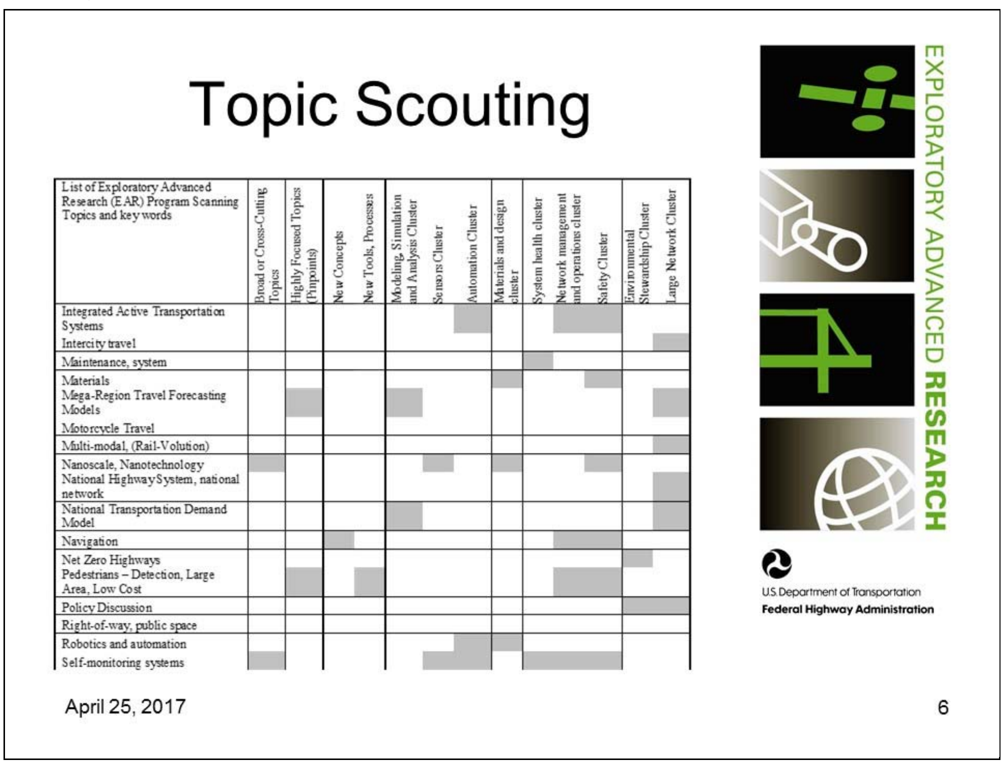

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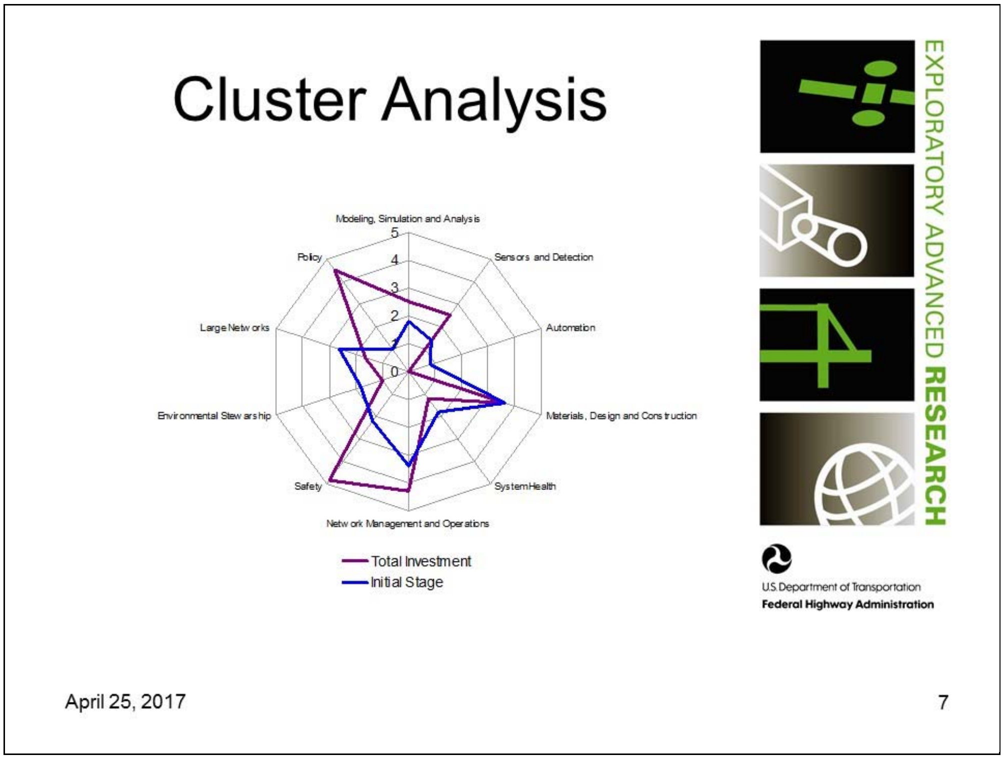


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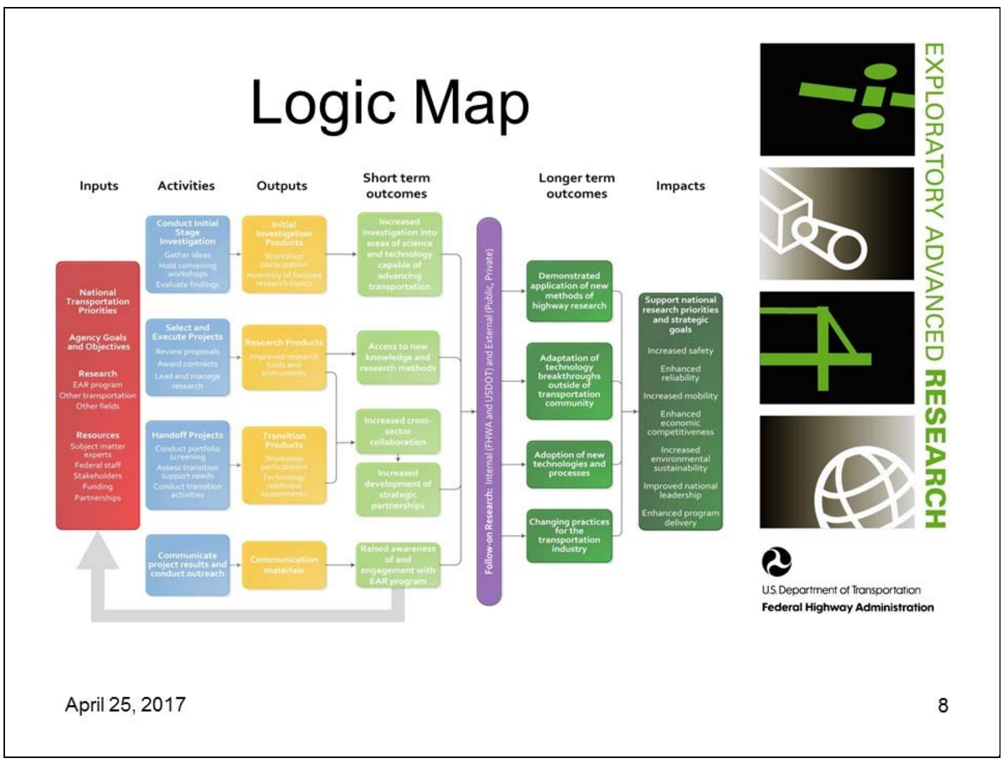

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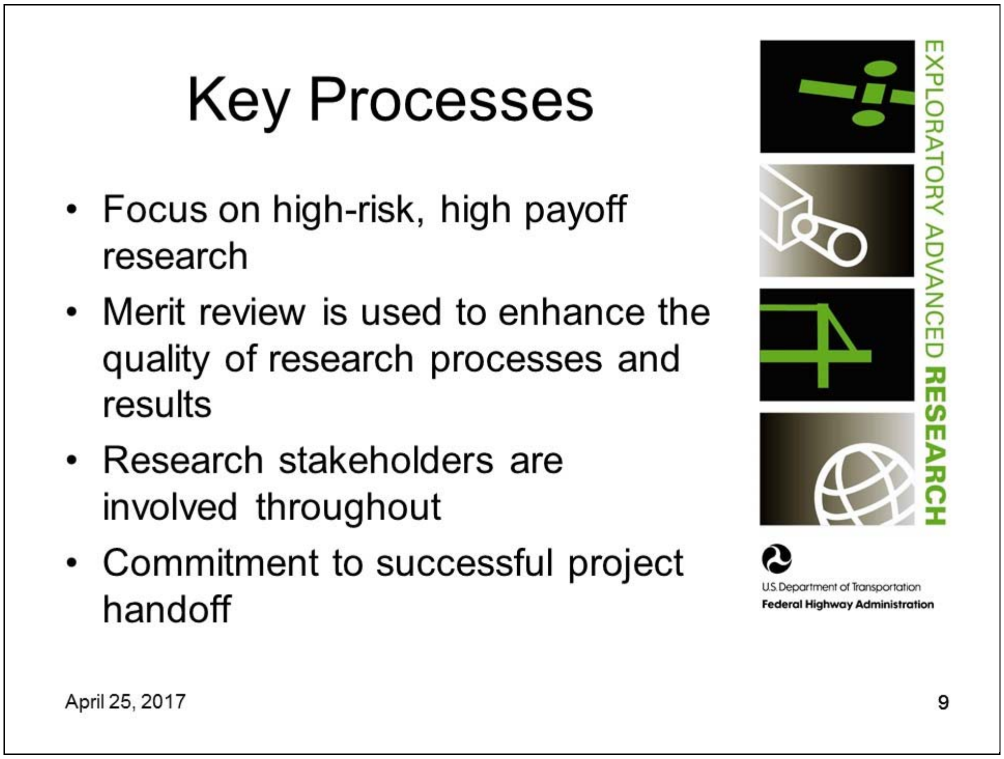


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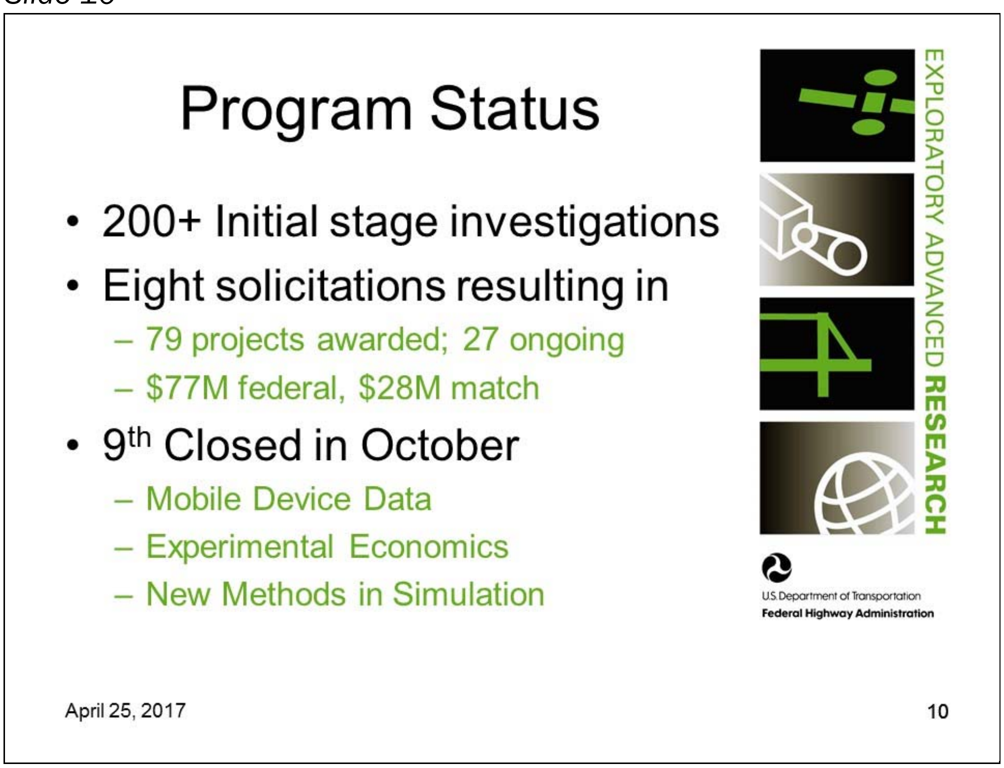

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*Slide 11*


*Slide 12*

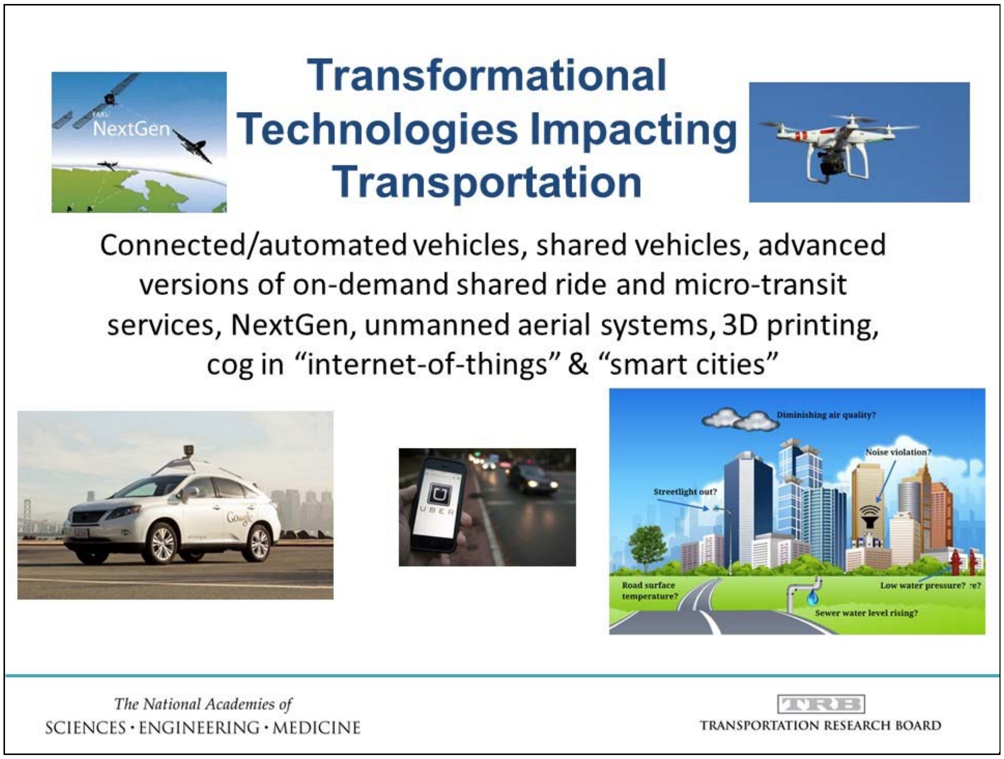
## Mark Norman – TRB

*Slide 1*


*Slide 2*

**Norman, continued**

*Slide 3*

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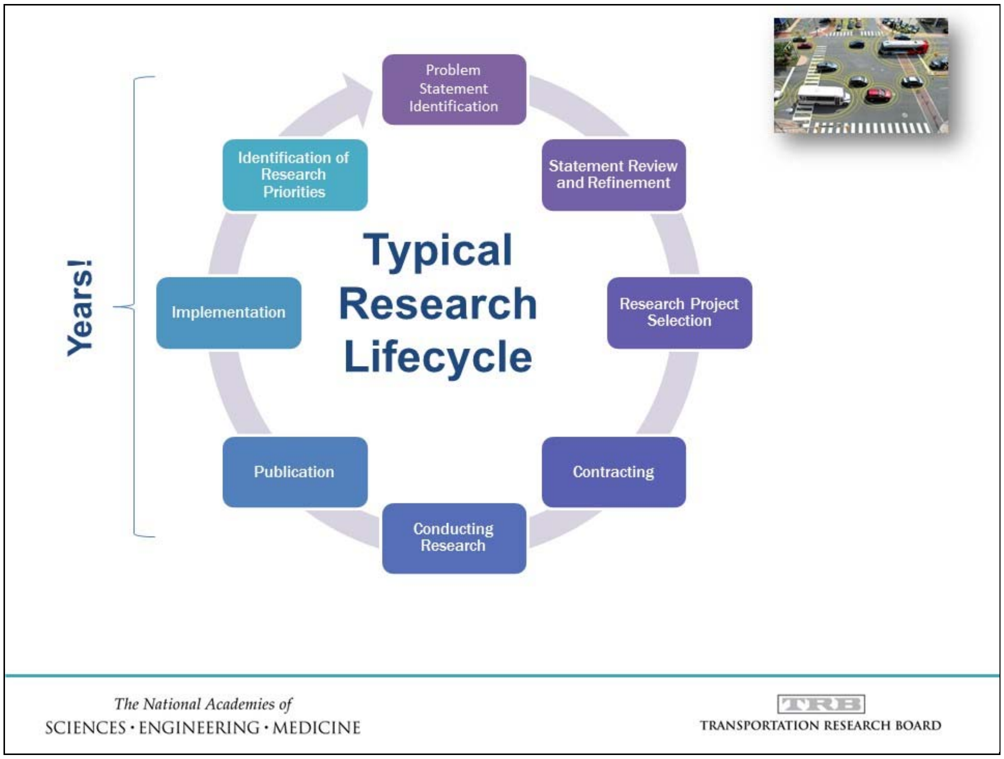


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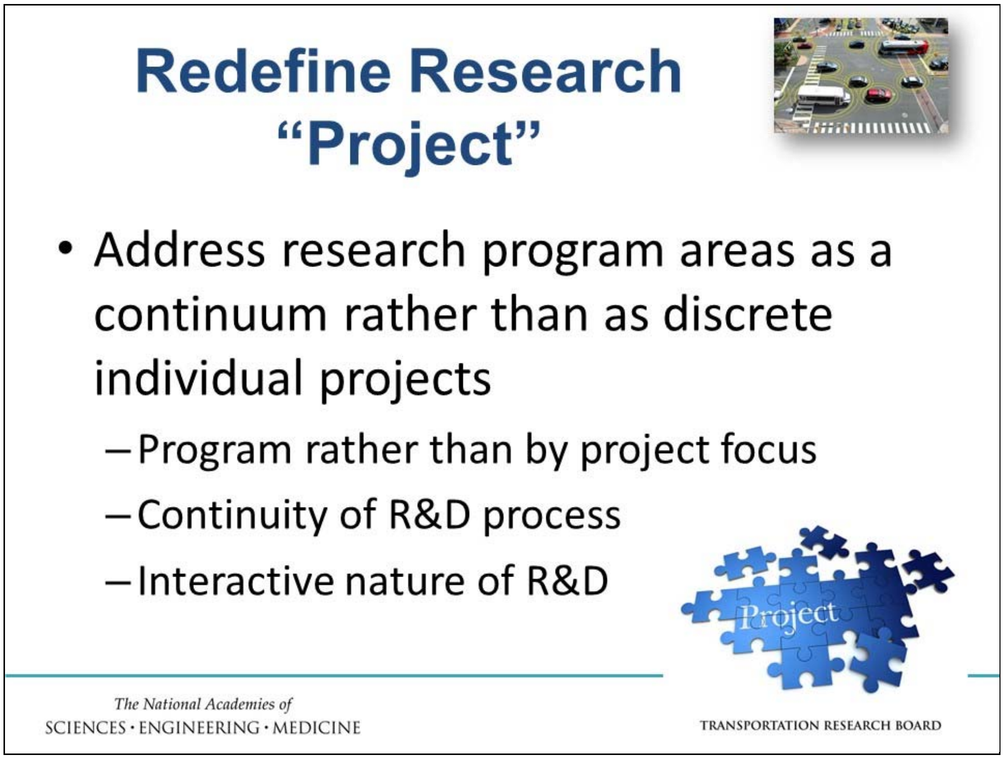


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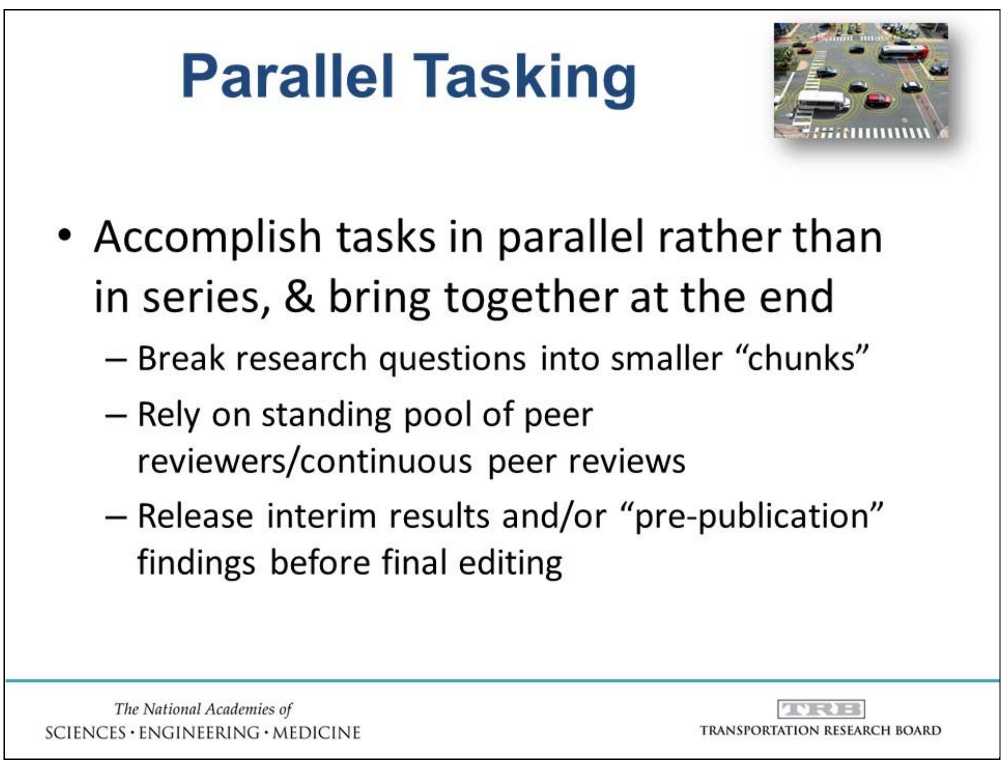

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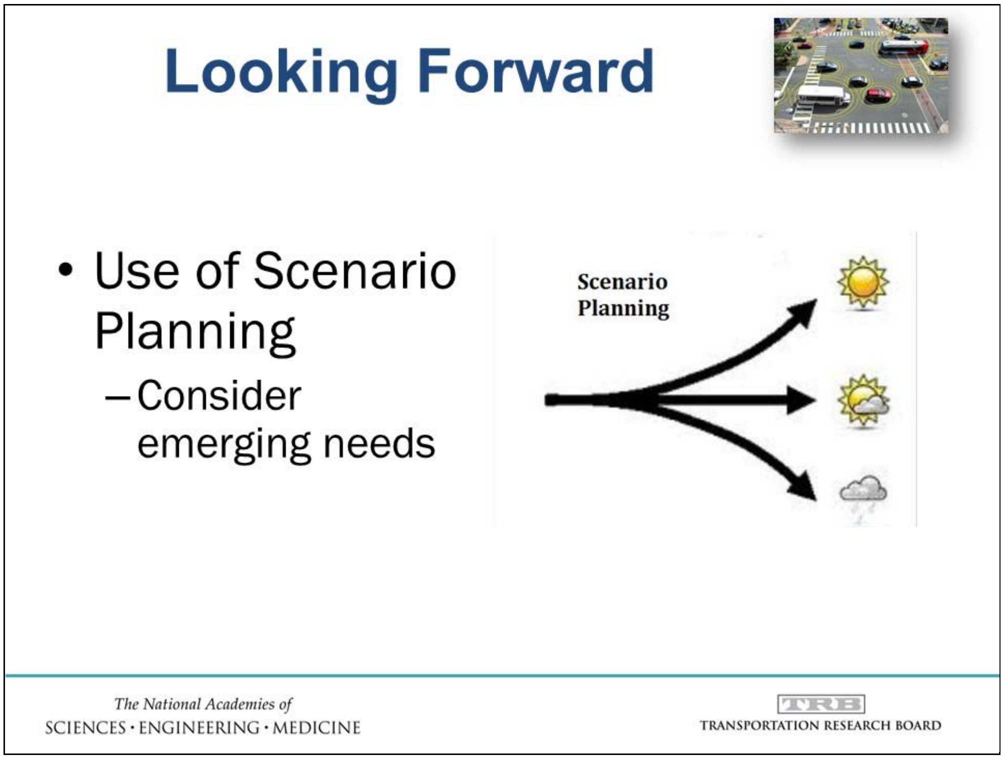


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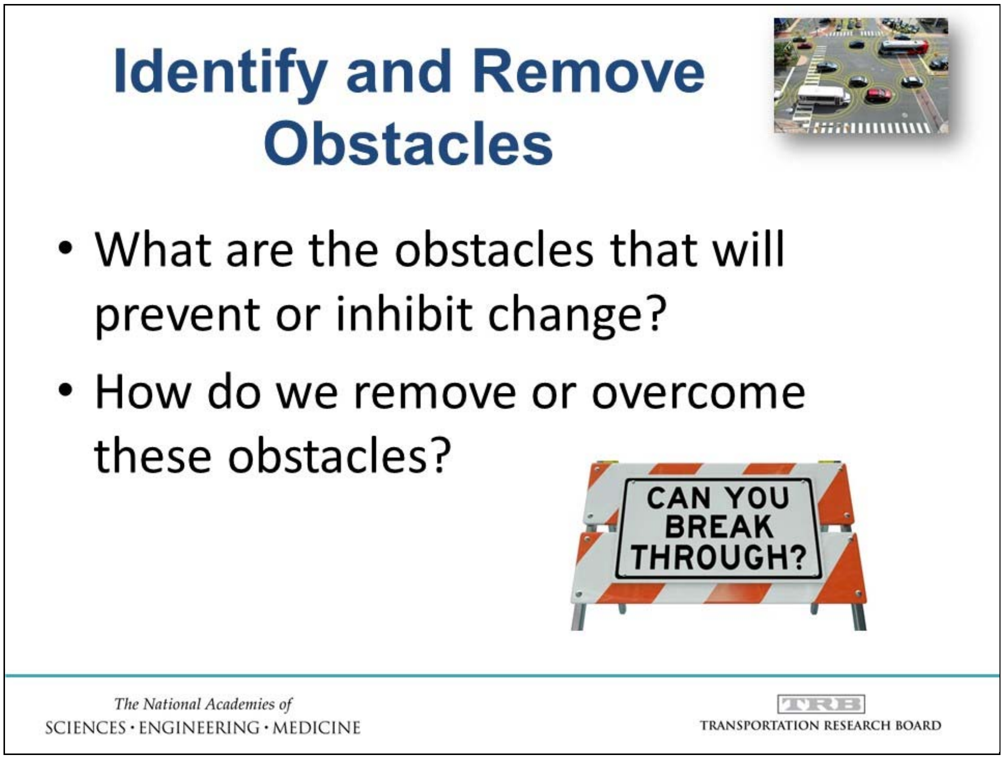


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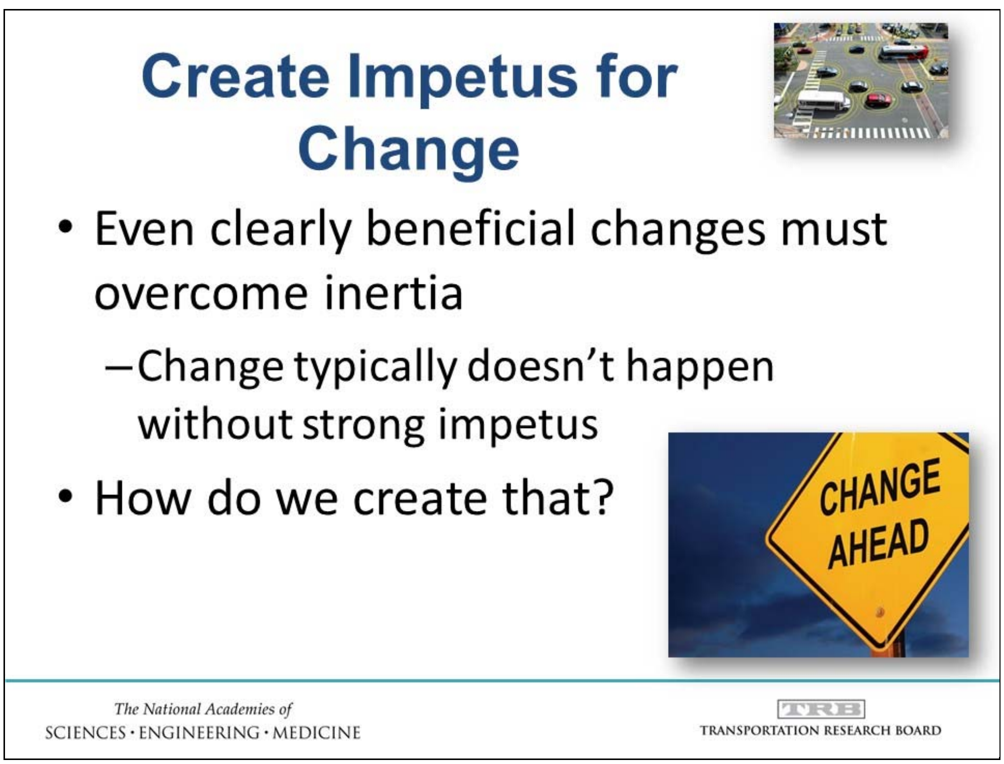

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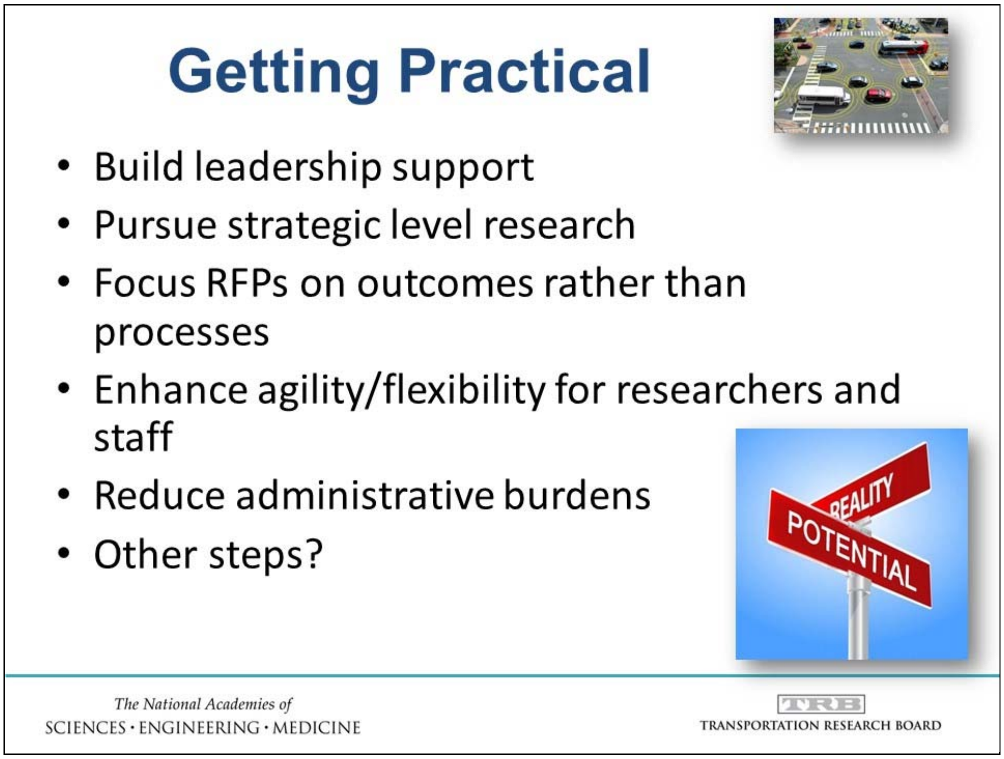


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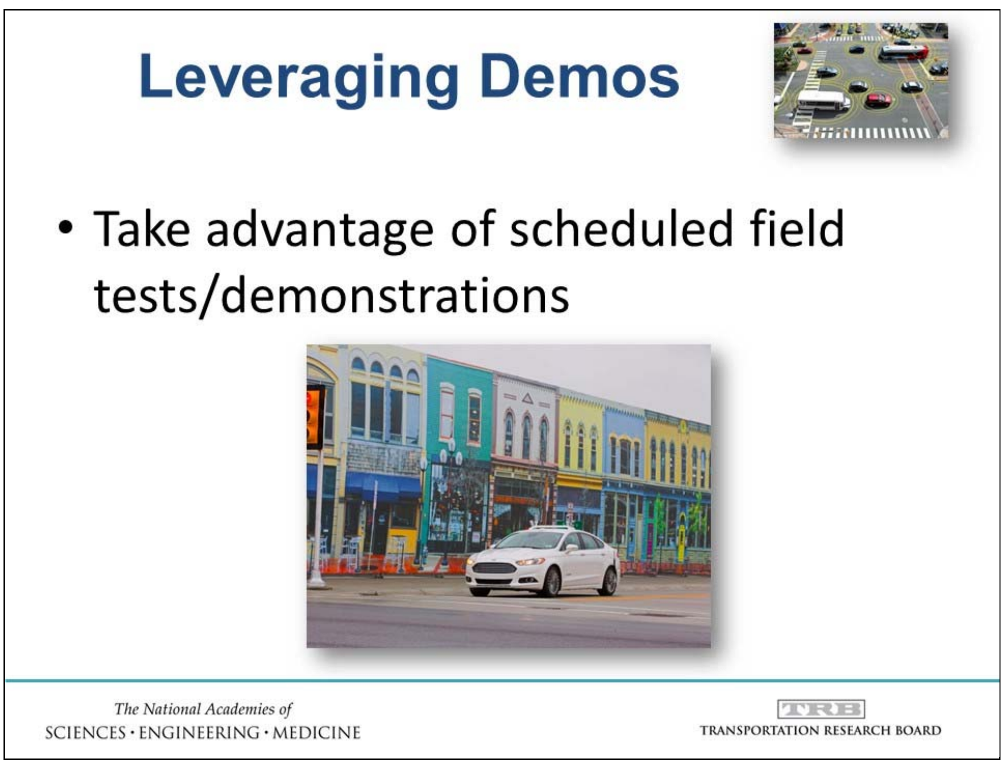

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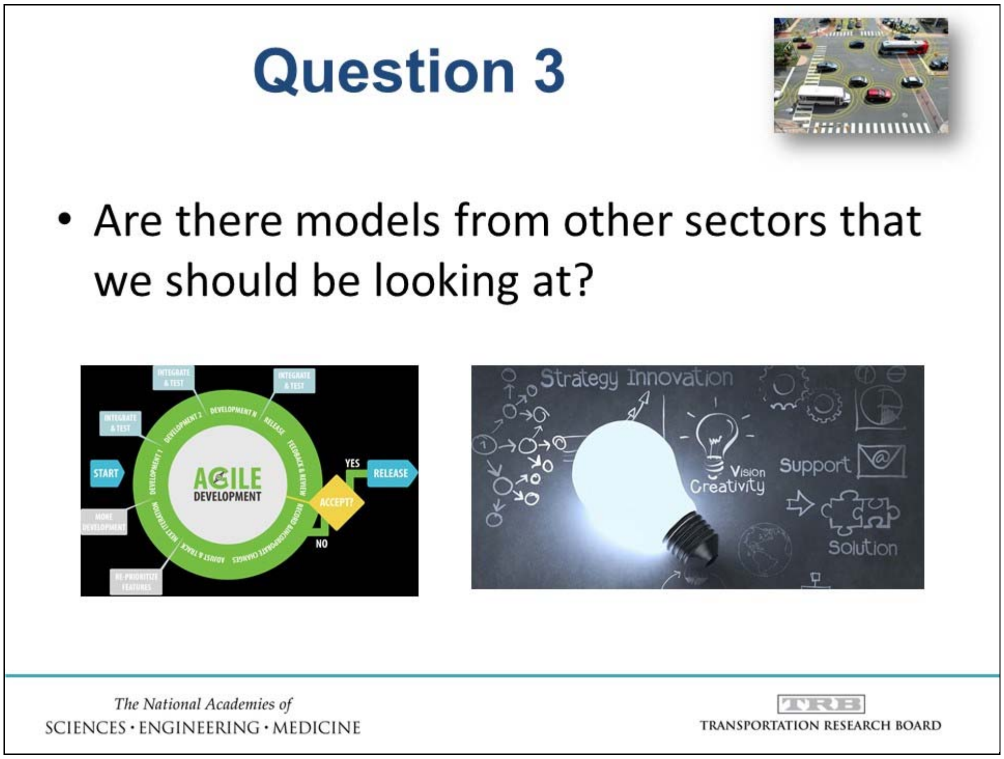


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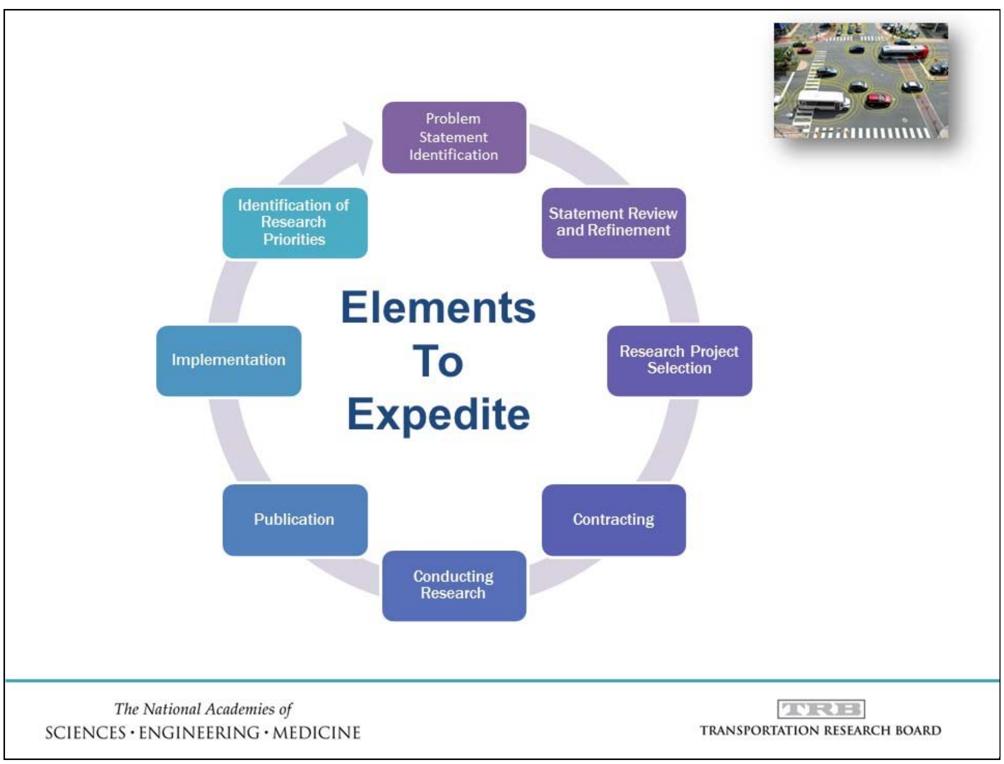

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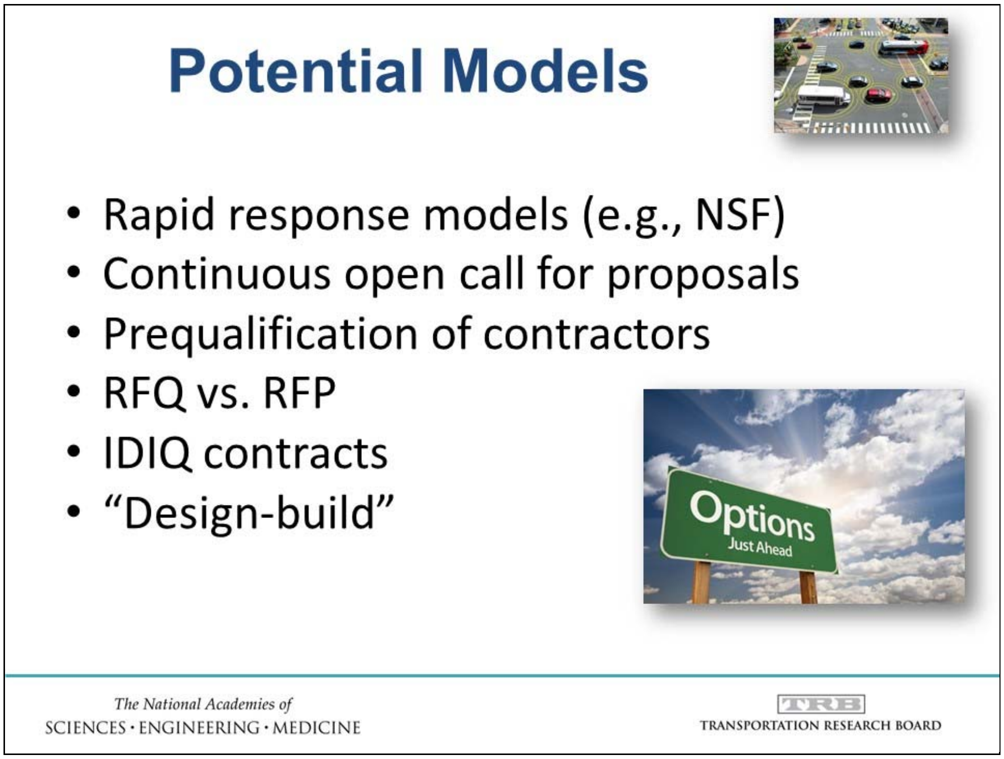


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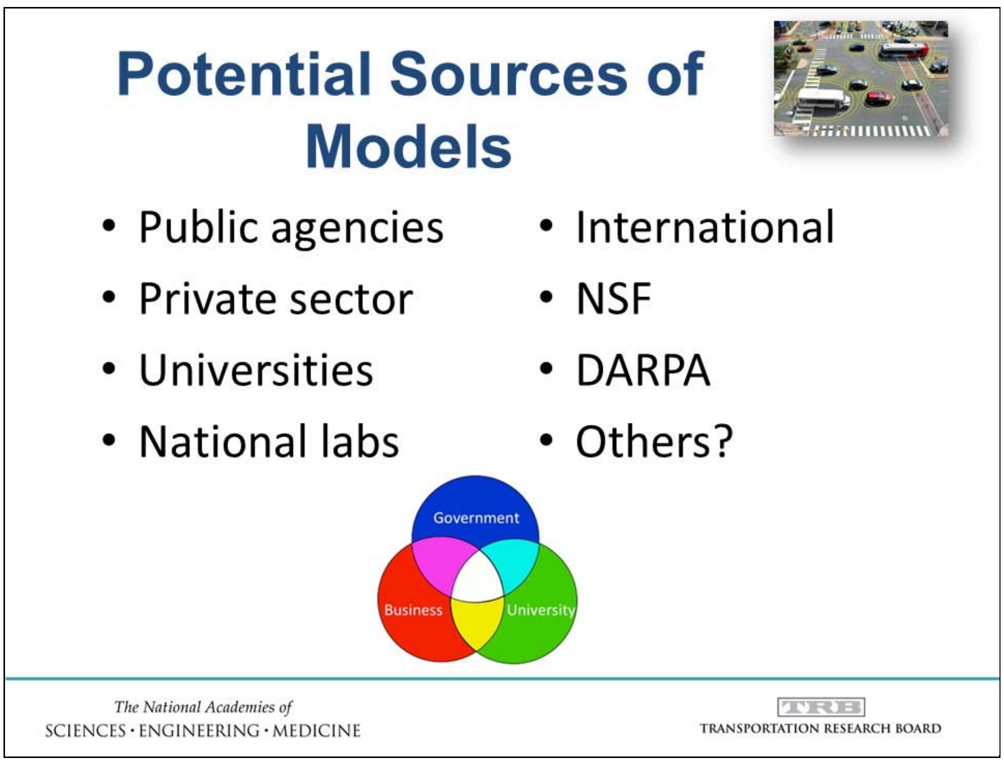

**Norman, concluded**

*Slide 19*

# Next Steps

- Synthesize comments and feedback
- Review by TRB Conduct of Research committee
- Share results
  - Summary flyer
  - More in-depth report
  - Distribute/publicize
  - Present at webinars, sessions, etc.


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*Slide 20*


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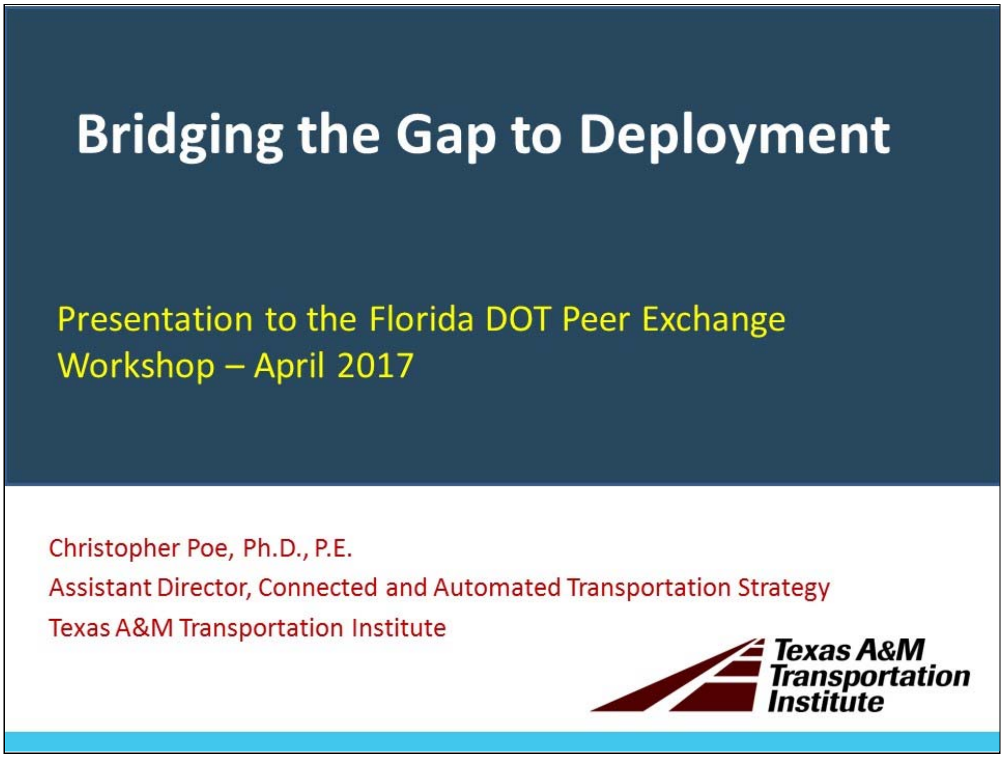
## Dr. Christopher Poe – Texas A&M Transportation Institute

*Slide 1*

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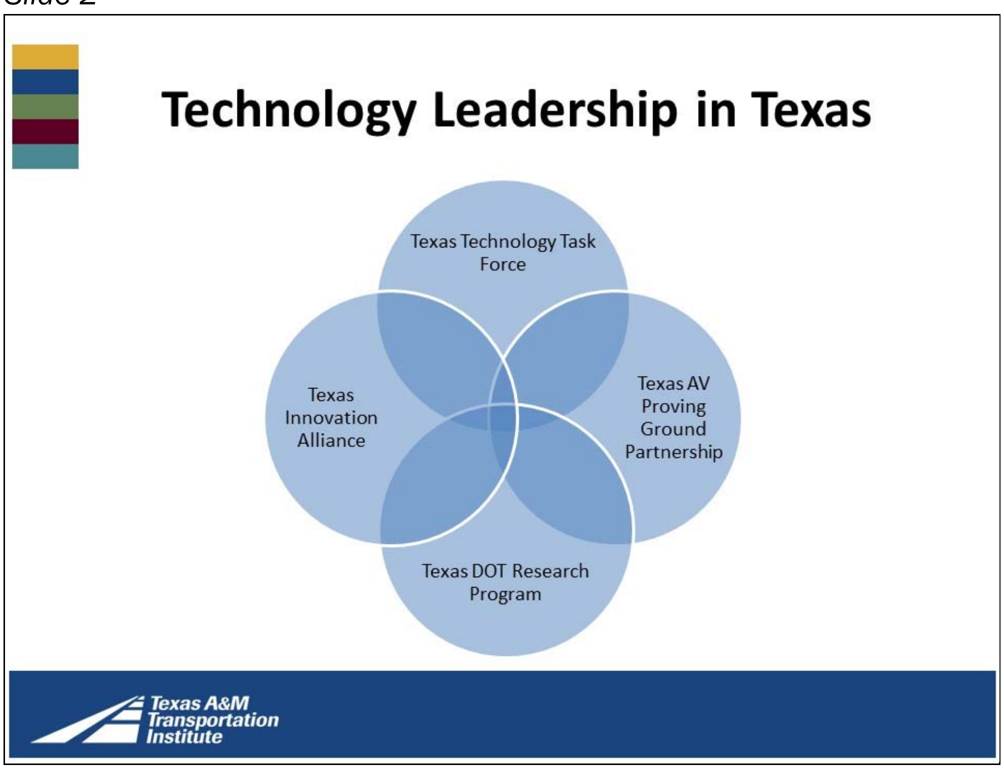


**Poe, continued**

*Slide 3*

## Texas DOT Innovative Research Program

- No RFP / Problem Statements
- Let Universities propose transformative research to support TxDOT Goals
  - Encourage private sector partnership
- Example of Projects
  - Commercial Truck Platooning
  - Wrong-way Driving Detection and Mitigation
  - Transit/Pedestrian/Bicycle Testbed
  - High-speed Sensing of Infrastructure

Texas A&M Transportation Institute

*Slide 4*

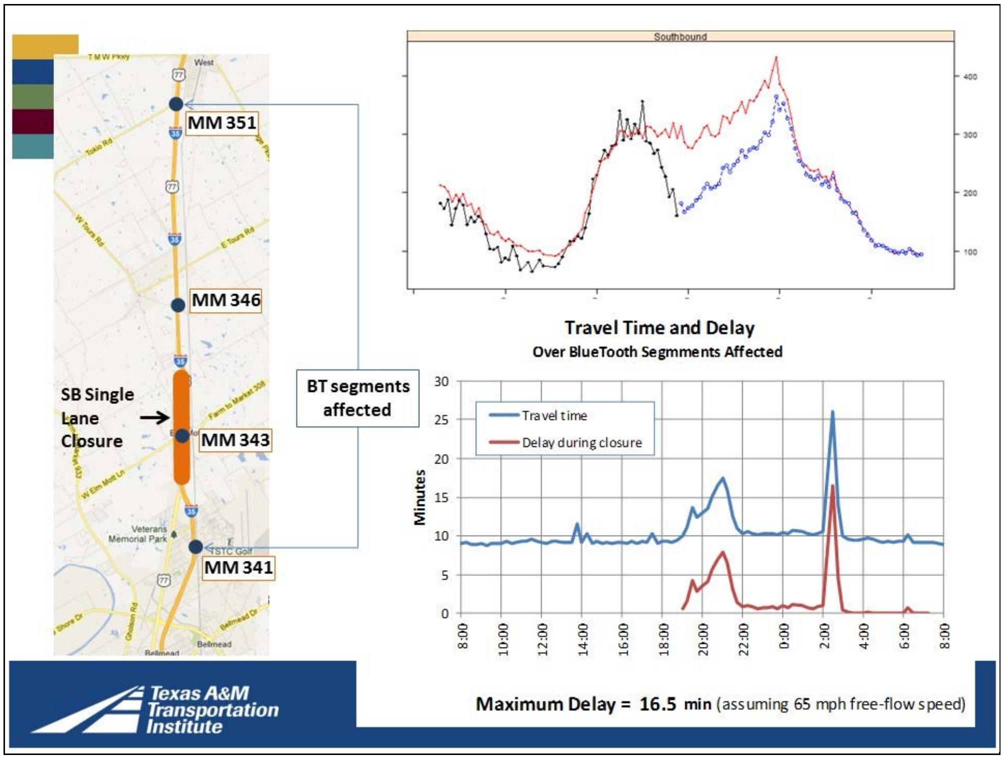
## Working Test Bed: I-35

- Bluetooth travel time detection
  - 40 segments, 2-5 miles in length
  - ~20 additional segments AUS, SAN, DAL, FTW
- 19 Wavetronix radar detector sites
- 7 CCTV cameras sites
- 21 portable changeable message signs (PCMS)
  - ~10 per direction at approximate10 mile spacing

Texas A&M Transportation Institute

**Poe, continued**

*Slide 5*

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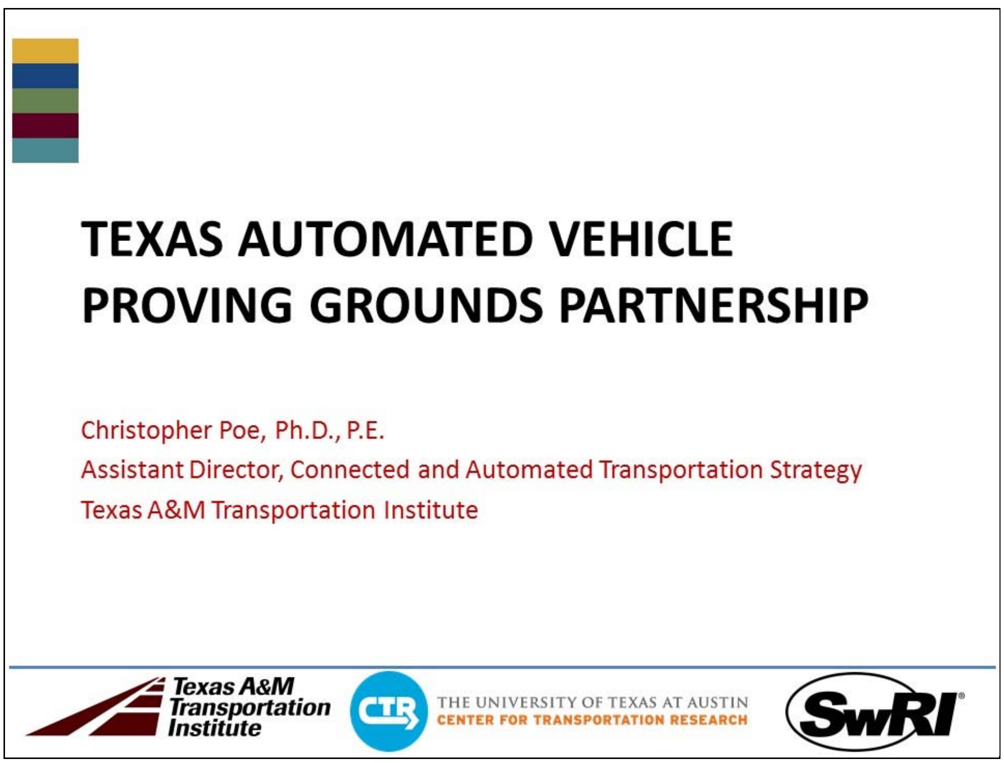

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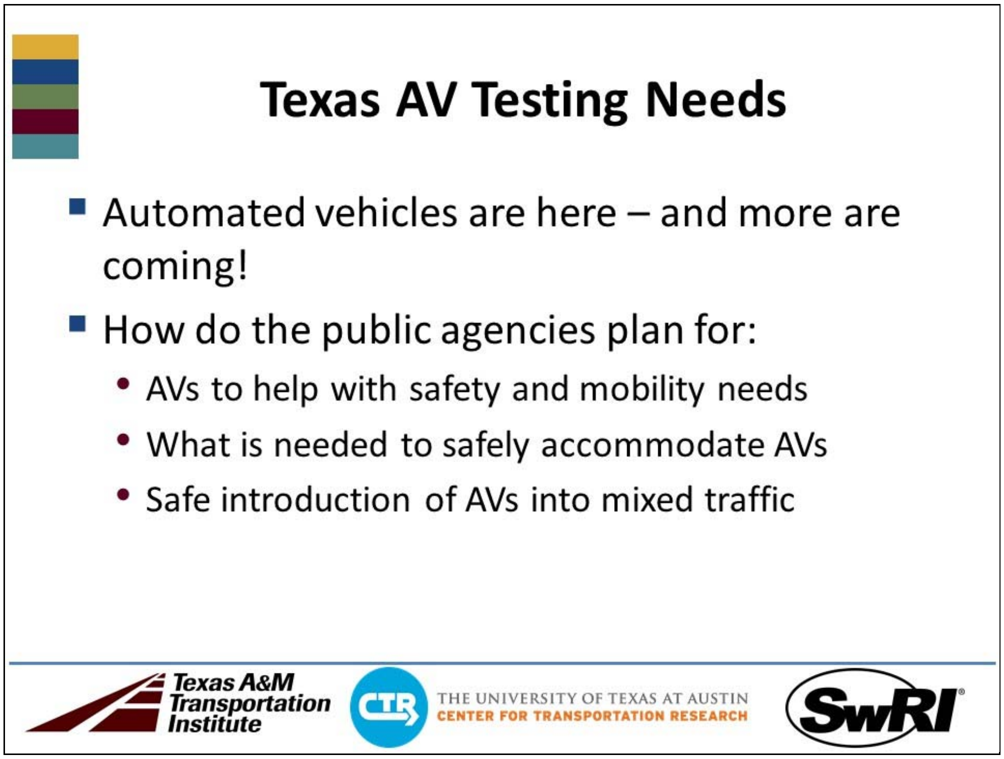


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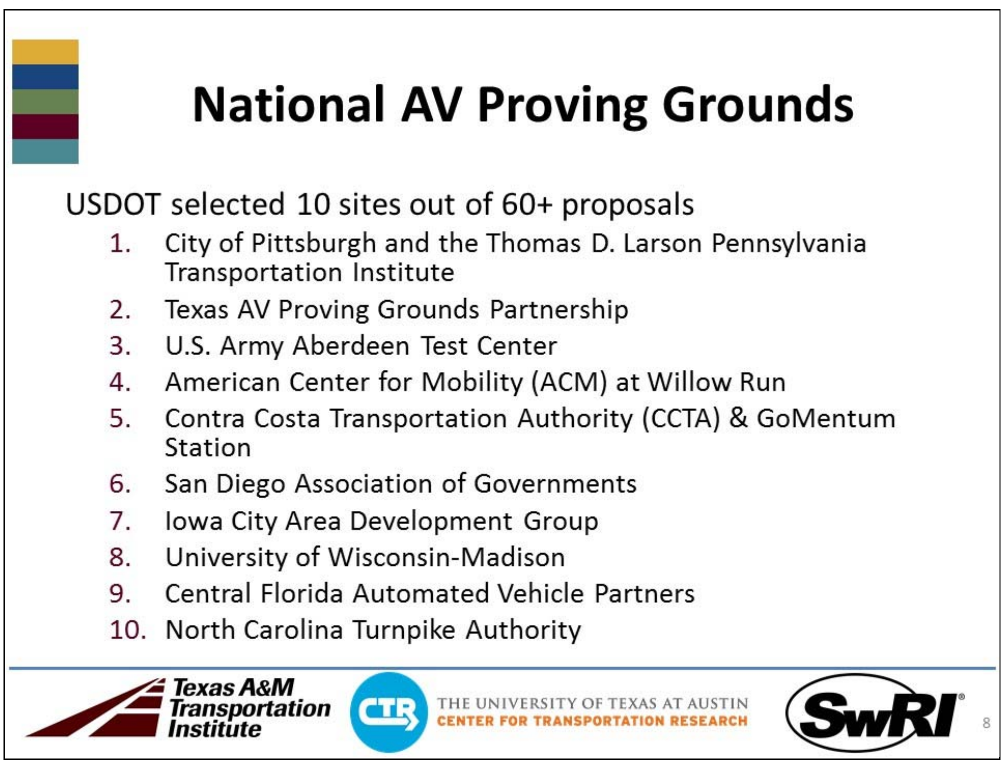

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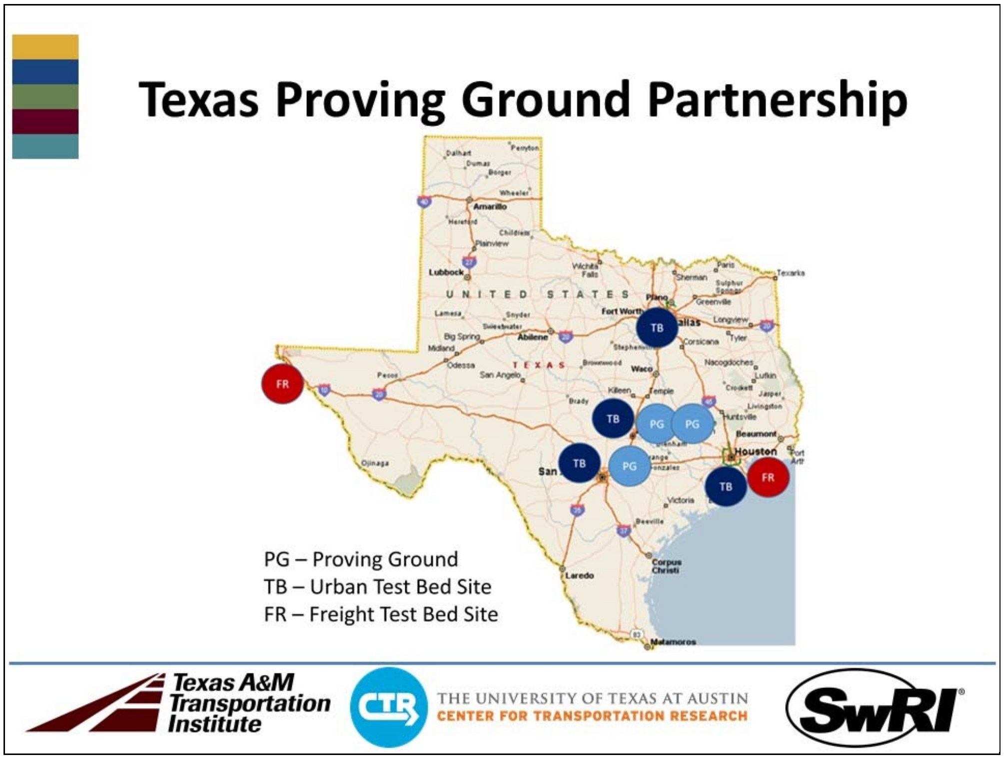


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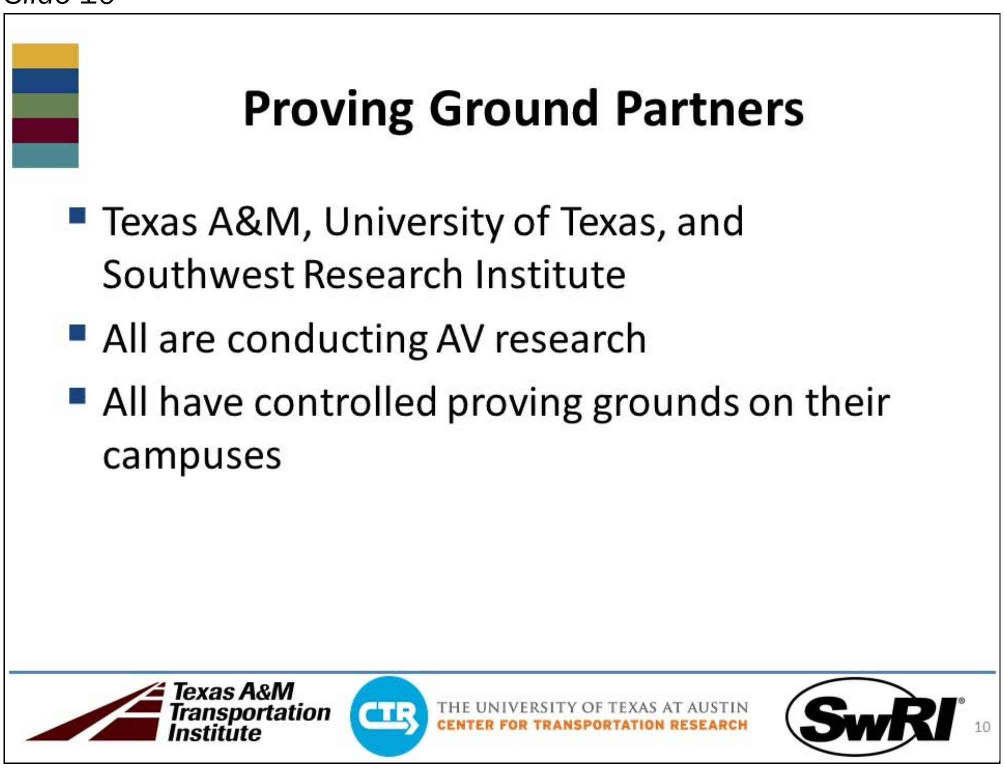

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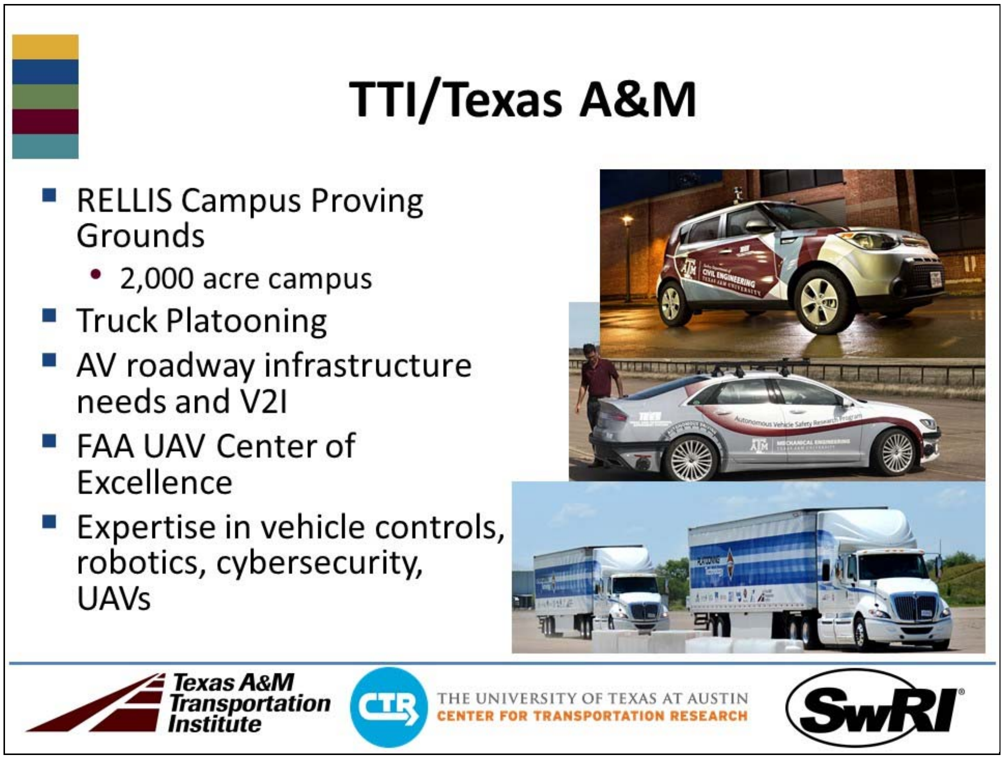


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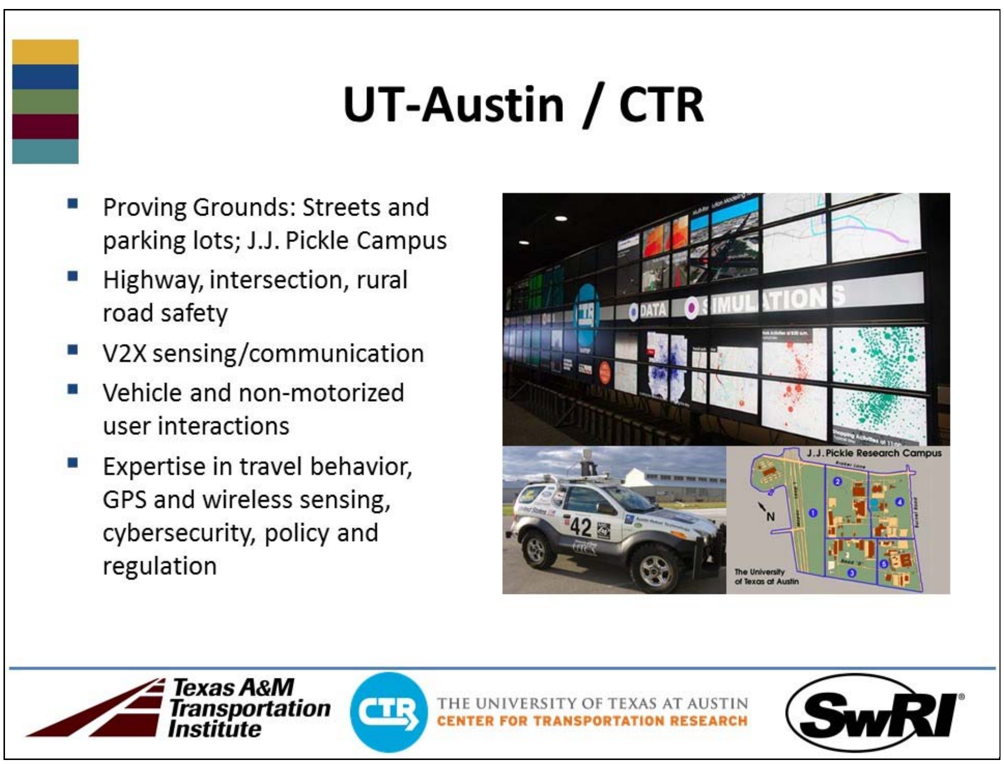

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*Slide 13*


*Slide 14*

**Poe, continued**

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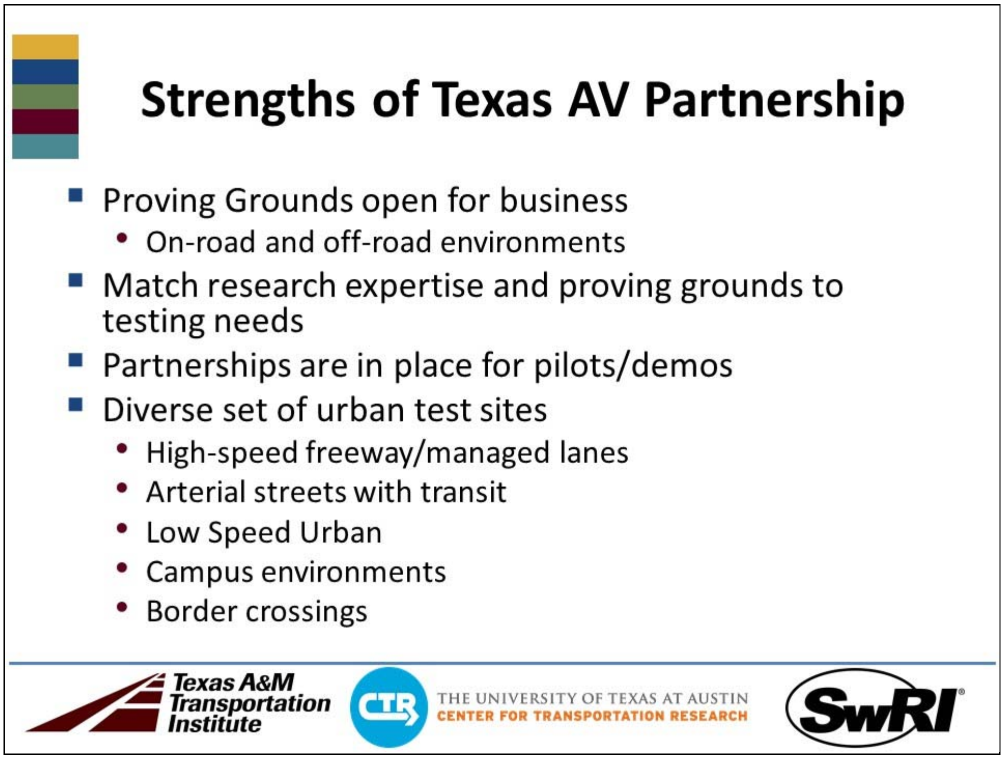


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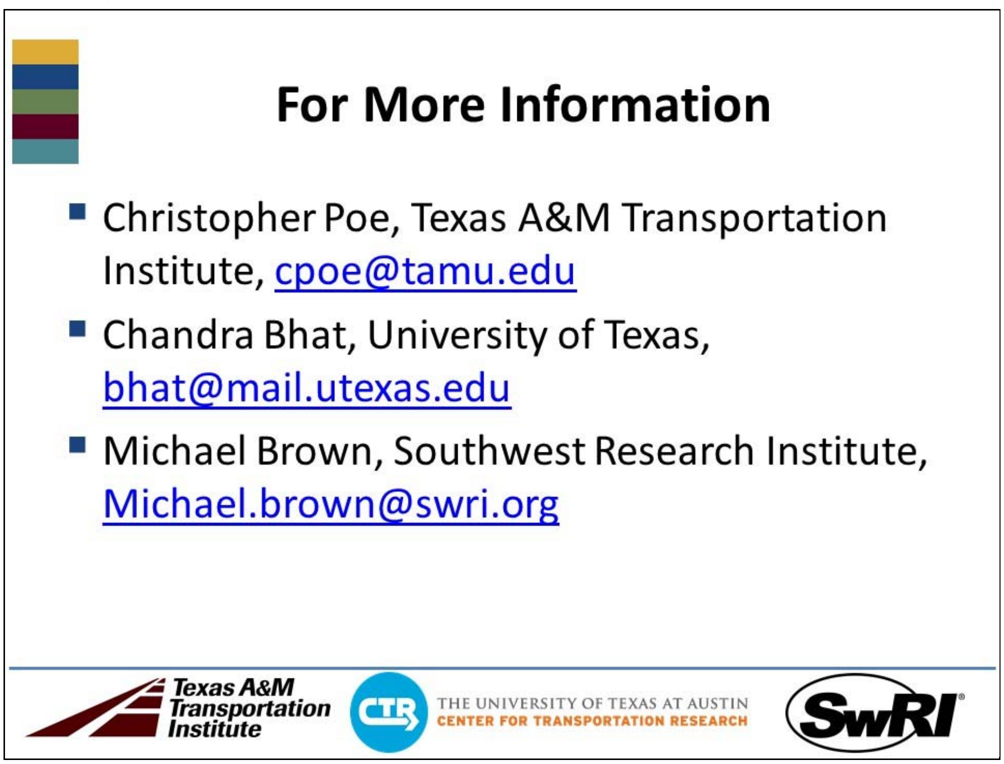

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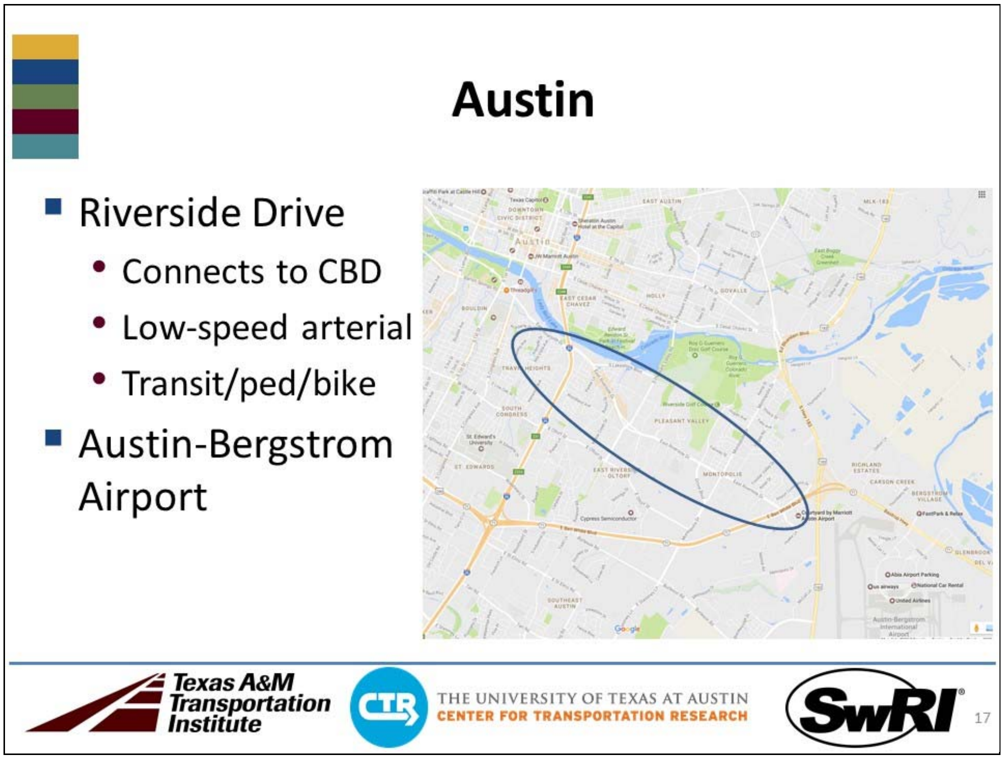


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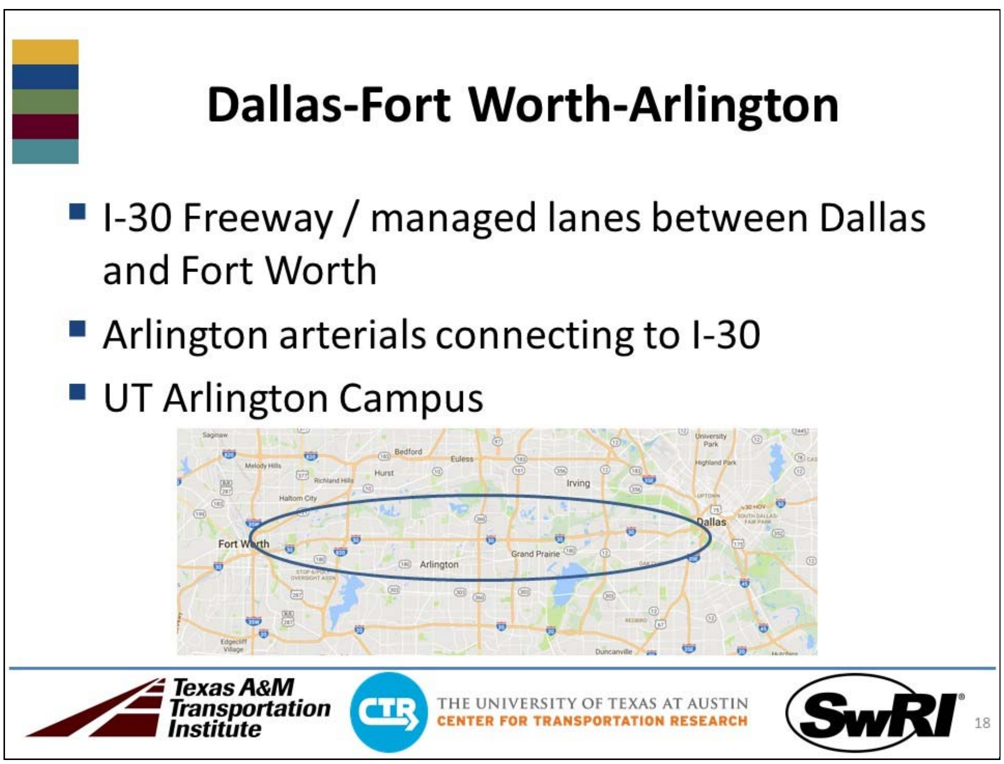

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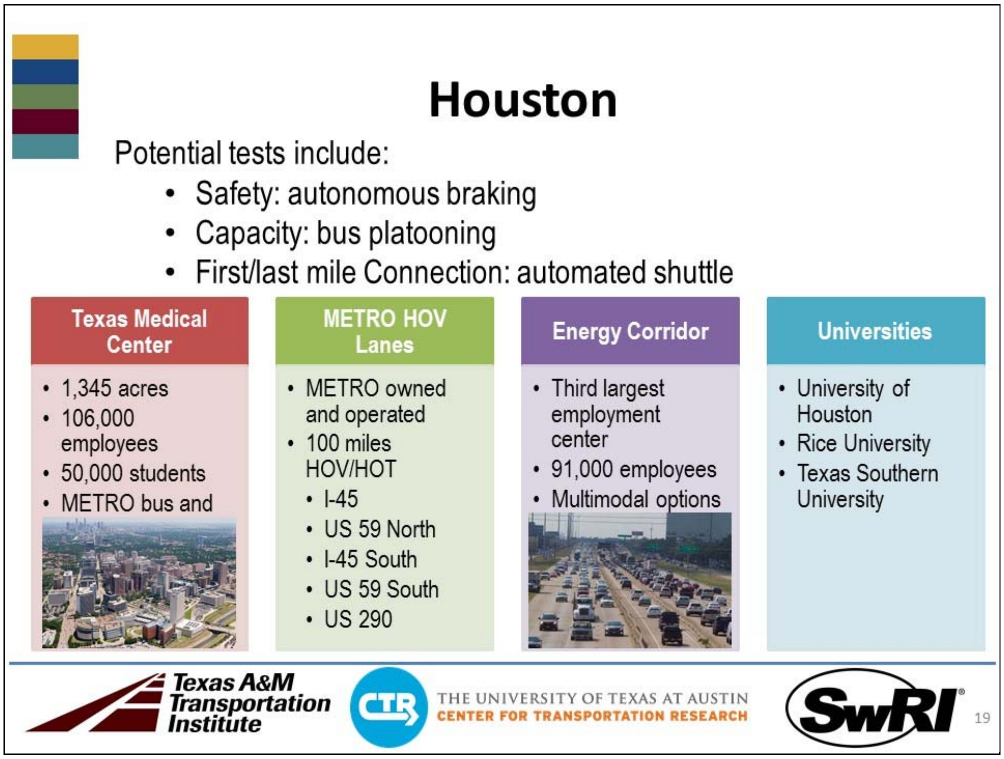


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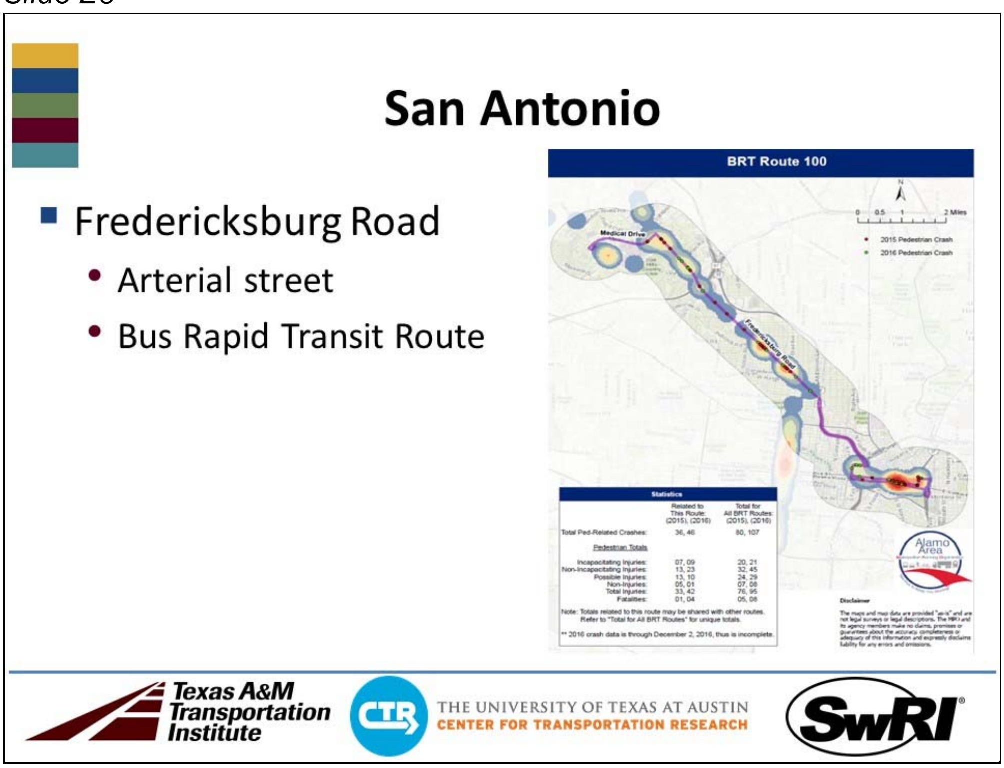

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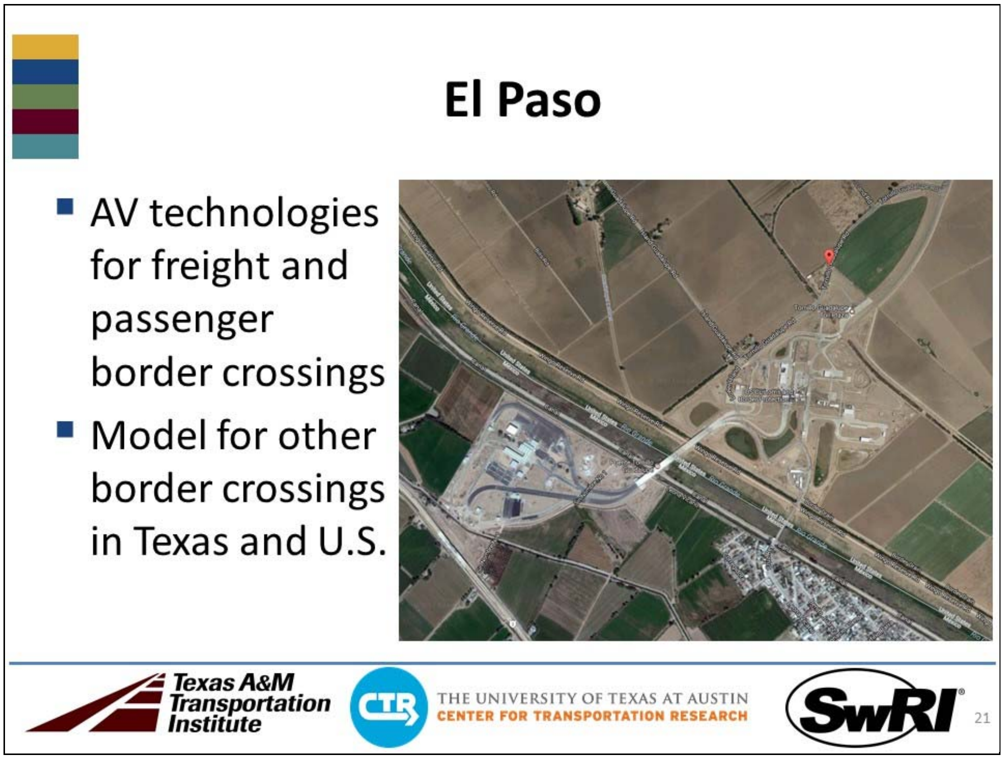



*Slide 22*

## Dr. Kate Lawson – University at Albany

*Slide 1*

**Road to the Future is Paved with Data**

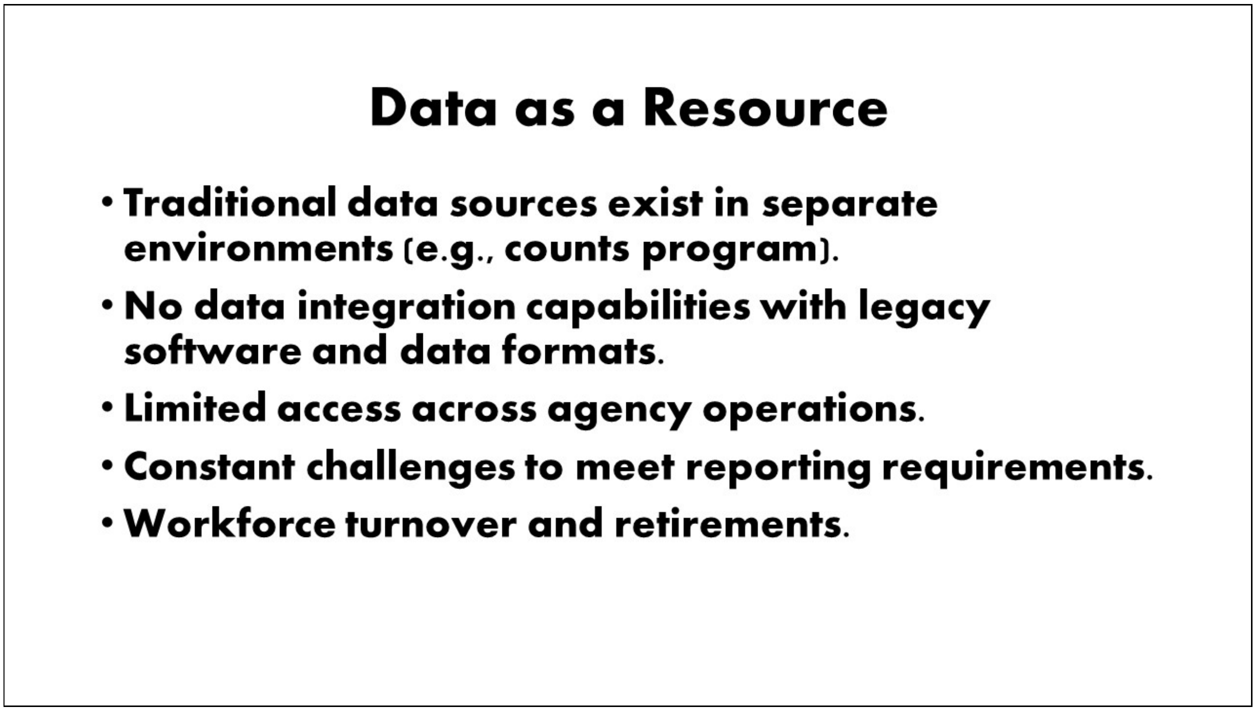
**Dr. Catherine T. Lawson**
**University at Albany/AVAIL**
**Peer Exchange/Tallahassee, FL**
**5/25-5/27, 2017**

*Slide 2*

**Traditional Approach:**
**Data used for decision-making**

**Lawson, continued**

*Slide 3*

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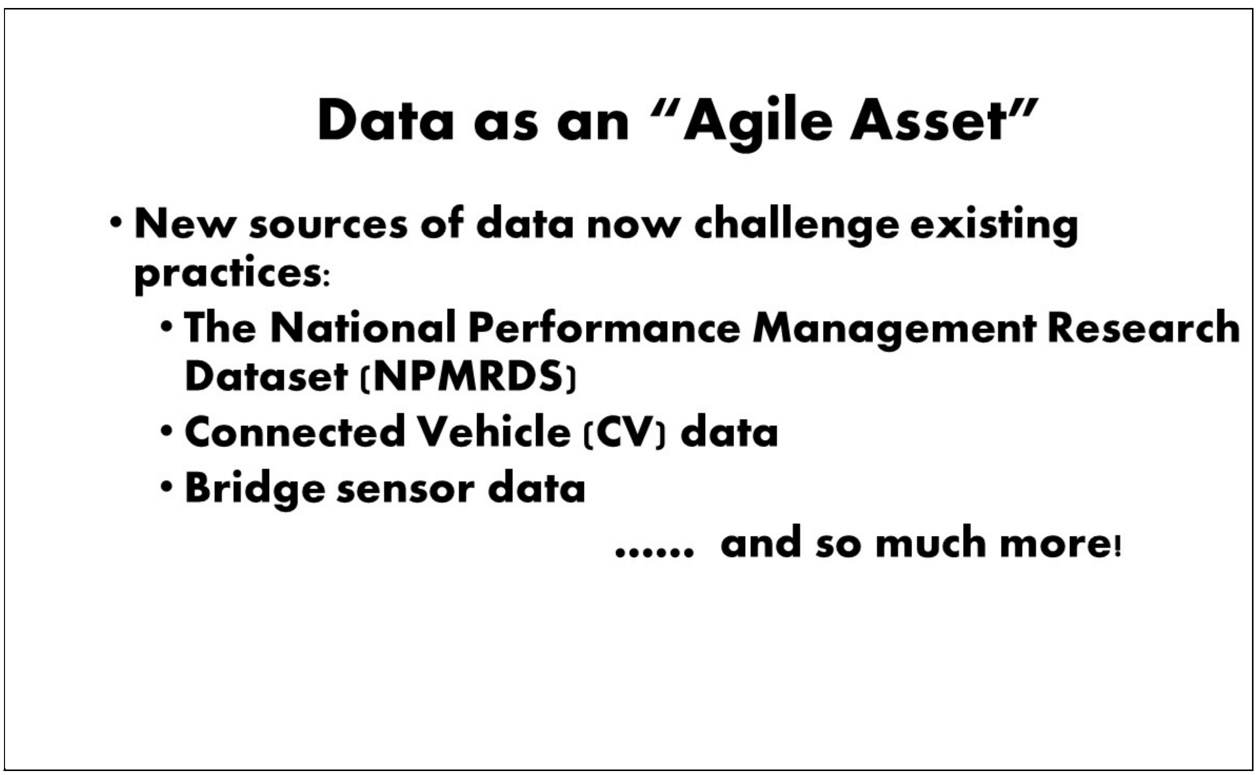


**Lawson, continued**

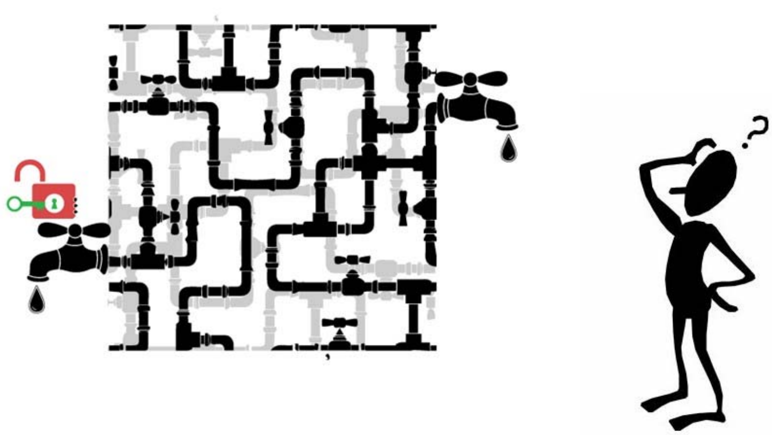
*Slide 5*

## New York State DOT: Taking on the challenge

- Data delivery strategies
- Analytics options
- Organizational approach
- Relationship to workforce needs
- Internal/External dissemination
- Maintainability and investment longevity

*Slide 6*

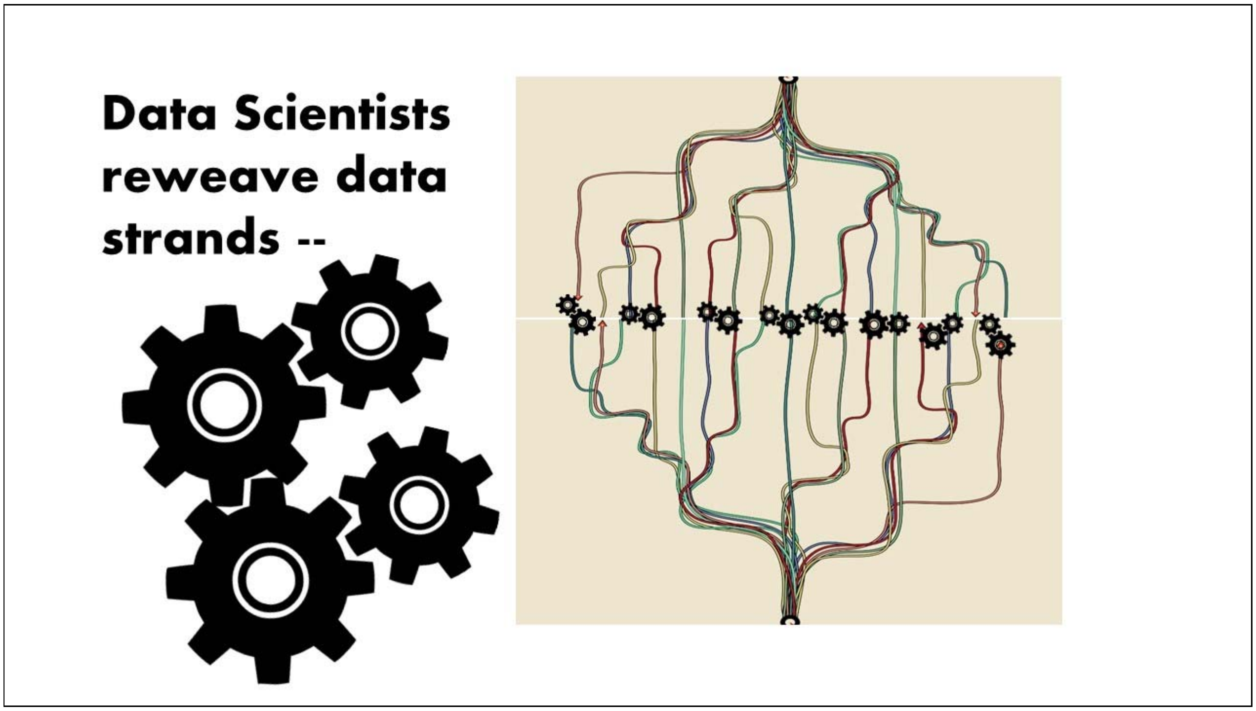
## Thinking like a Data Scientist




**Application Programming Interfaces (APIs)**

**Lawson, continued**

*Slide 7*

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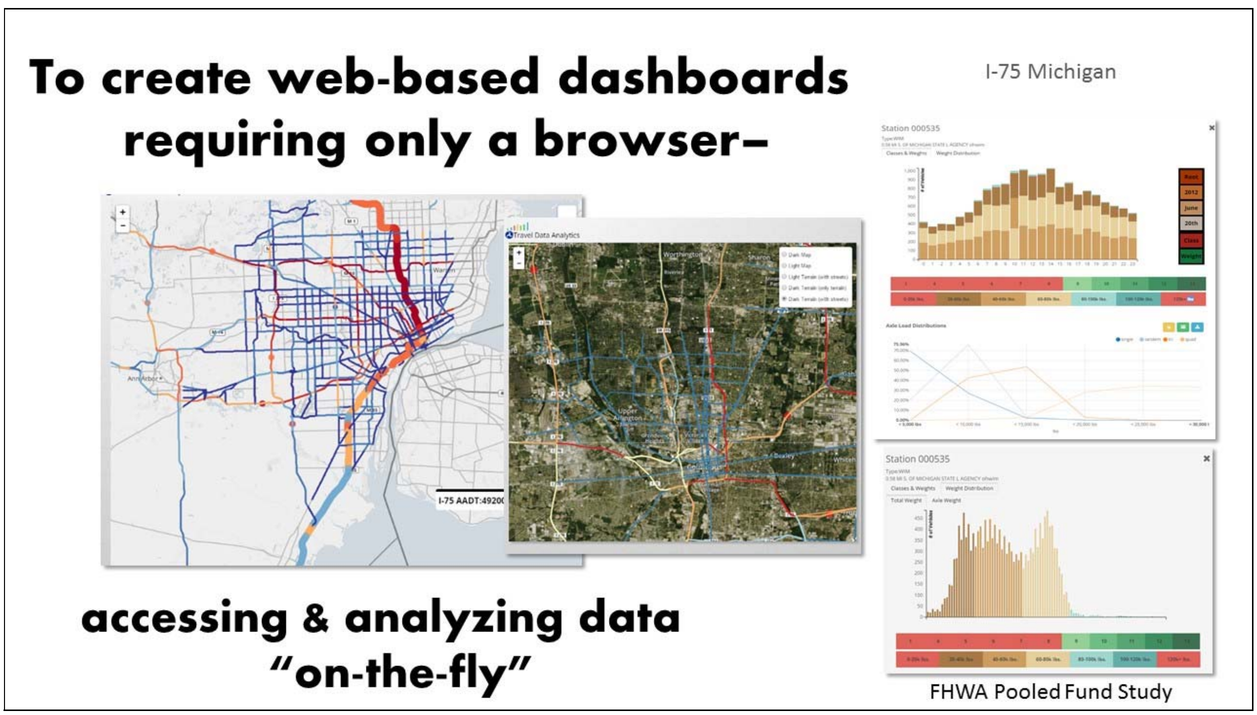

**Lawson, continued**

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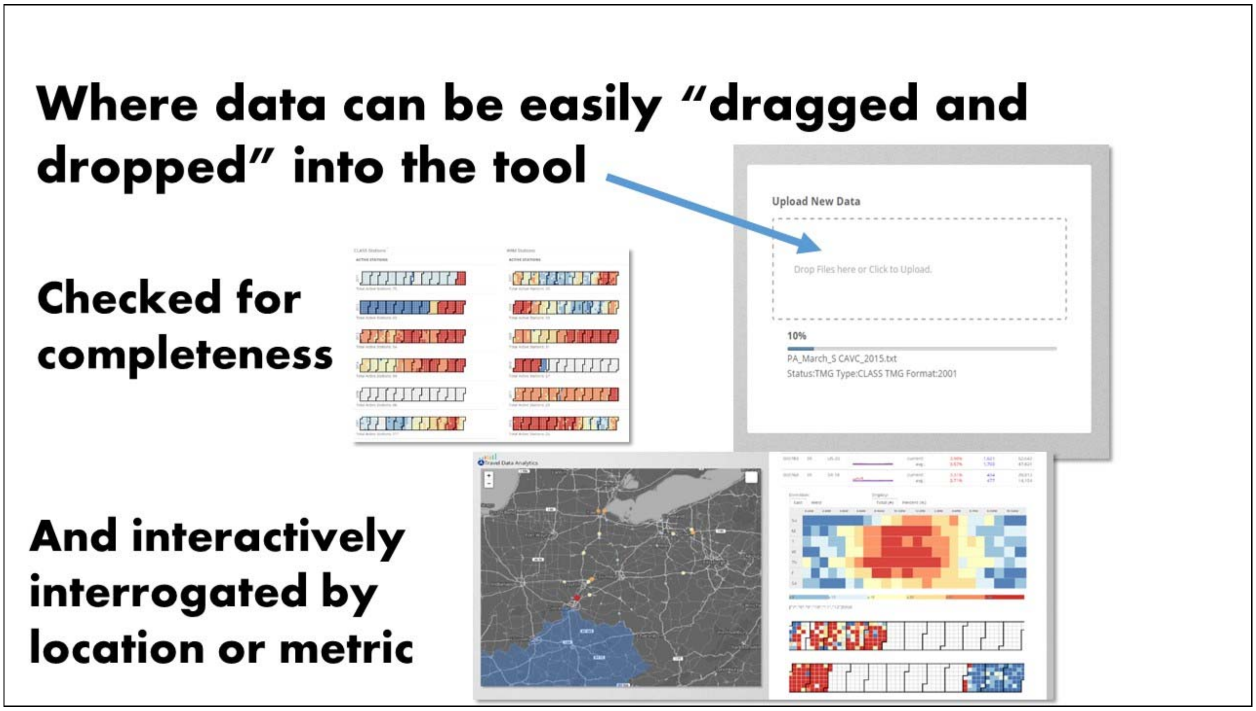


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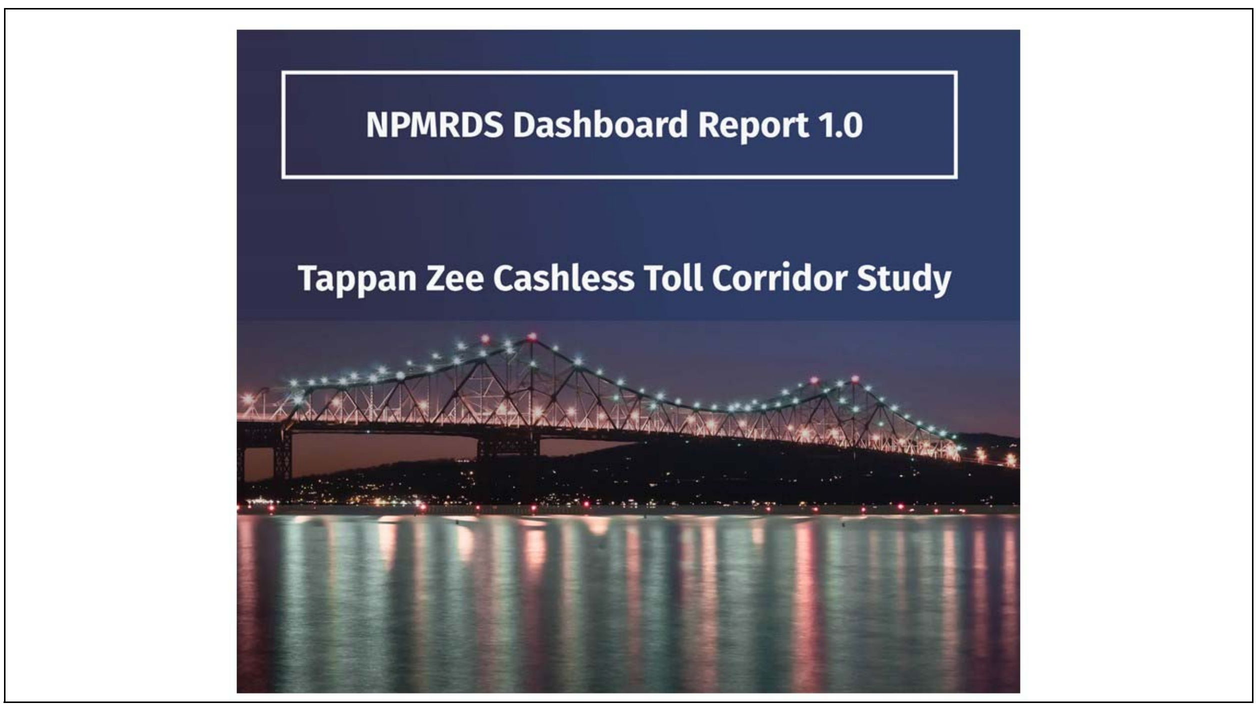

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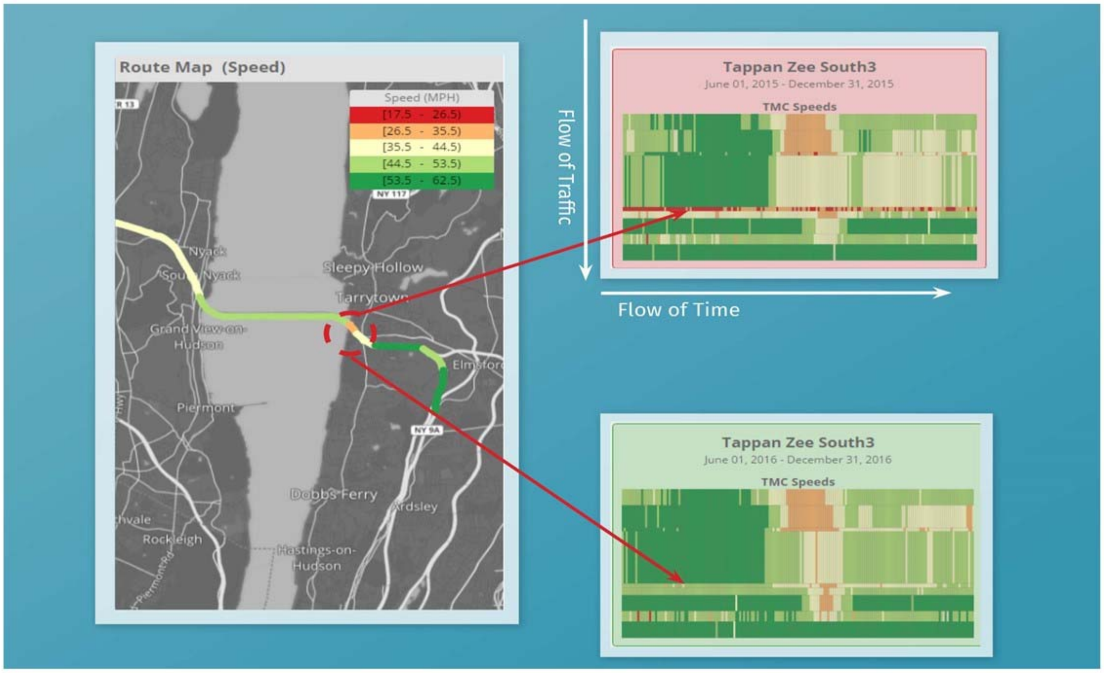


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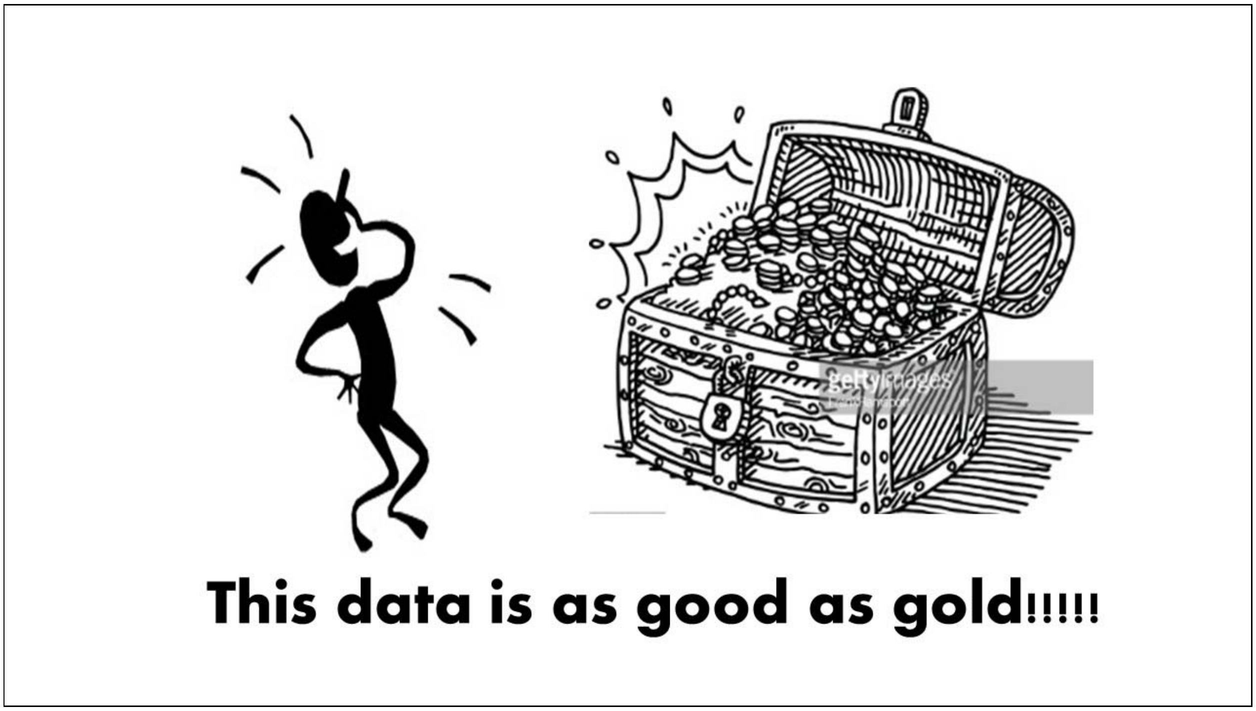
**Lawson, continued**

*Slide 13*




*Slide 14*

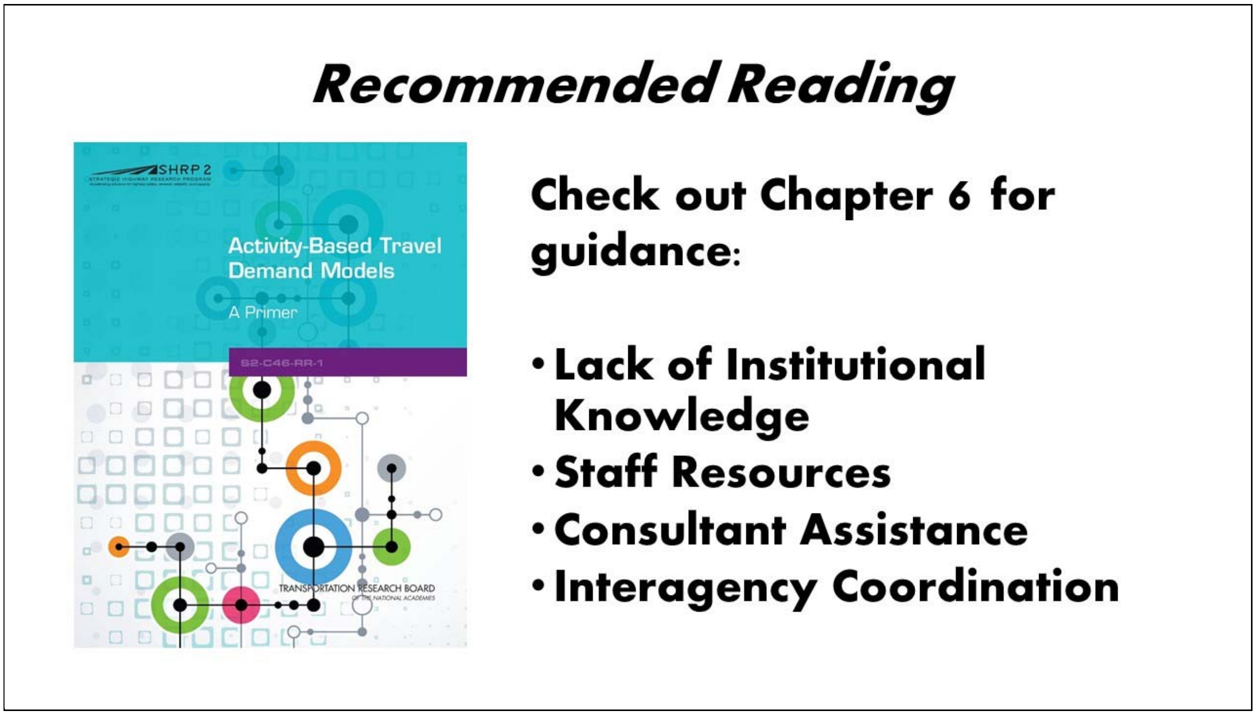
## The Way Forward

- Strategic Approach to Data
  - Platform Options (e.g., APIs, tools)
- Intra-agency Integration
- Multi-agency Integration
- Regional Integration
- Micro- to Mega-scale Geographies
- Day Forward Trajectory –

***Think about your data needs for tomorrow - TODAY!***

**Lawson, concluded**

*Slide 15*

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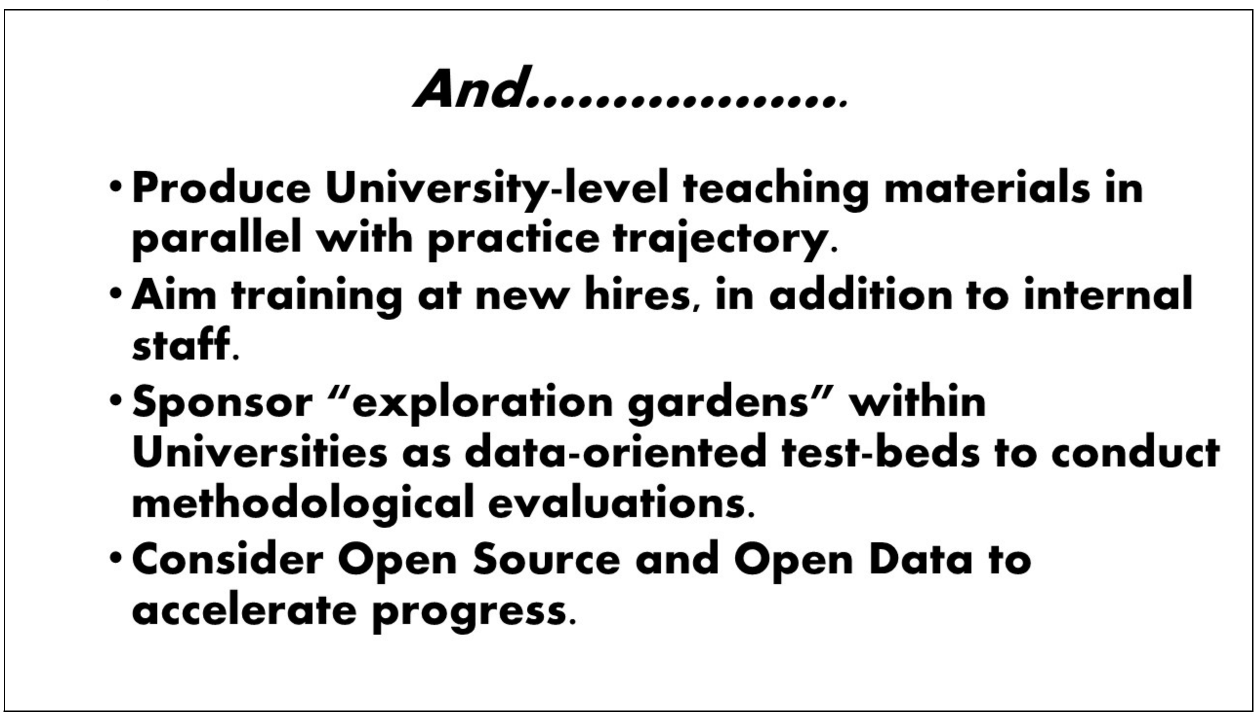

## Dr. Lily Elefteriadou – University of Florida

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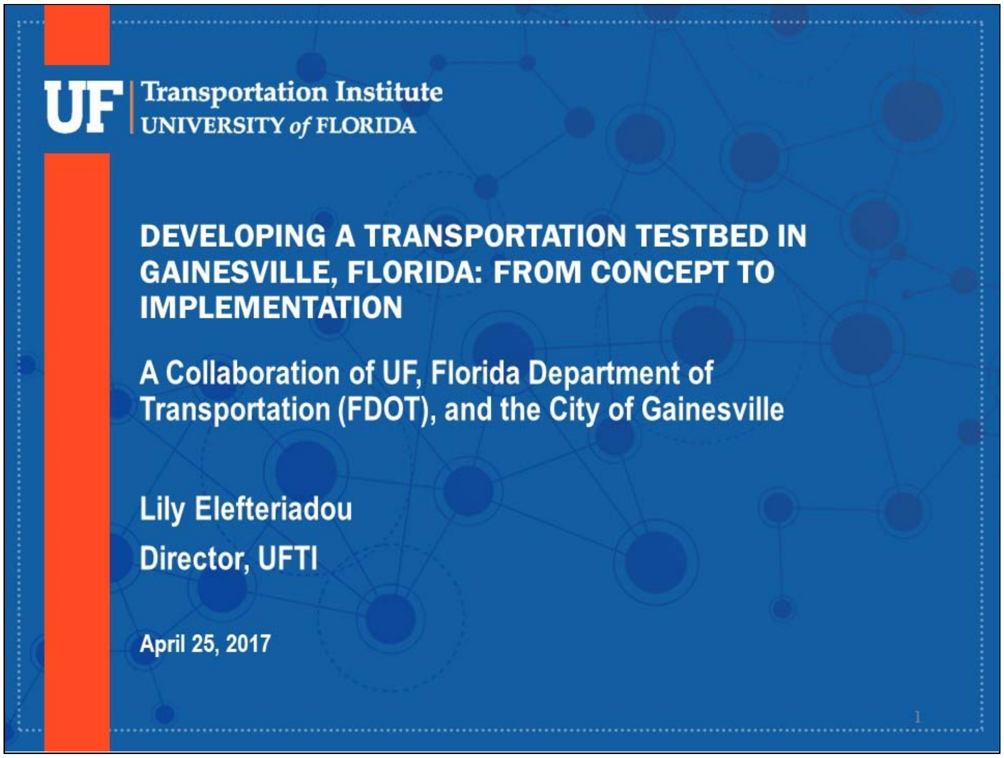


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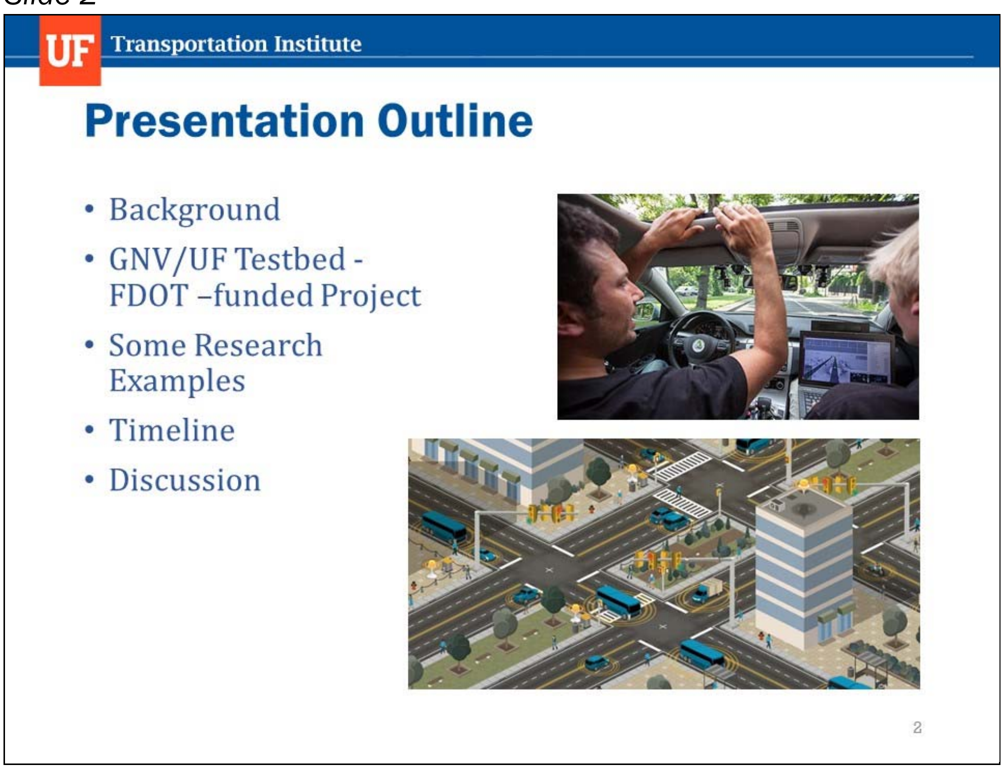

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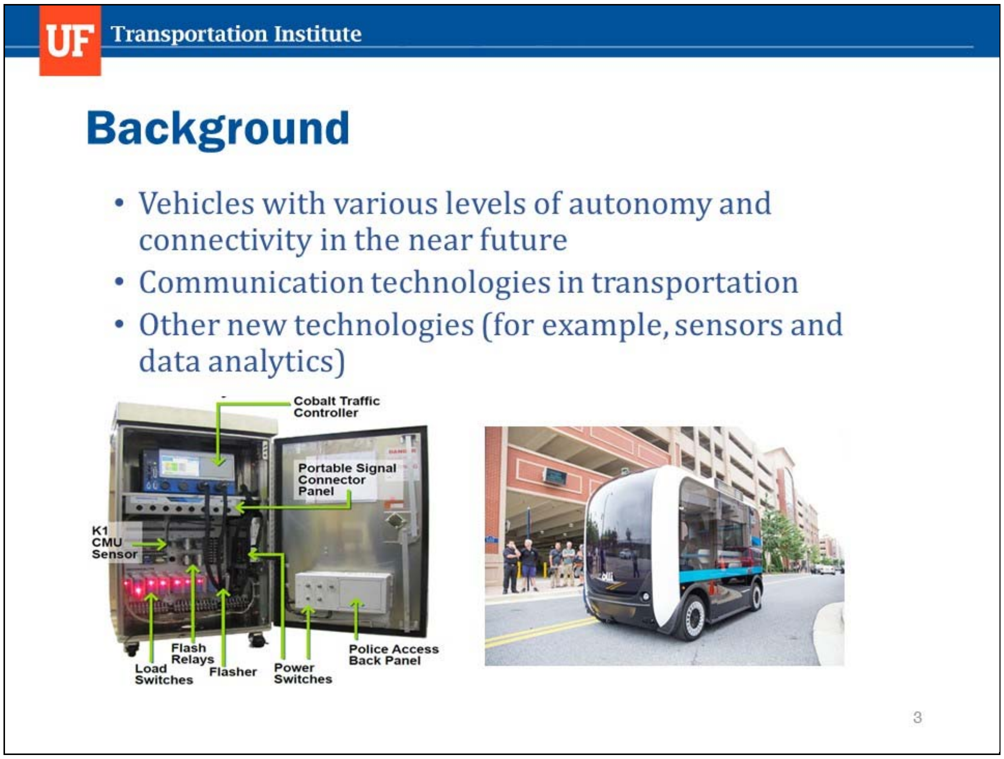


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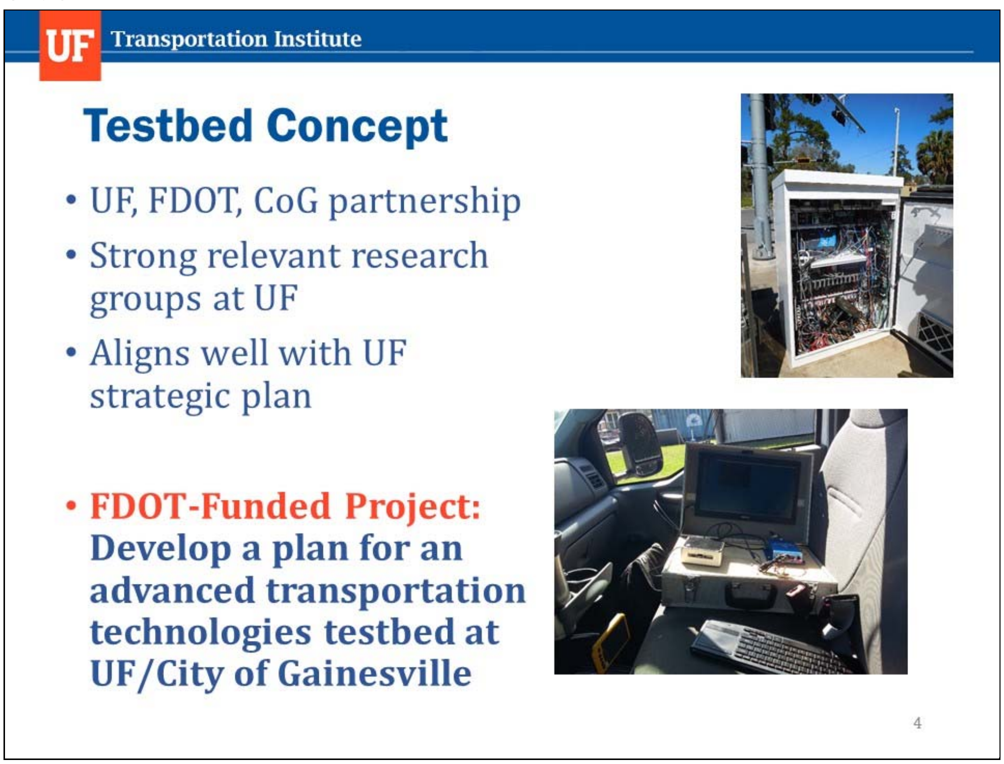

**Elefteriadou, continued**

*Slide 5*

UF Transportation Institute

## FDOT Project Objectives

1. Literature and State-of-the-art Review
   - Published literature and reports
   - Other testbeds
   - Industry
2. Assist FDOT with Peer Exchange
   - Roadmap of a state research program in the context of emerging technologies
3. Develop a Roadmap
   - Implementation and operation of the testbed
   - Industry engagement

5

*Slide 6*

UF Transportation Institute

## Testbed Initiatives in Florida

- Florida's Connected Vehicle Test Bed – Orlando
  ITS World Congress Roadside Unit Deployment
- Tampa-Hillsborough Expressway Authority (THEA)
  Connected Vehicle Pilot Deployment Program
- Advanced Driver Assistant Systems (ADAS)- District 7
- AV/CV/ITS Freight Applications (Perishable-goods delivery)– Miami
- Central Florida Automated Vehicle Partners - Florida
  USDOT Automated Vehicle Proving Grounds
- Transportation Testbed in Gainesville – University of Florida
  FDOT, UF AND COG

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**Elefteriadou, continued**

*Slide 7*


*Slide 8*

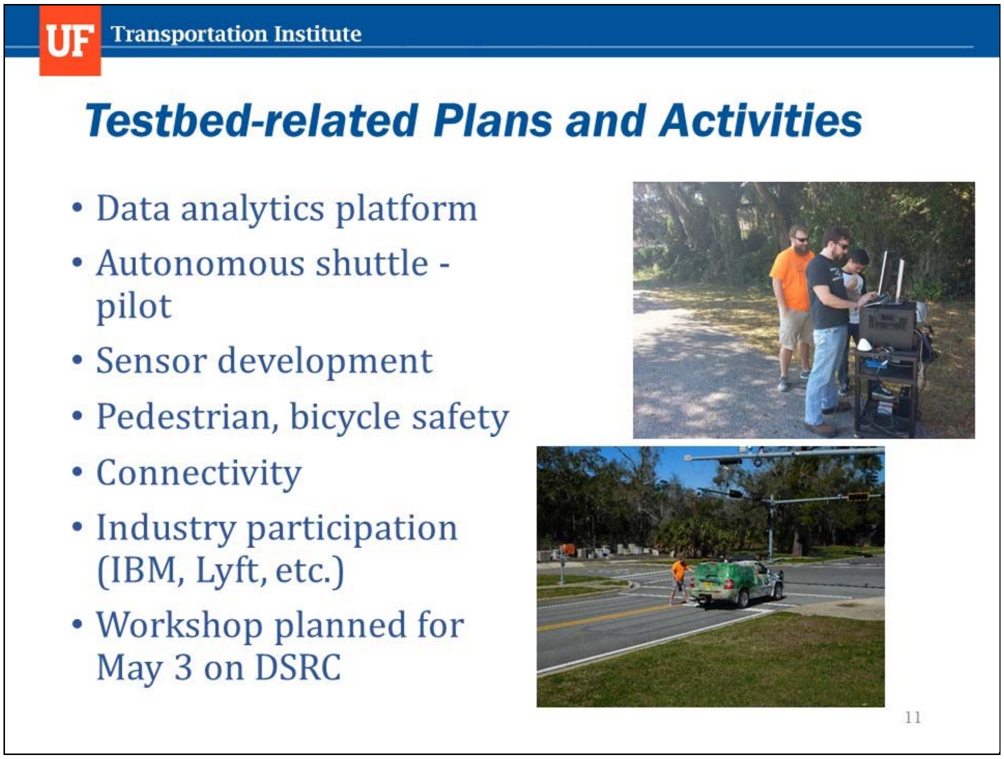
**Elefteriadou, continued**

*Slide 9*


*Slide 10*

**Elefteriadou, continued**

*Slide 11*

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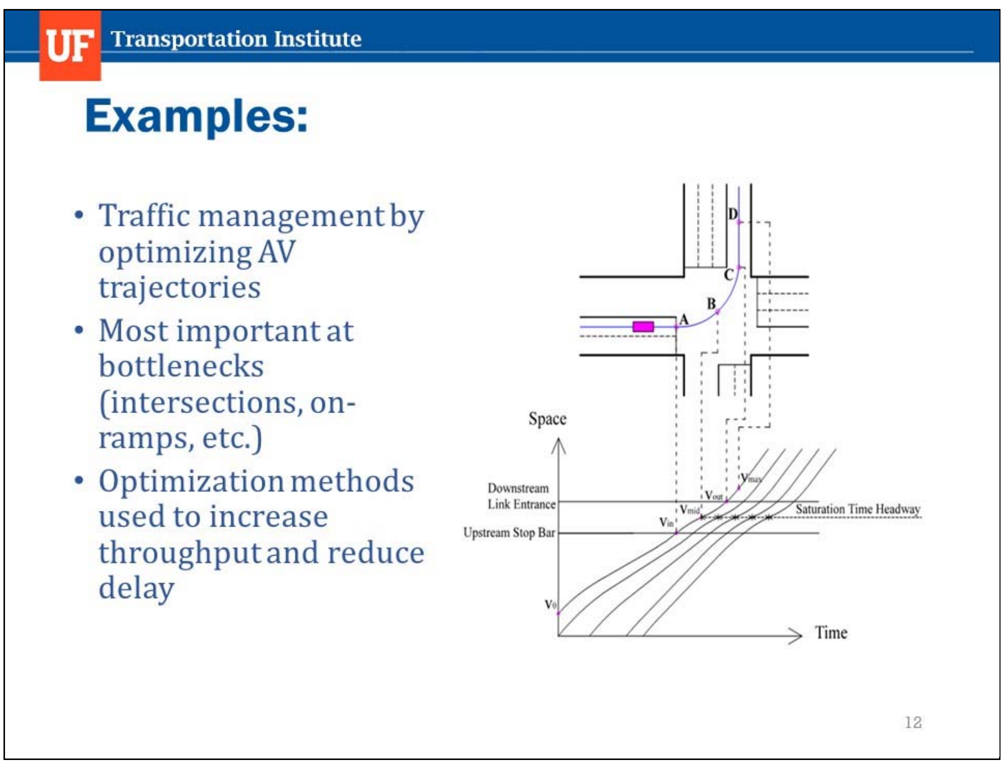

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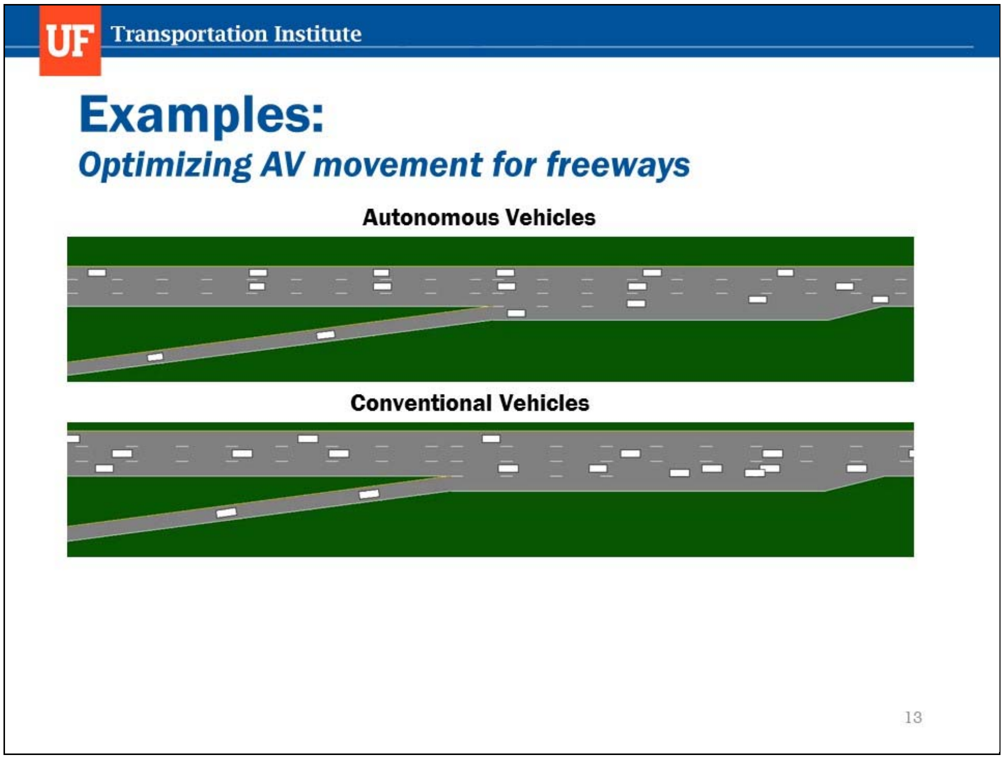


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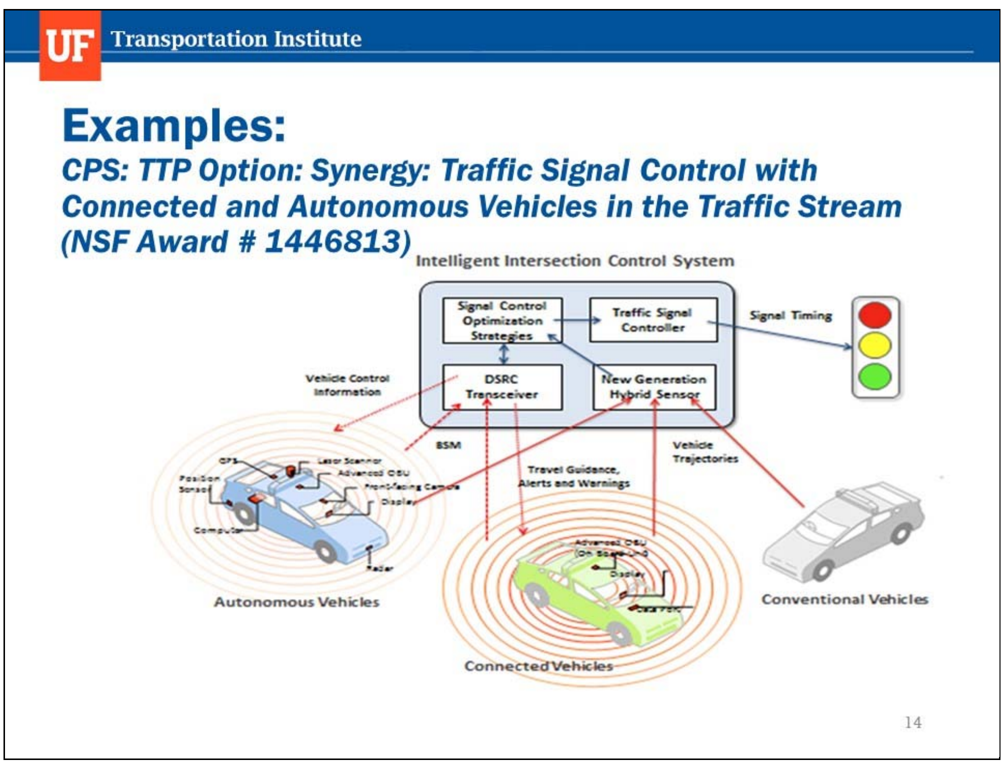

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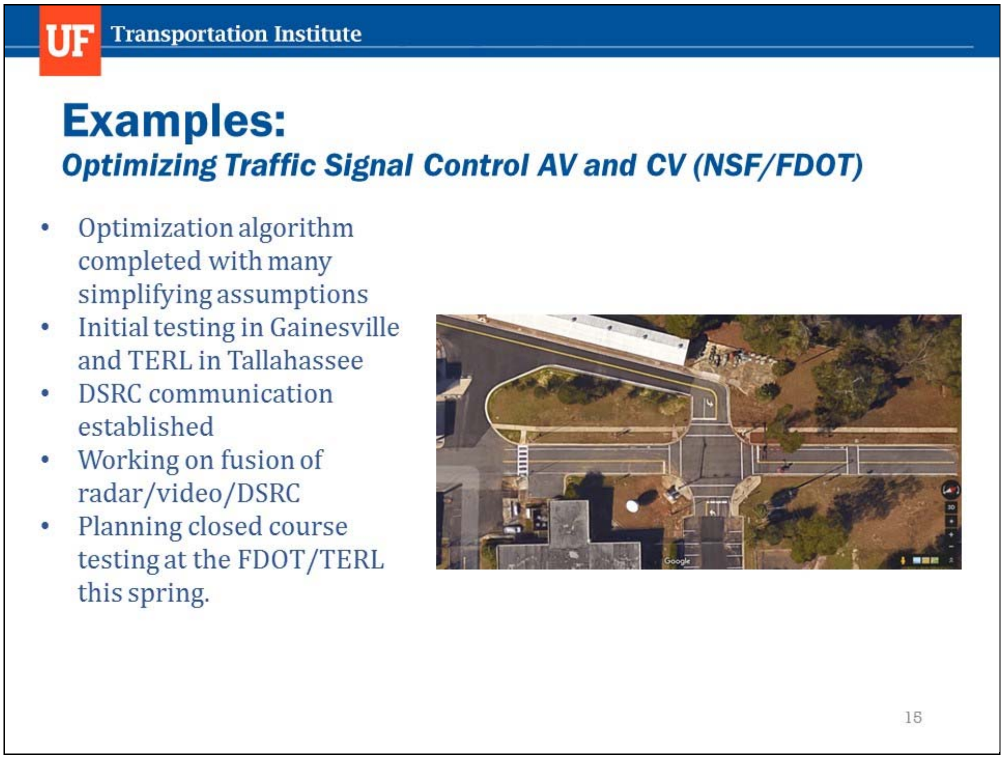


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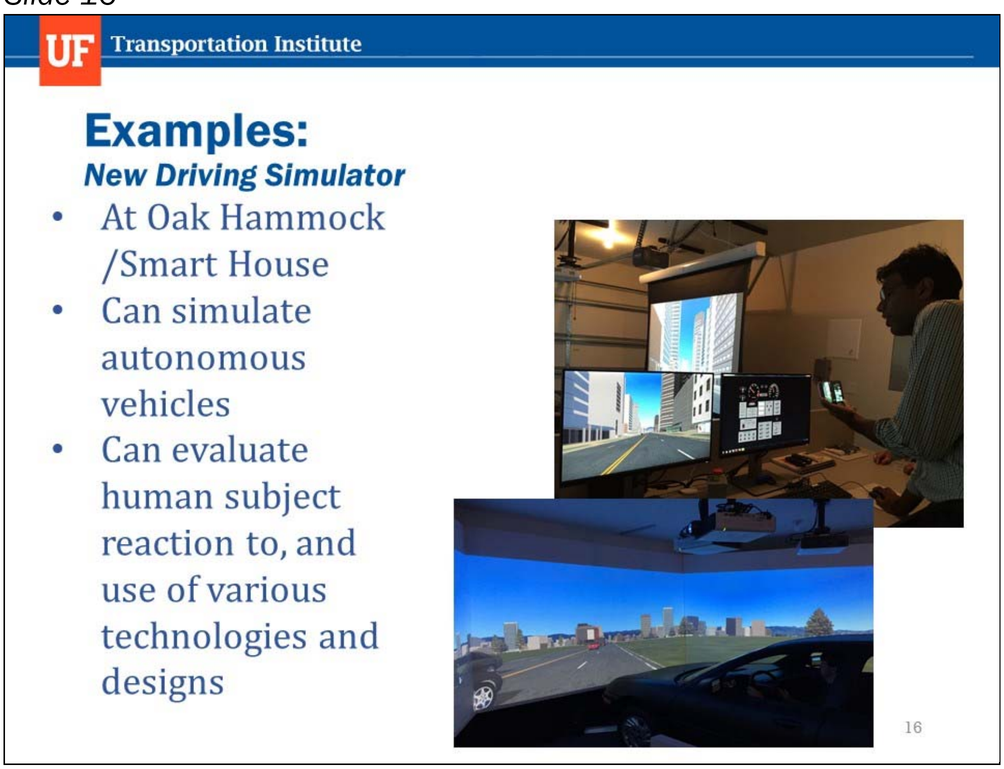

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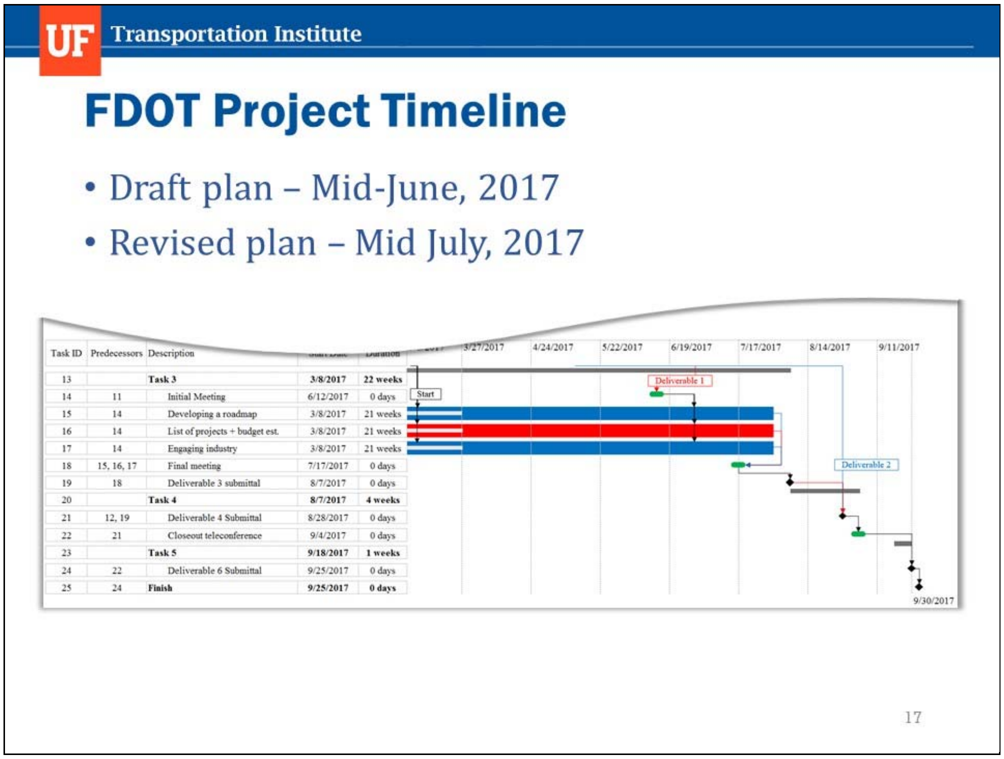


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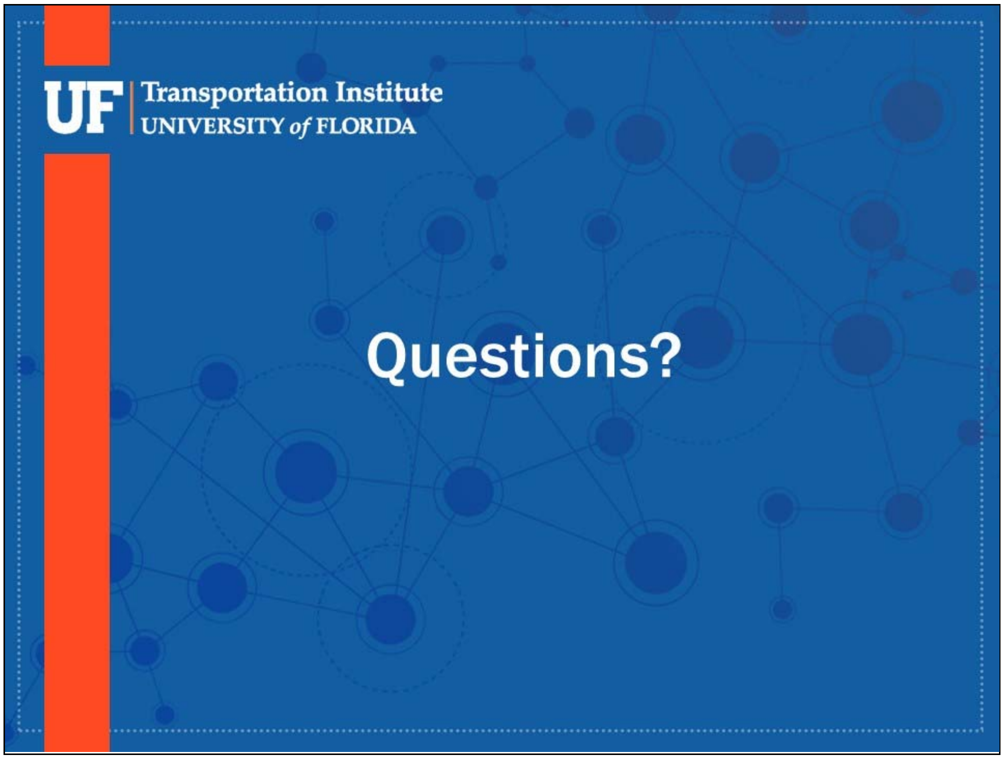


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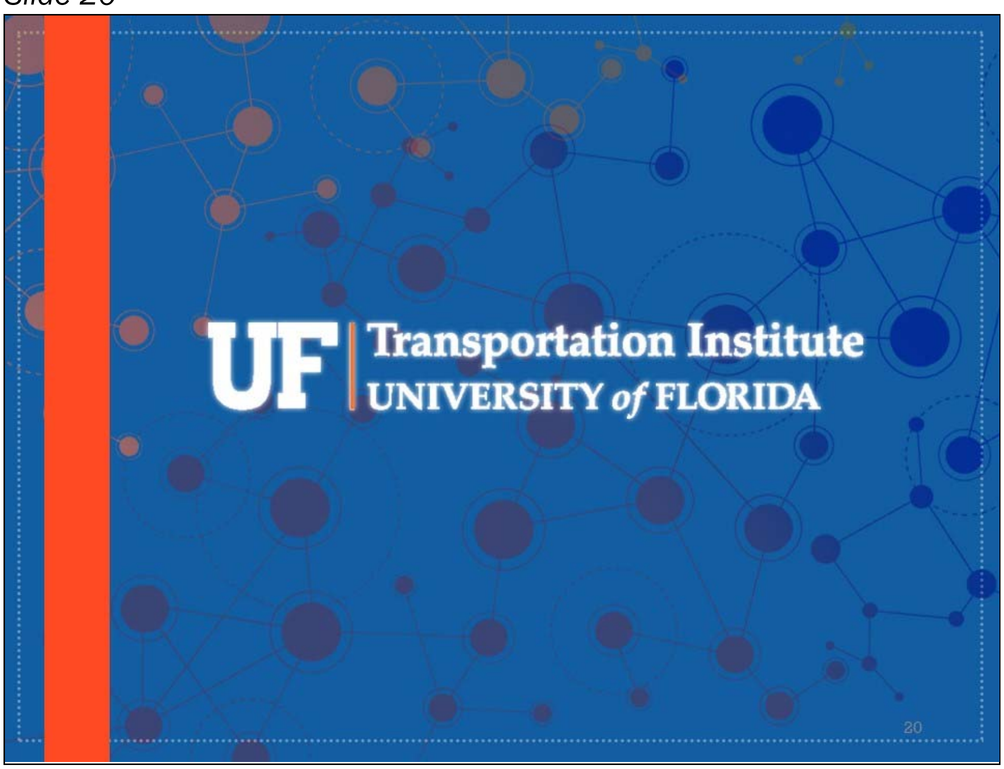
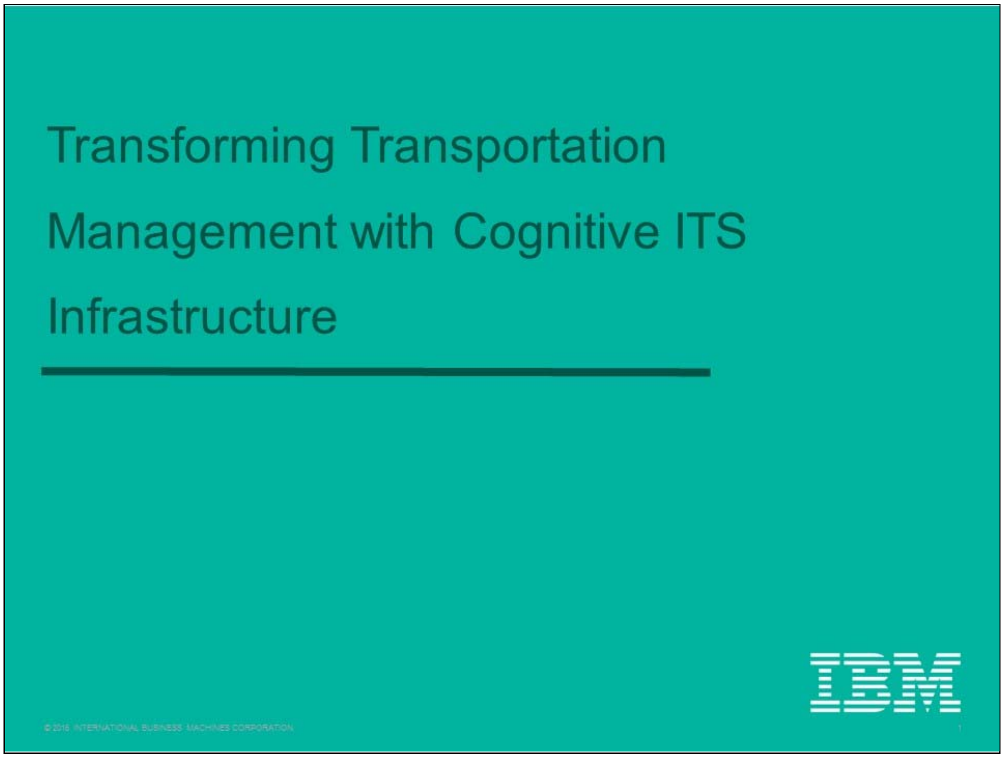


## James Lou – IBM

*Slide 1*

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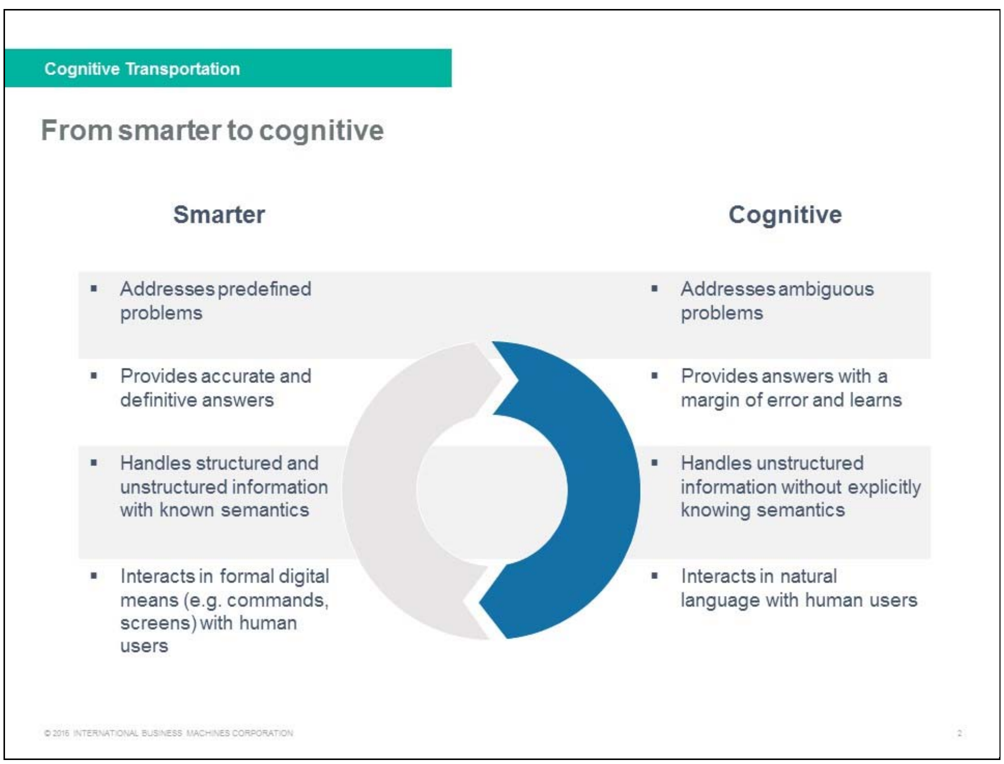

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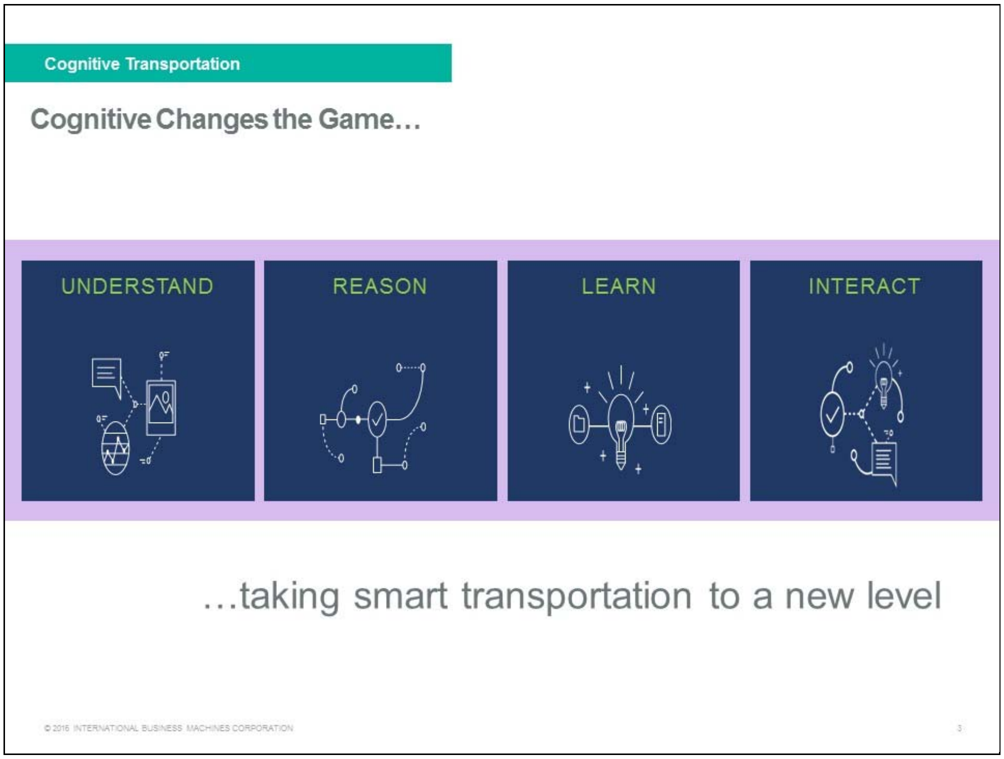


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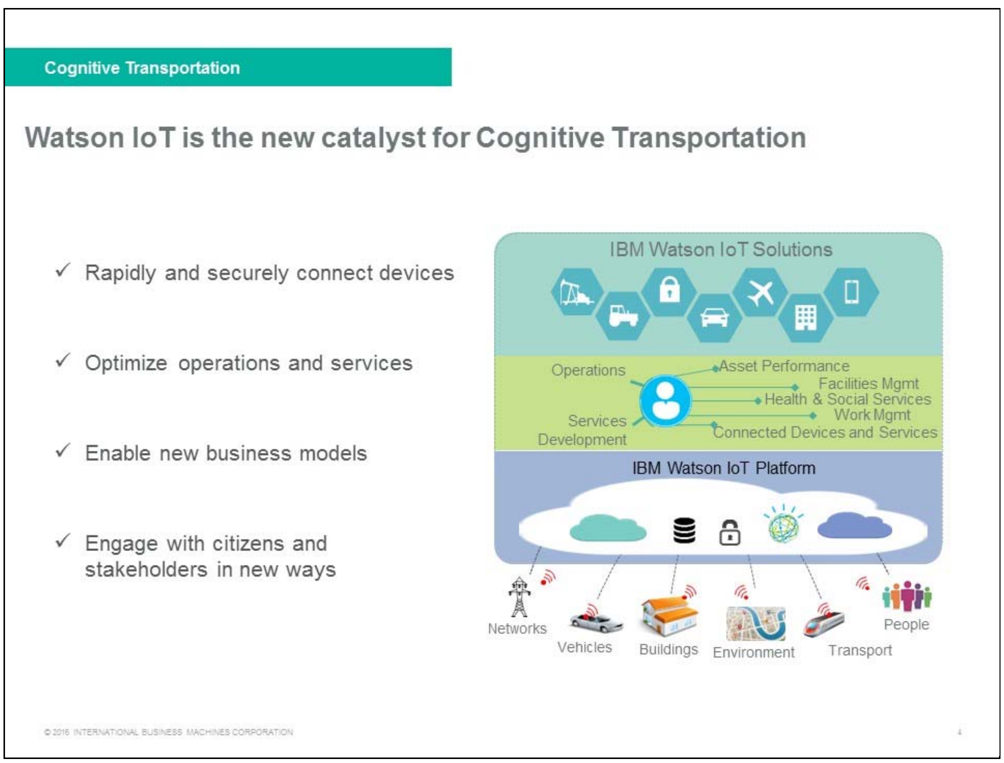

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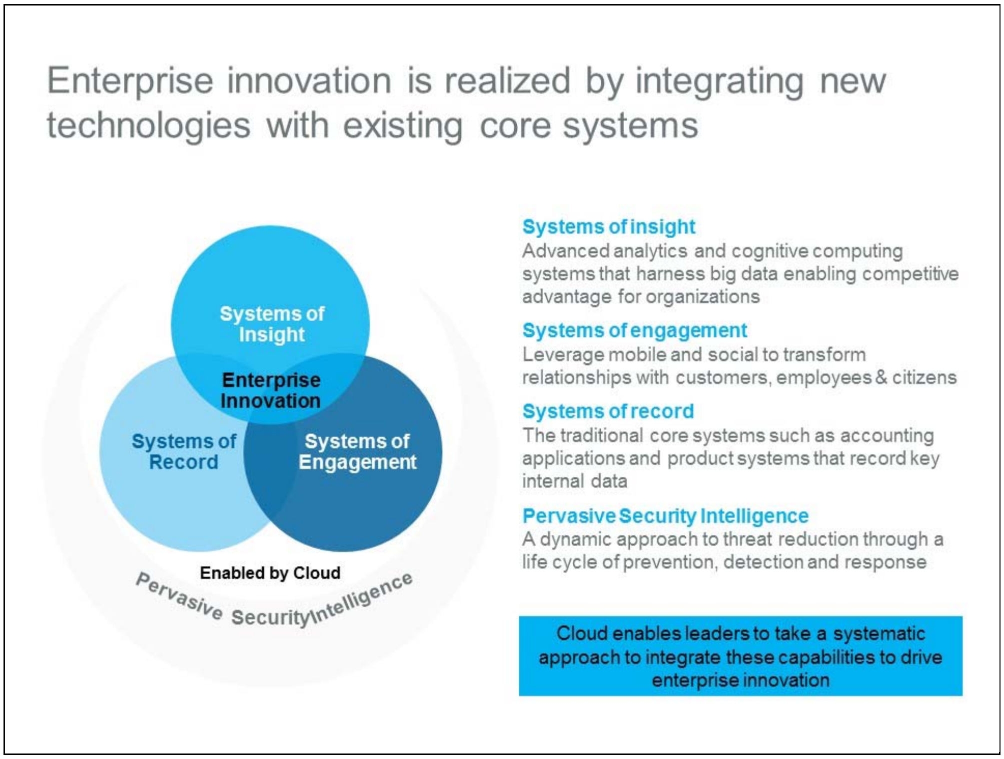


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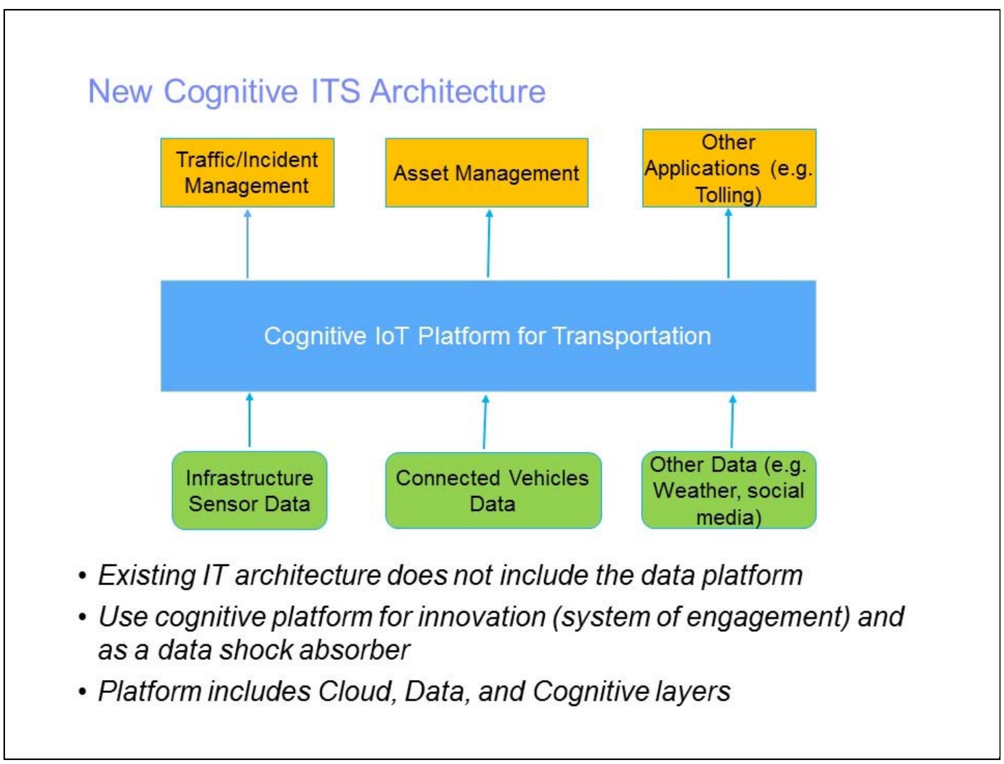

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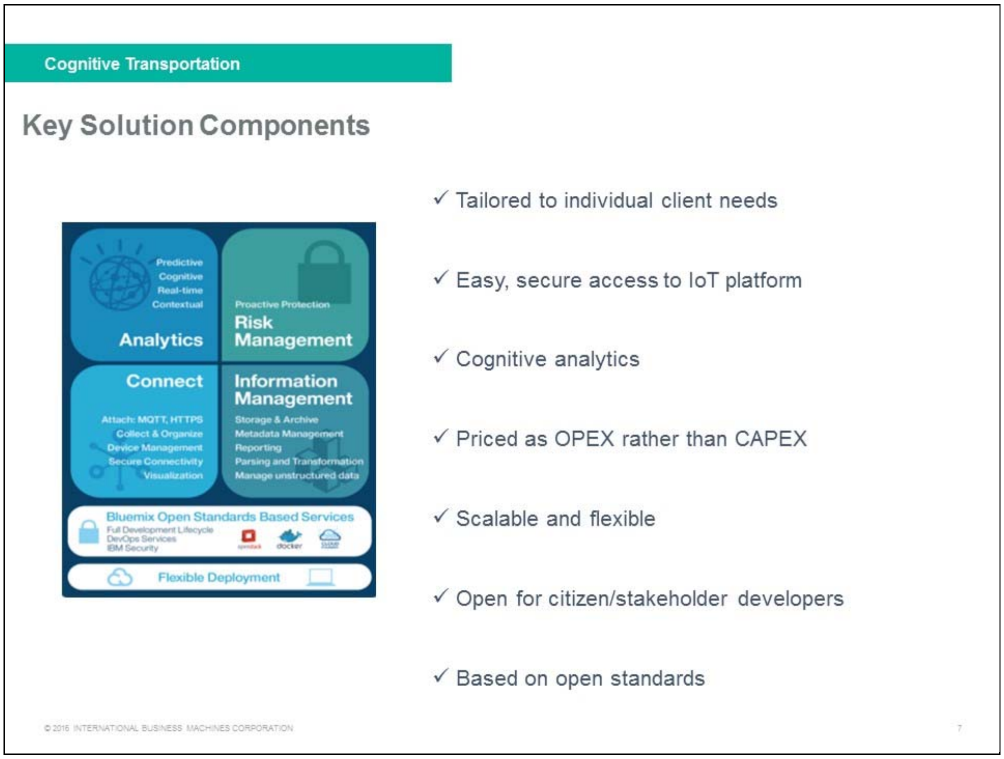


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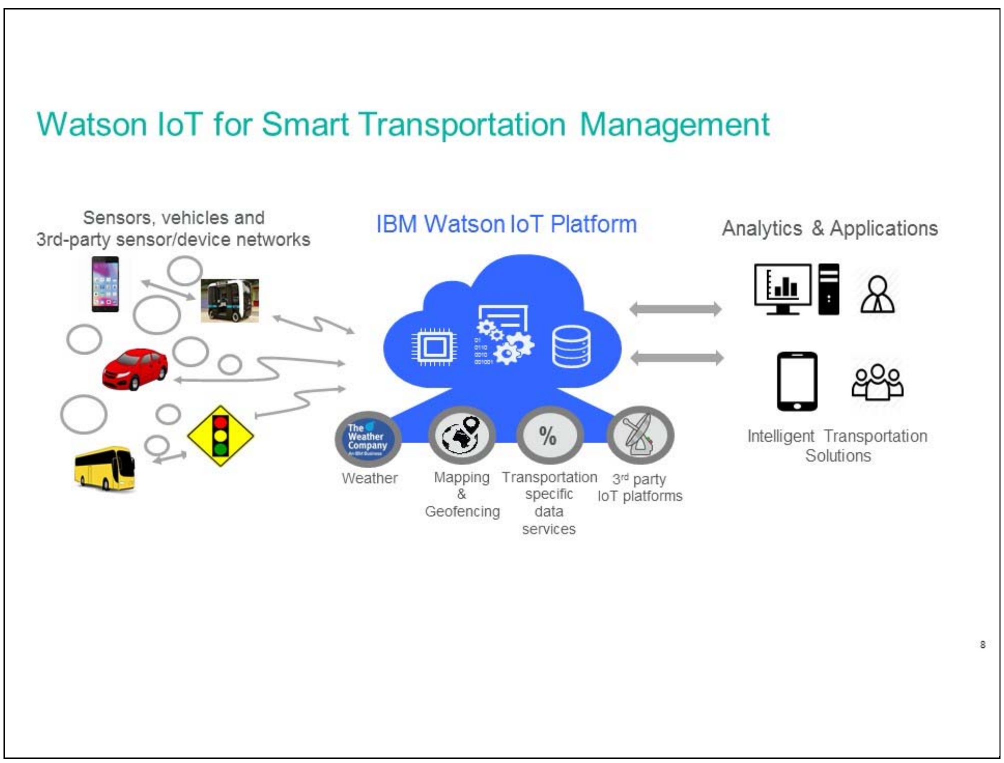

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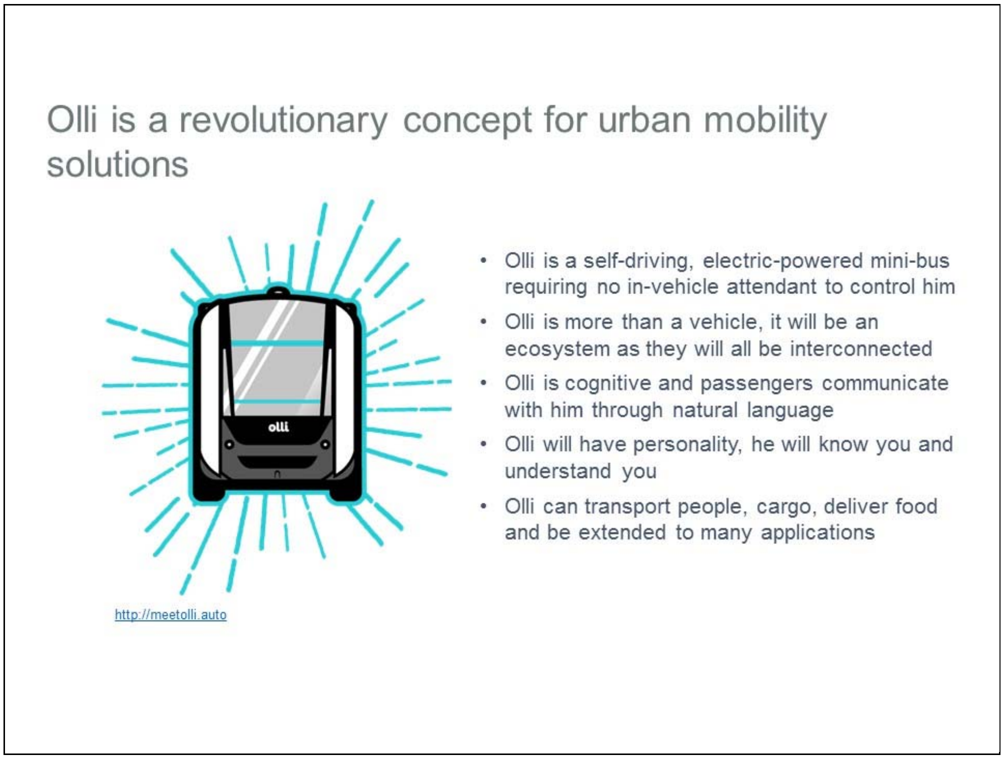


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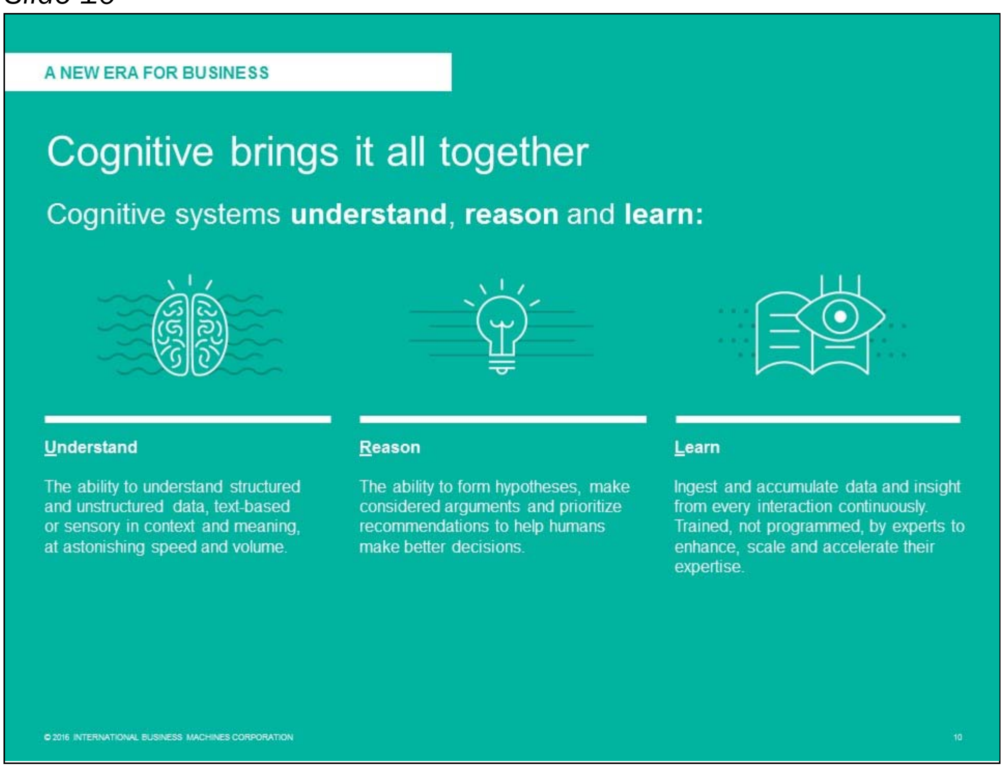

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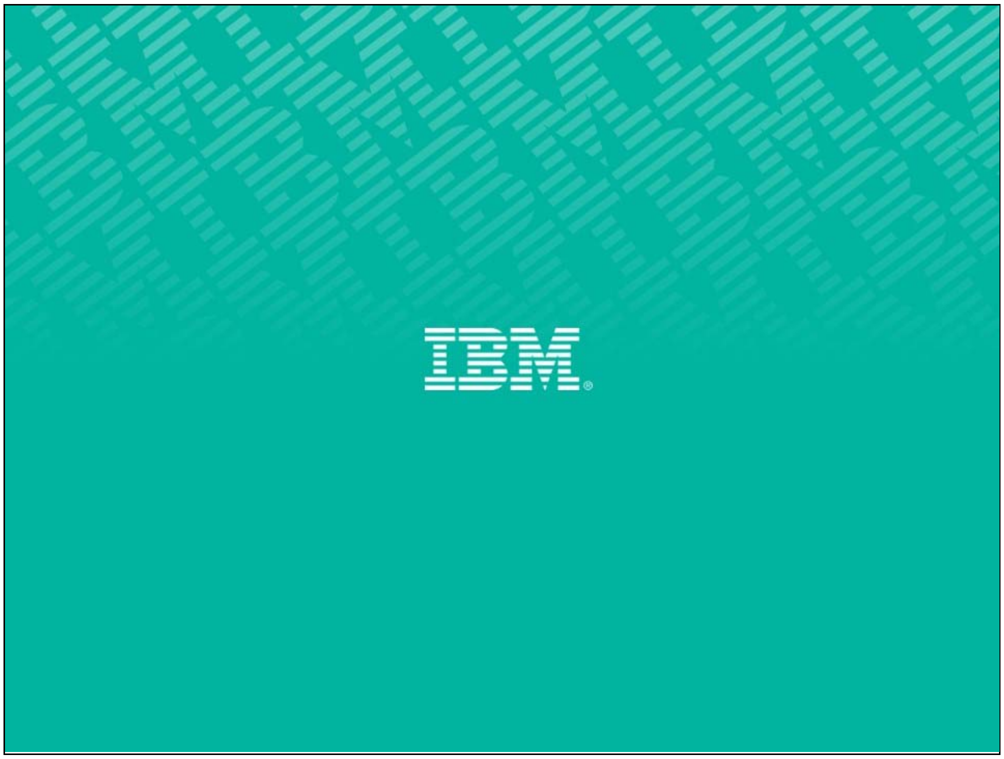

## David Jared – Georgia Department of Transportation

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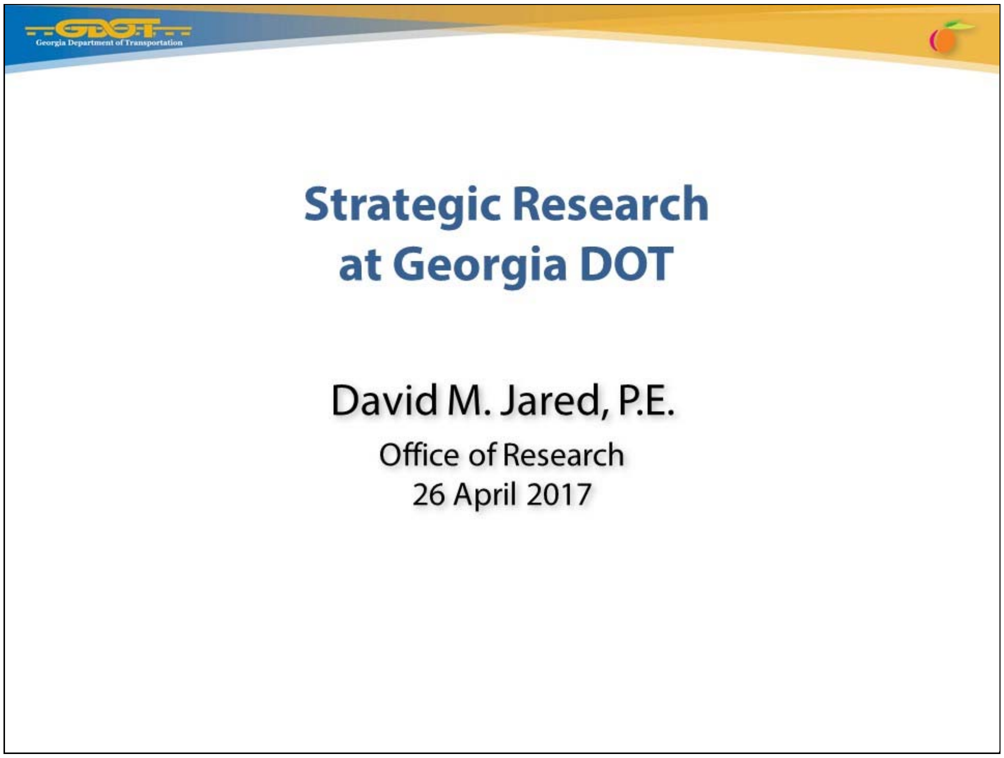


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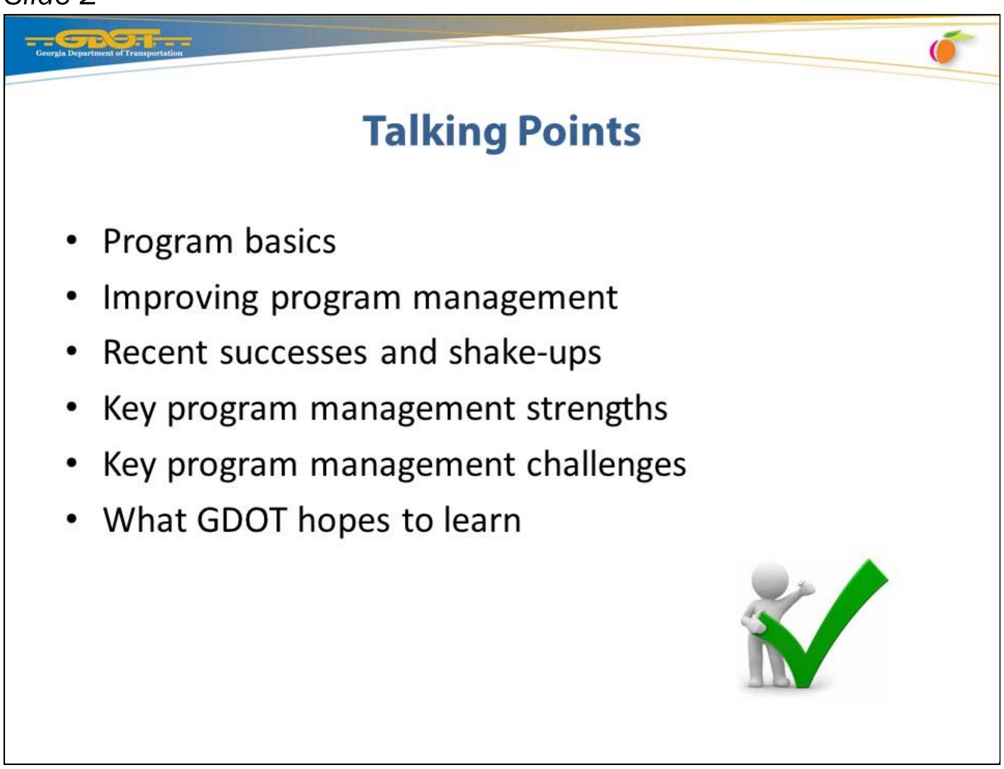

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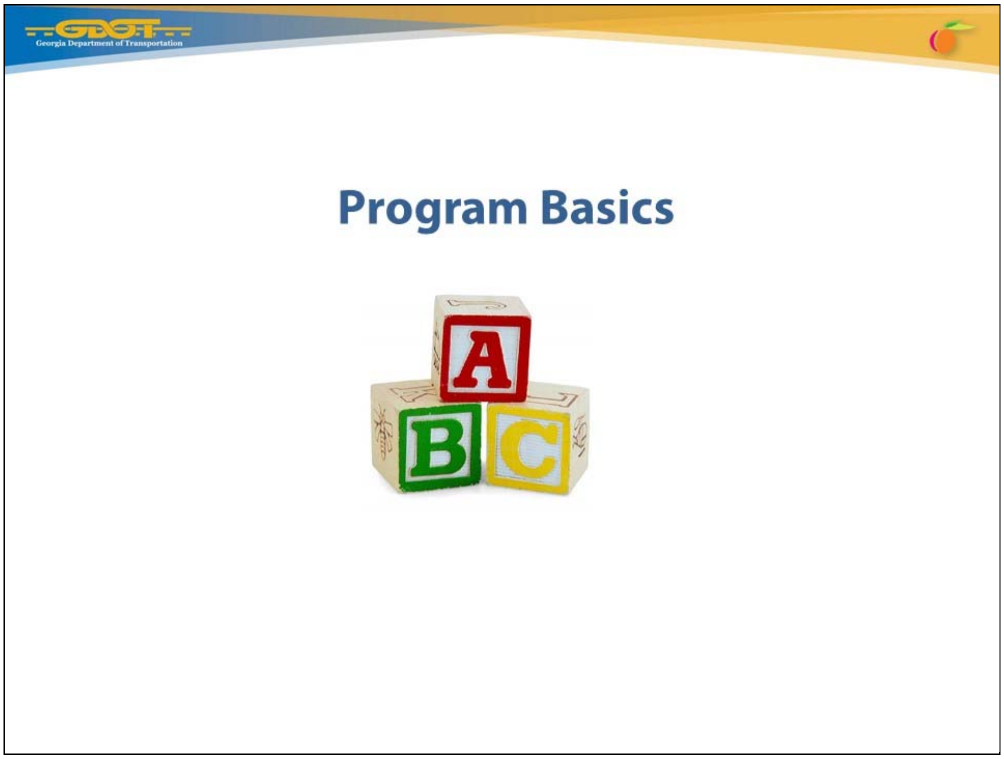


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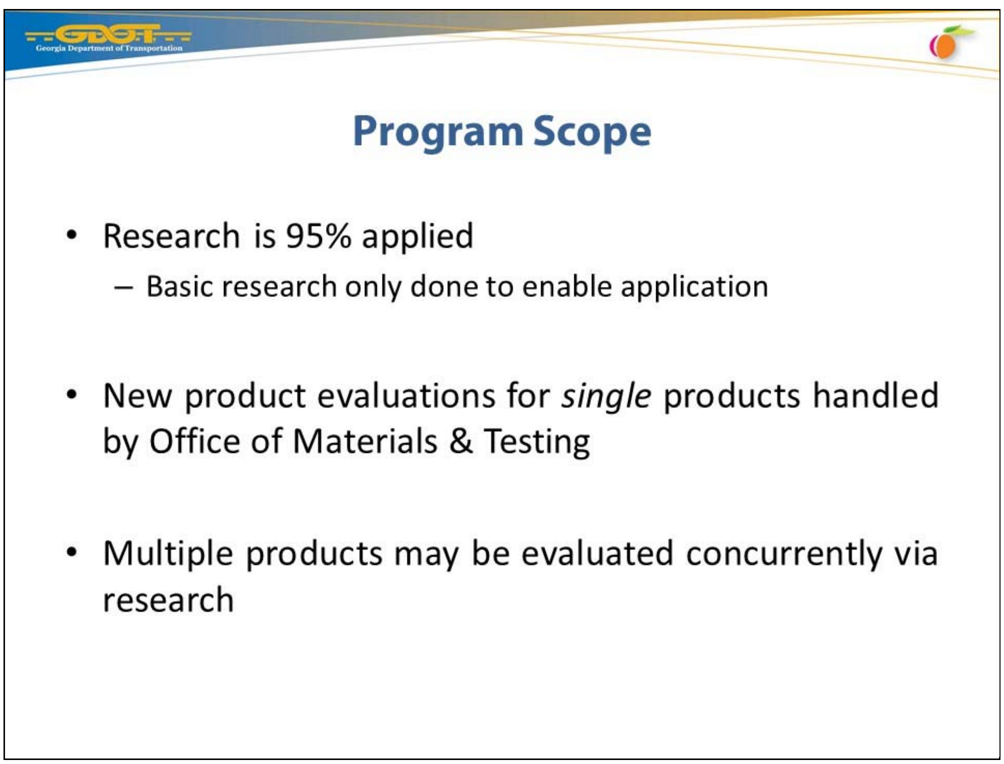

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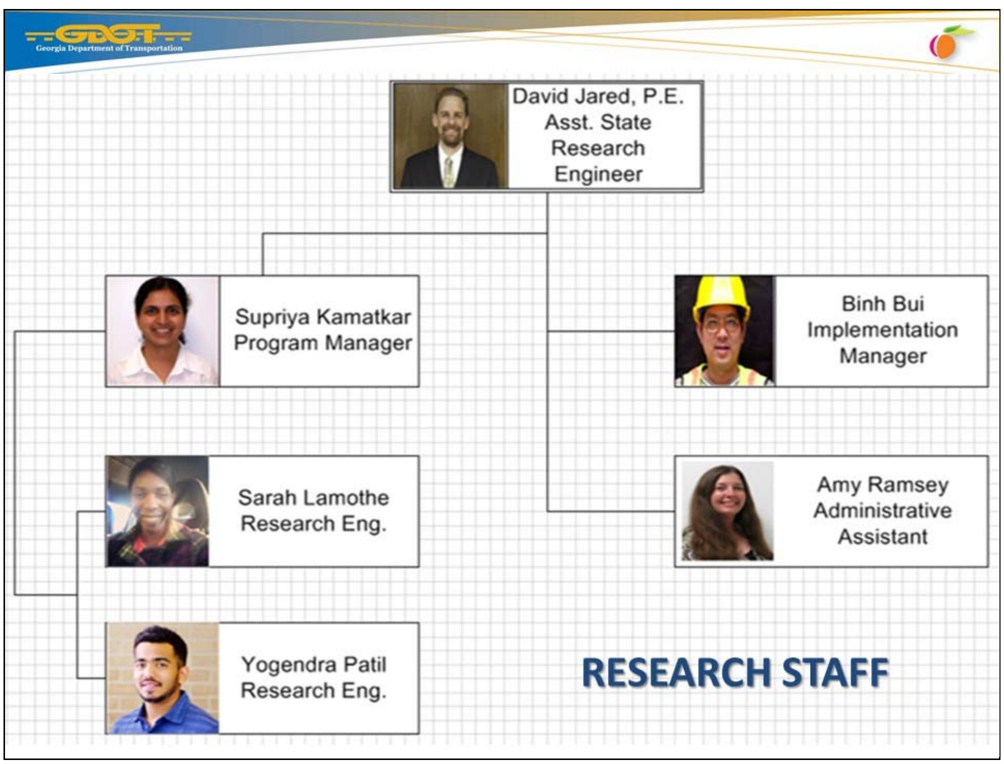

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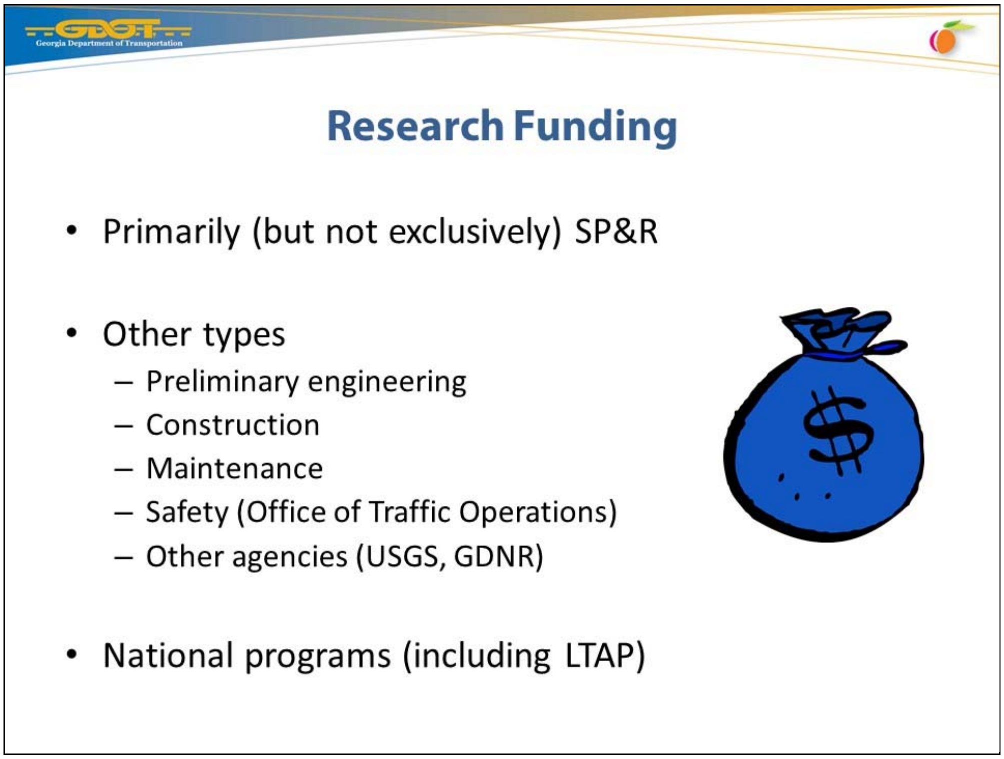


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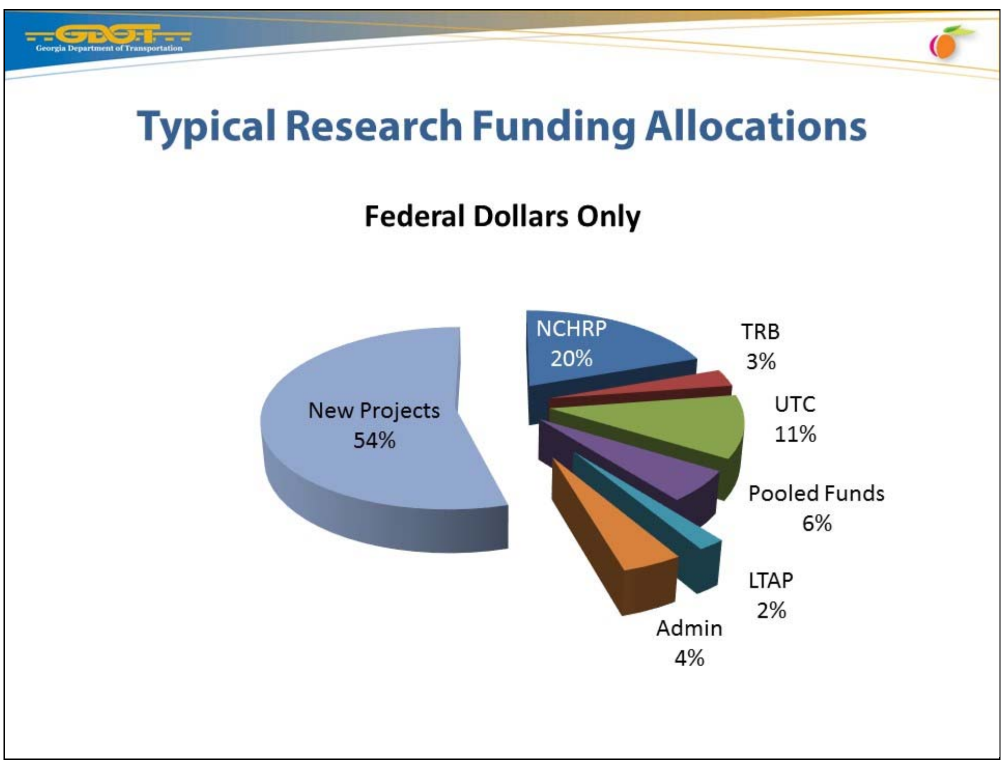

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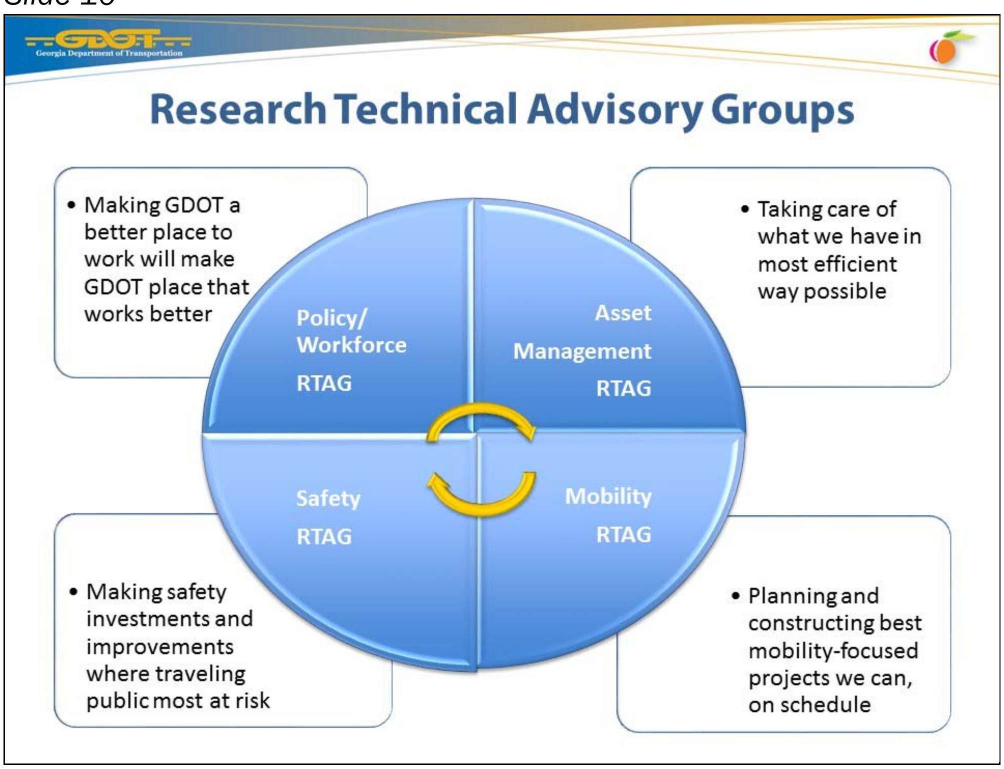

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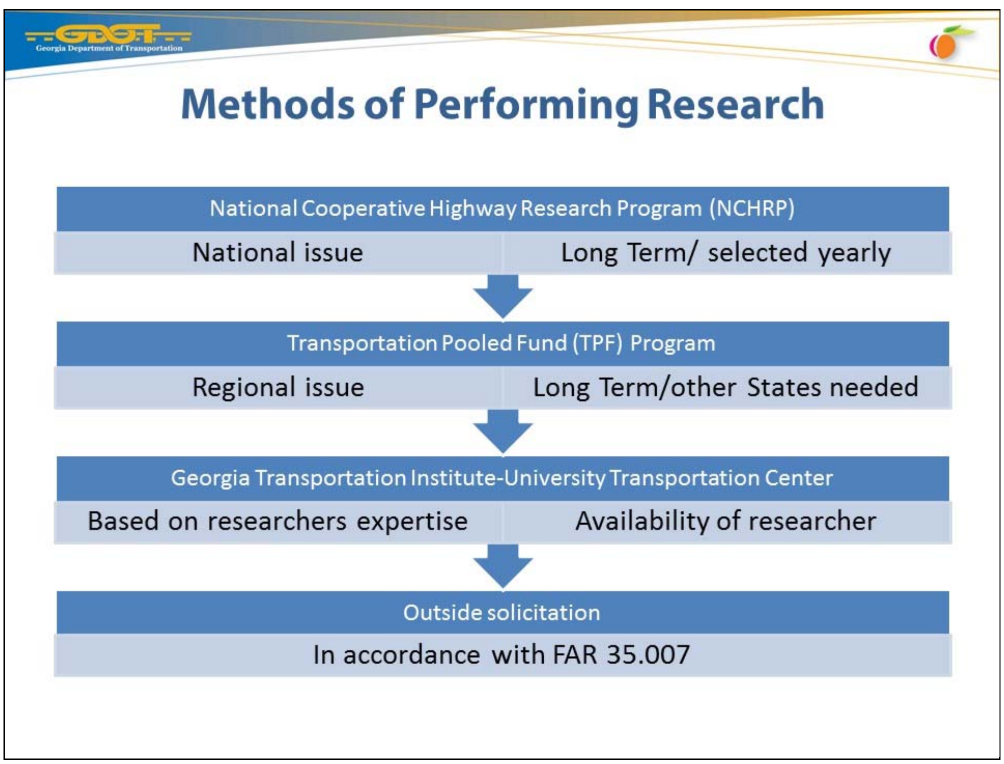

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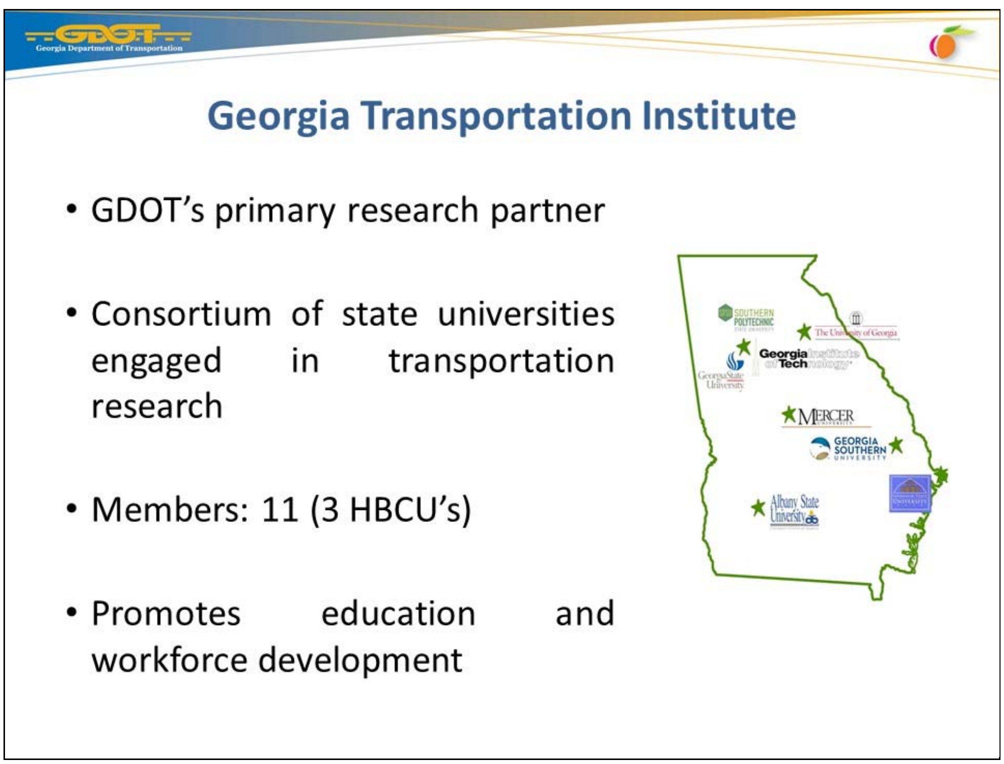

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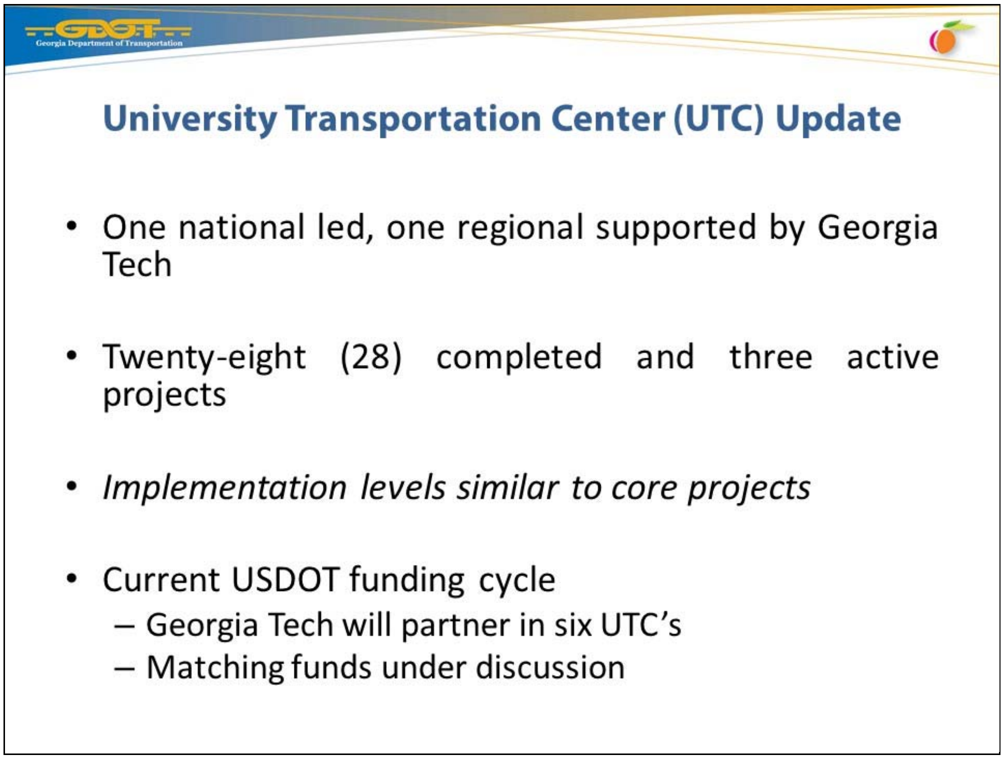


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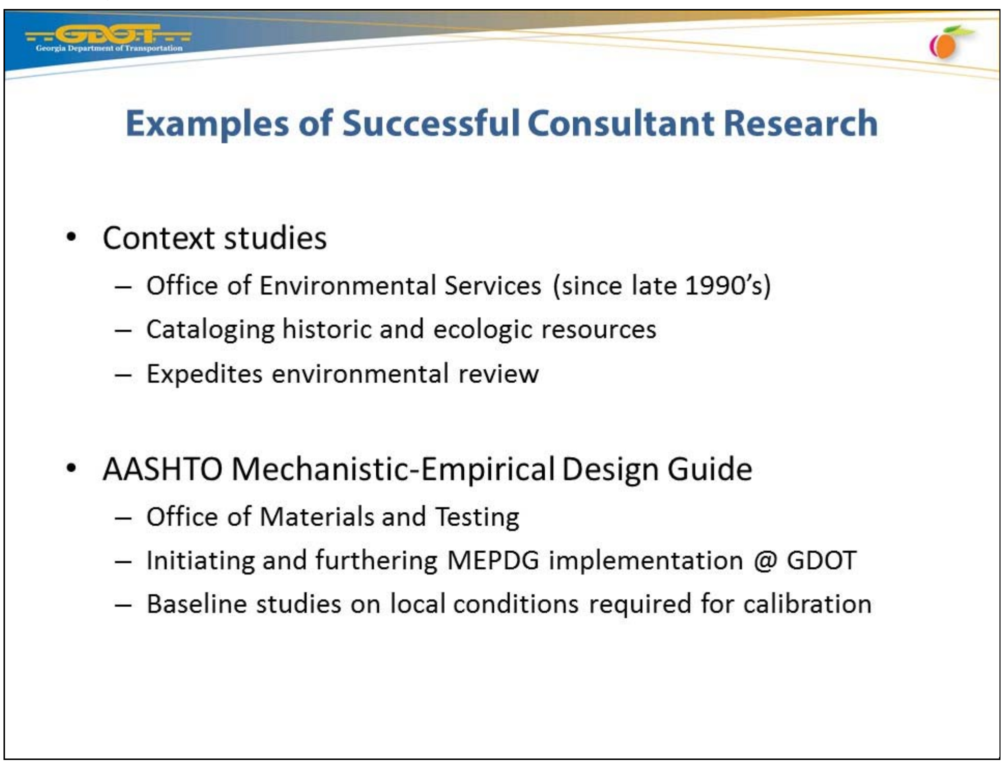

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## Improving Program Management

- GTI leadership meetings
  - Same day as GTI Poster Session
  - Director report
  - Admin items of GDOT concern
  - Open discussion
- Project meetings
  - Kick-off
  - Midpoint
  - 90-Day Wrap-up

*Slide 20*

## Research Roadmap Concept

- Emergence: 2015
- Pilot topic: Autonomous vehicles
- Scope: research, design, and implementation
- Possible outcome: template for other topics (e.g. UAS)

**Jared, continued**

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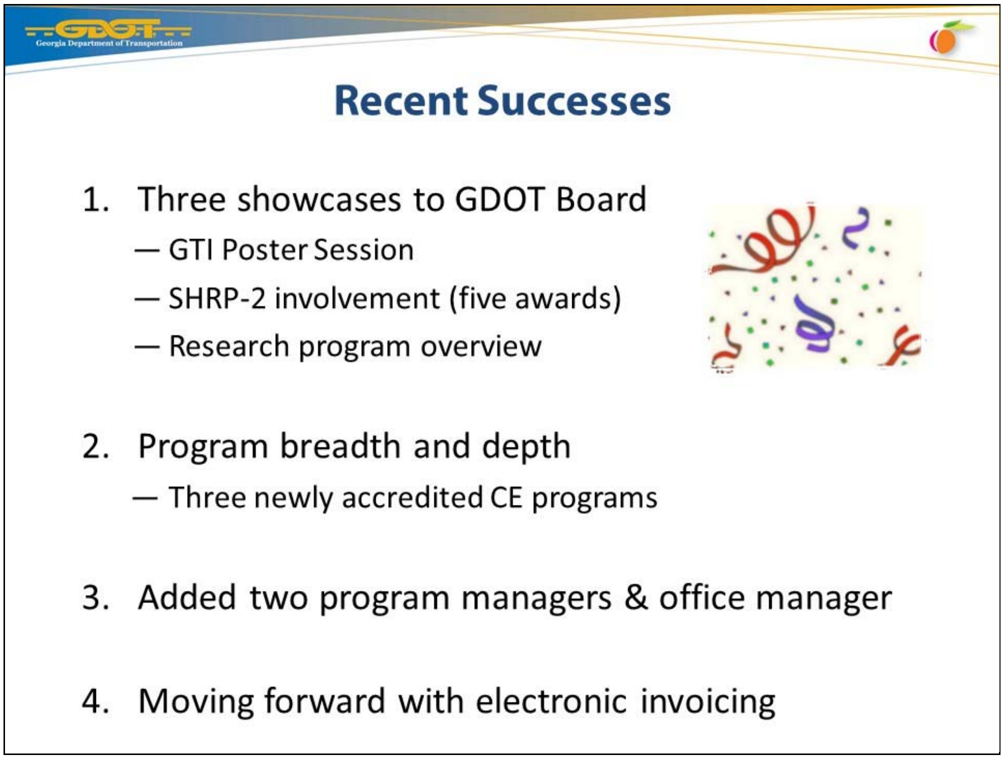


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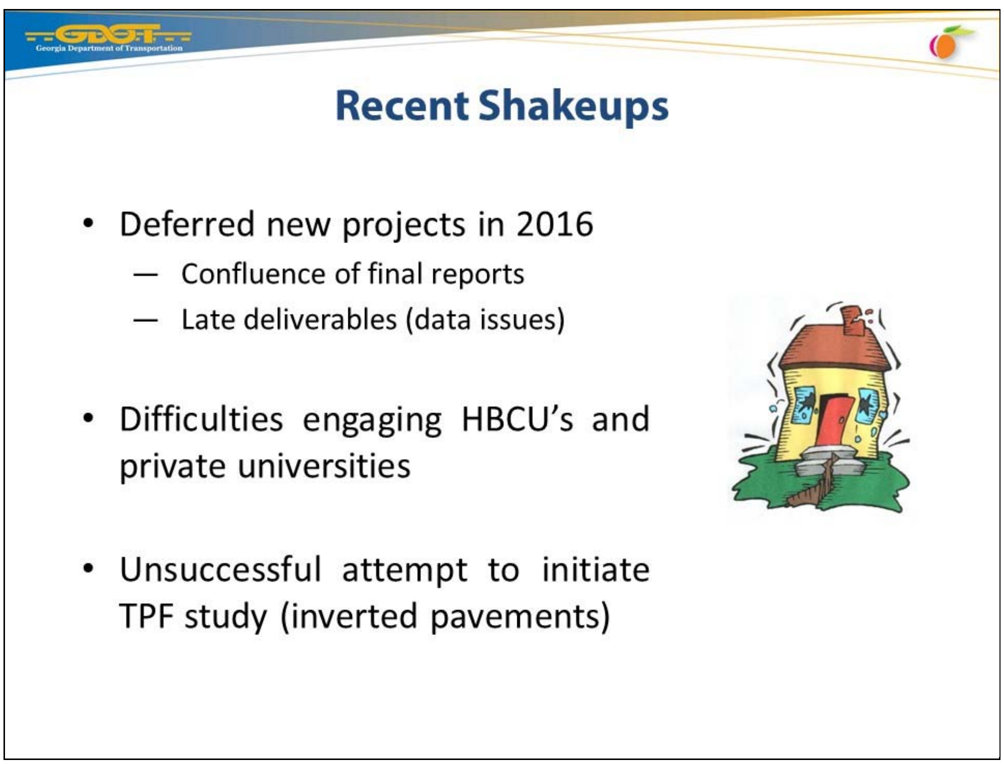

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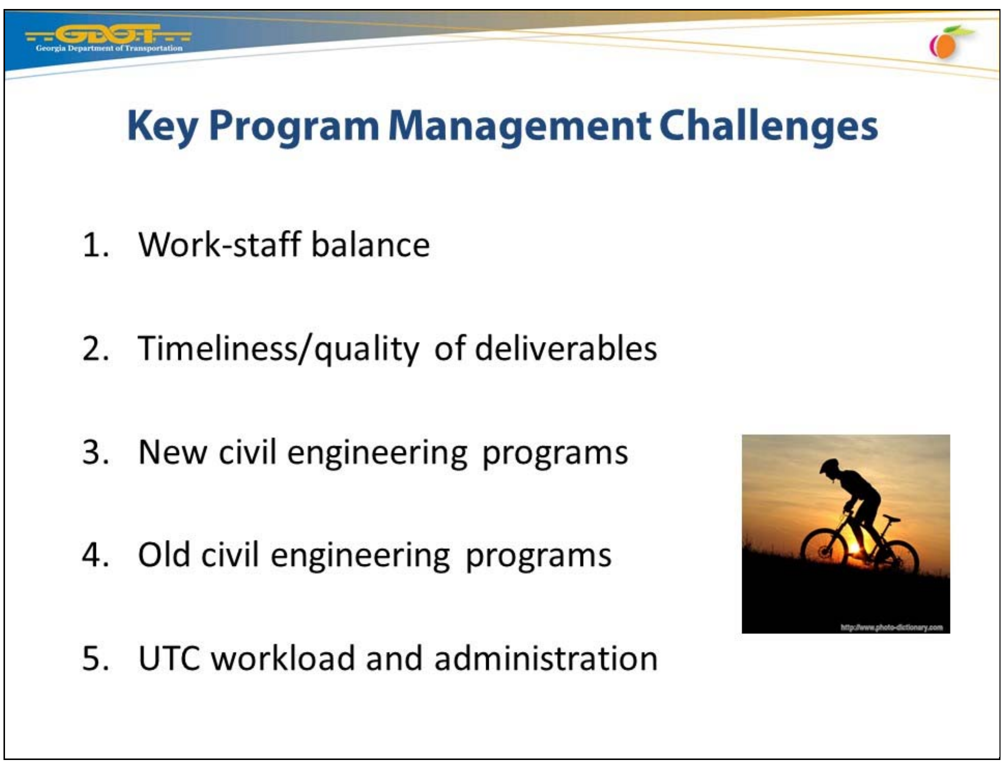

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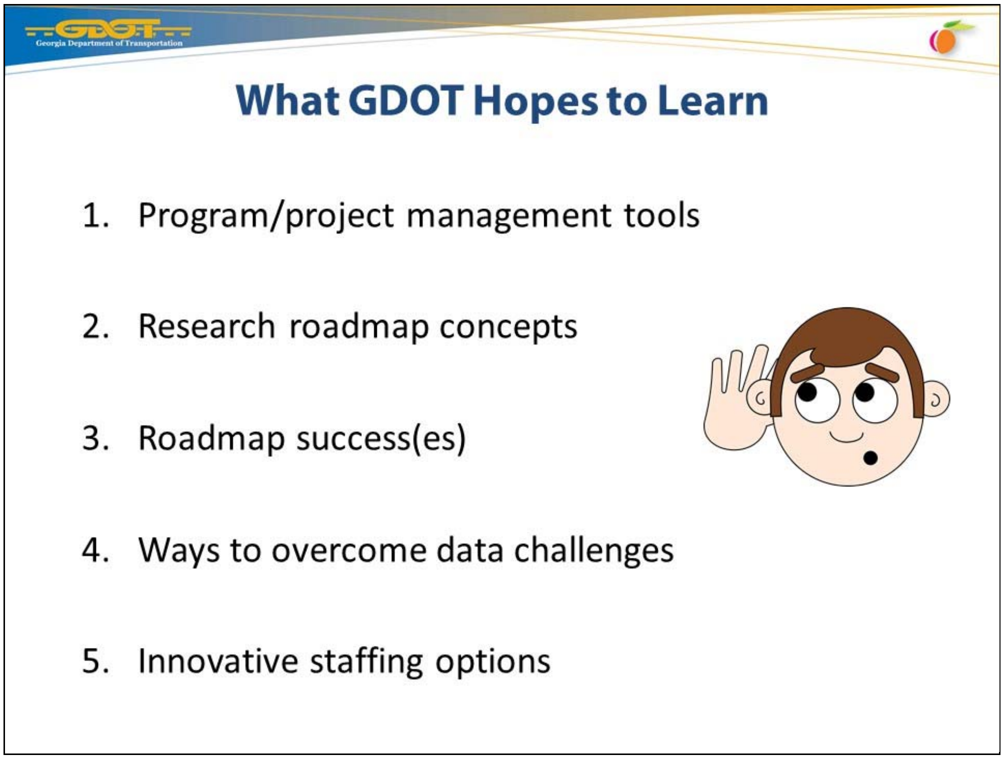


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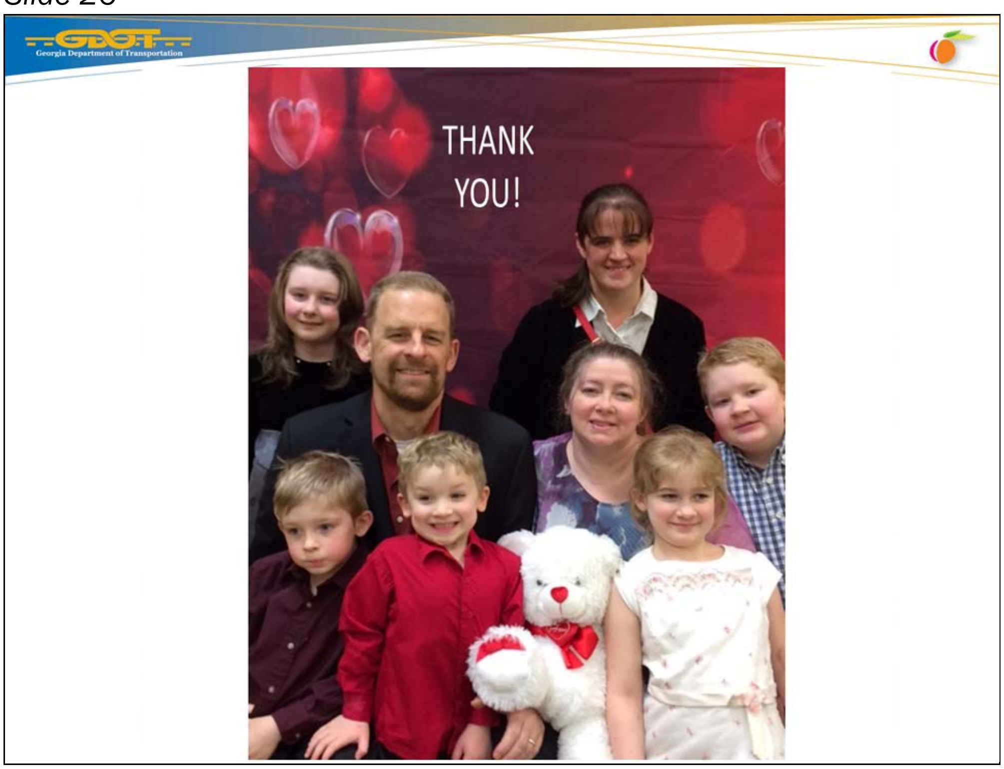

## Joe Horton – California Department of Transportation

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**Horton, continued**

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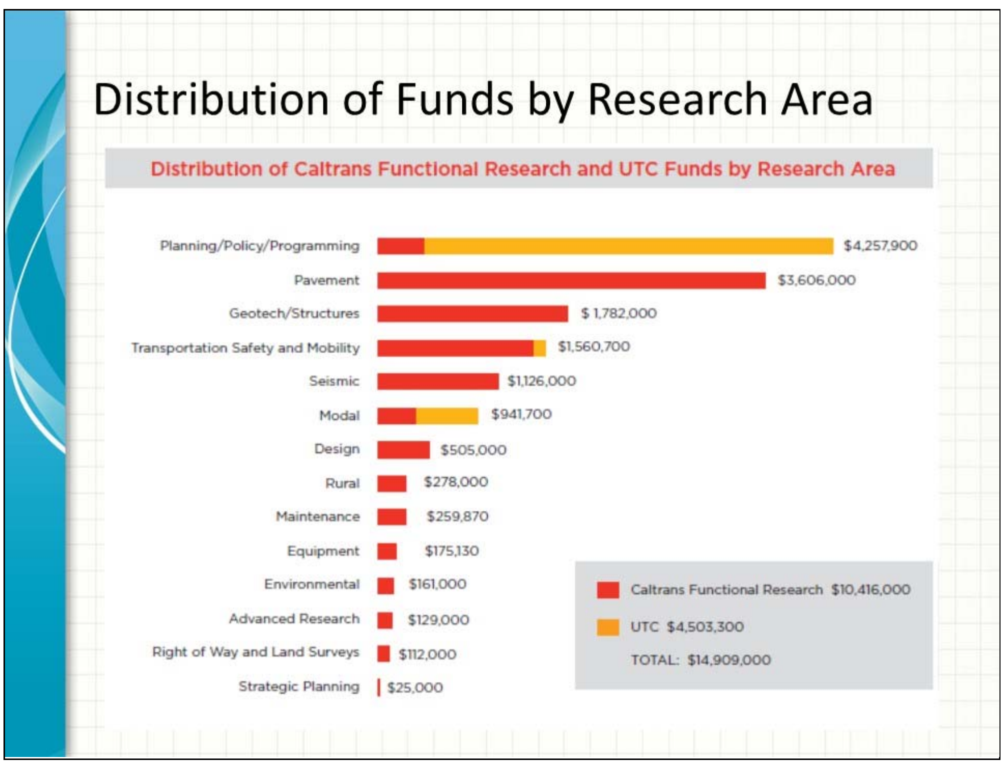

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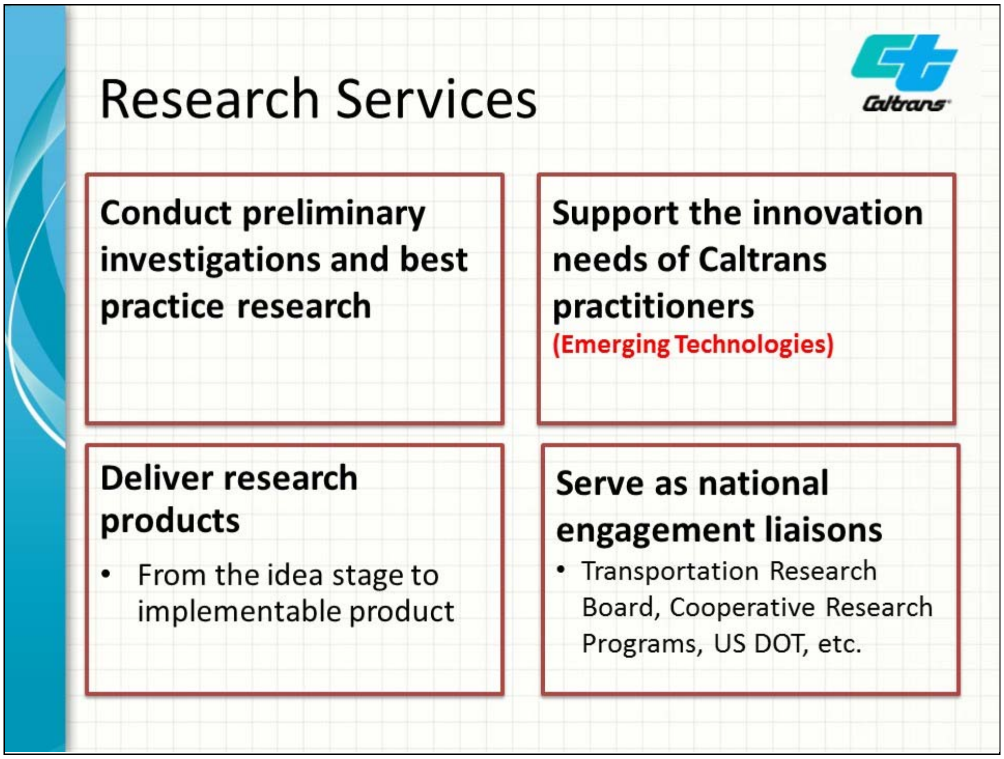


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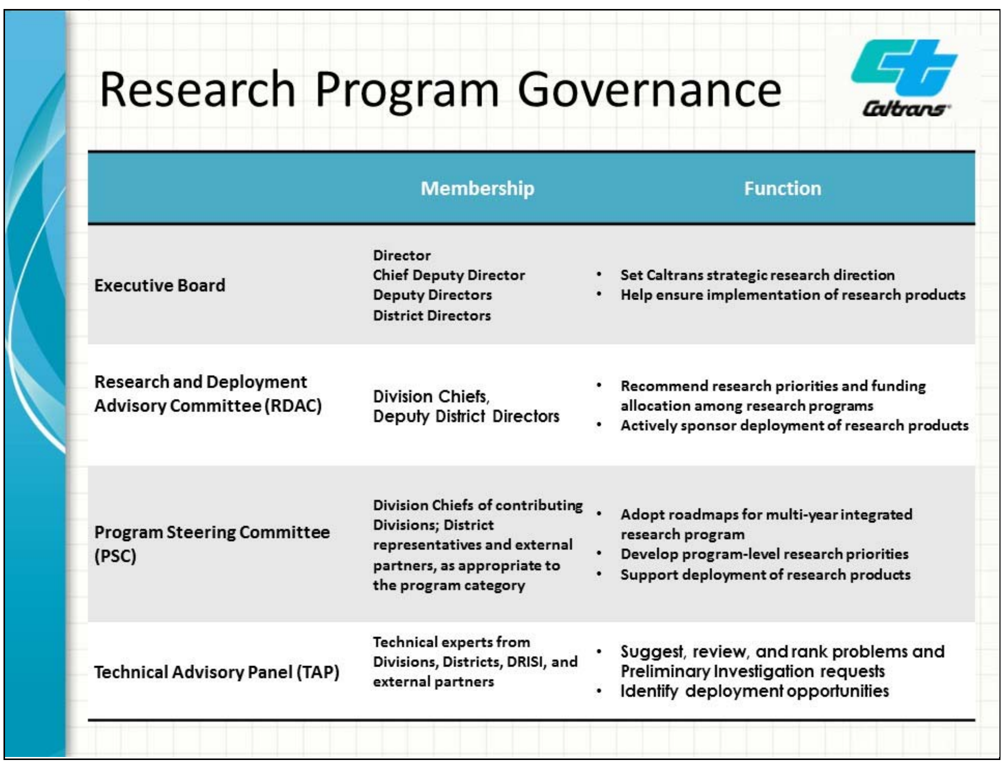

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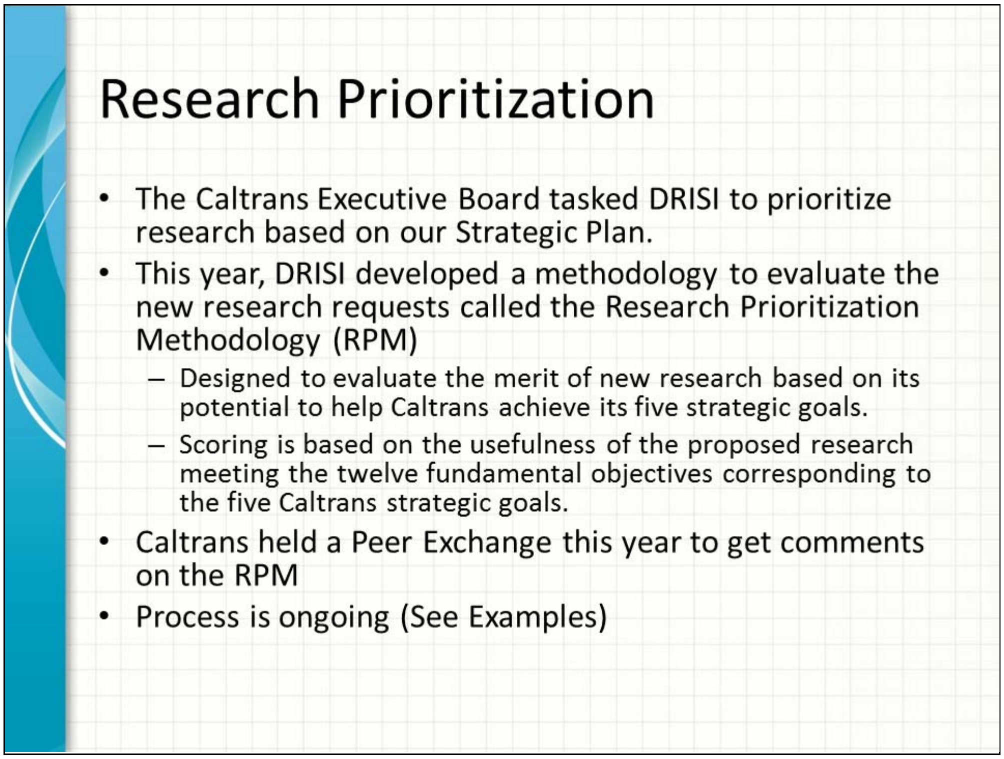


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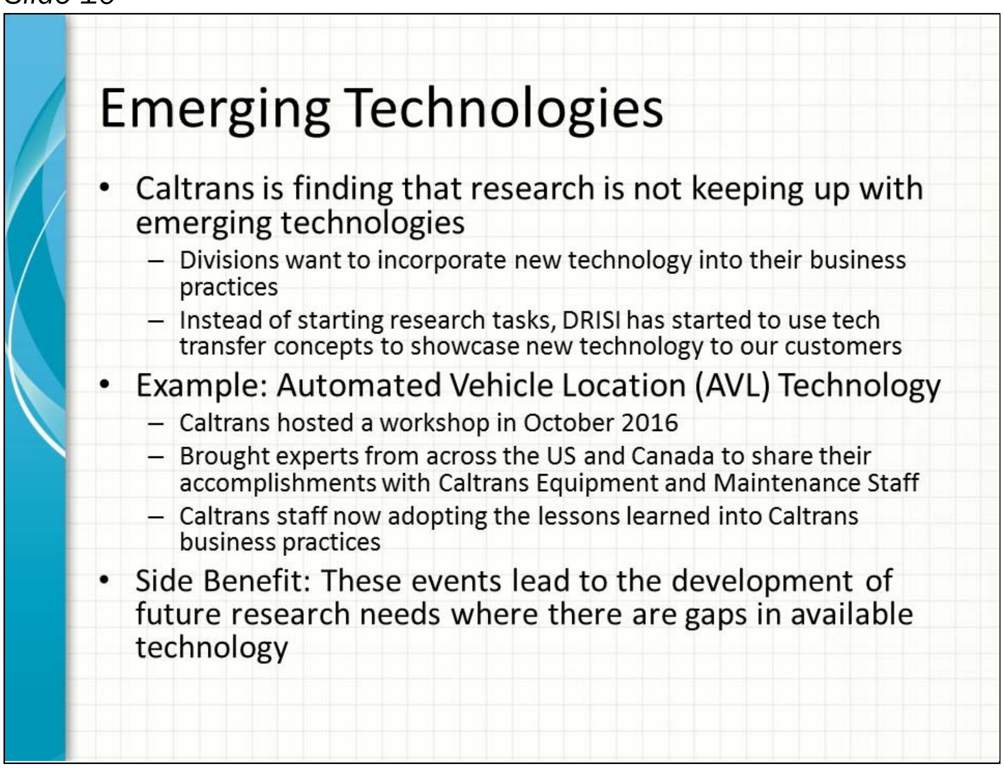

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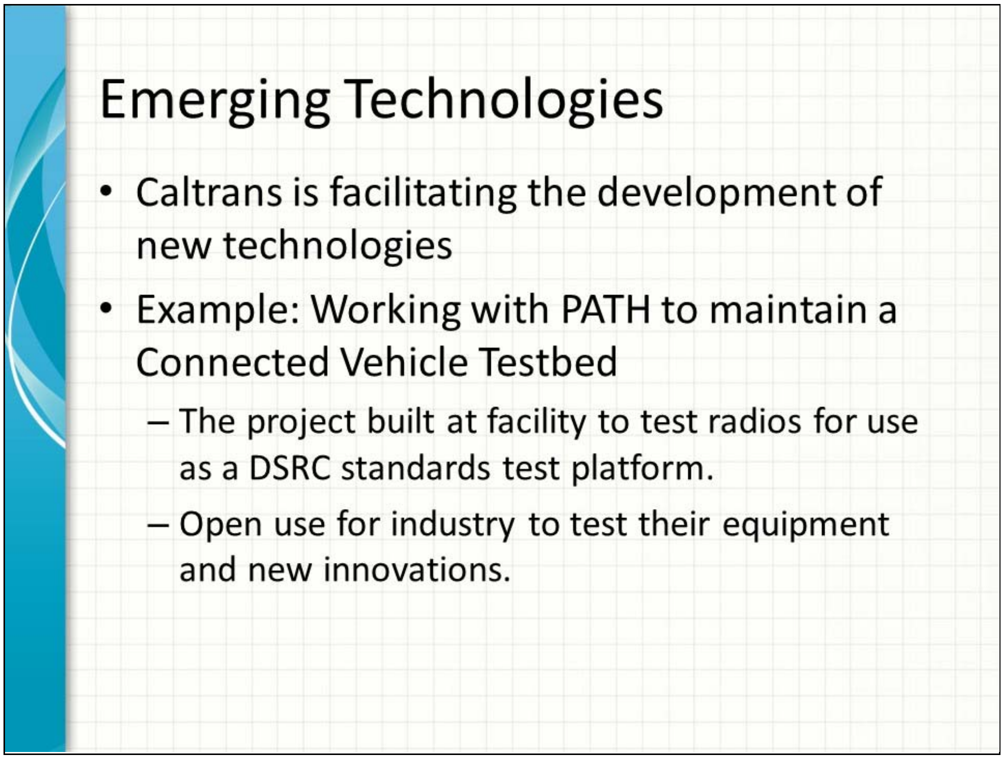


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## Sue Sillick – Montana Department of Transportation

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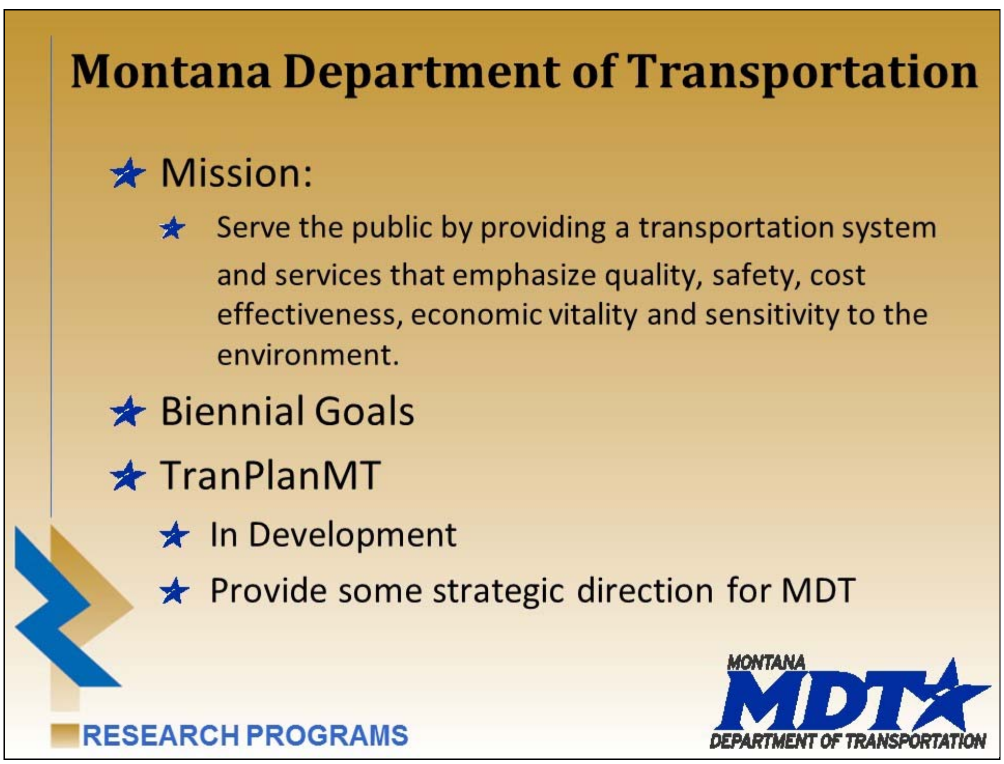

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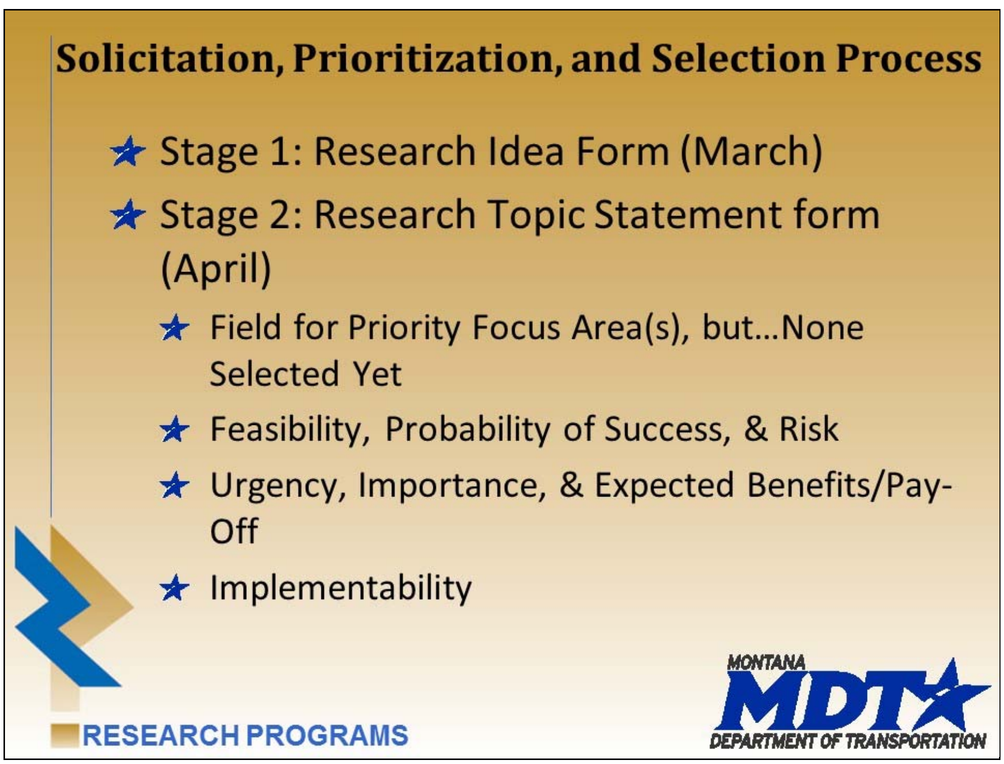

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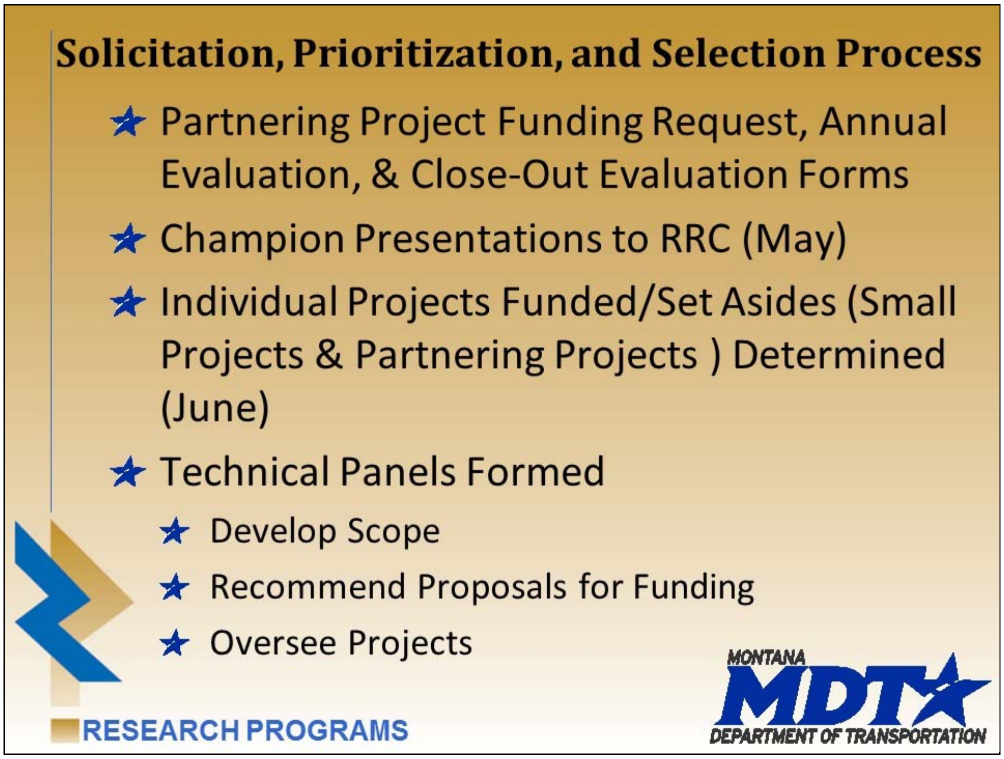


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## April Blackburn – Florida Department of Transportation

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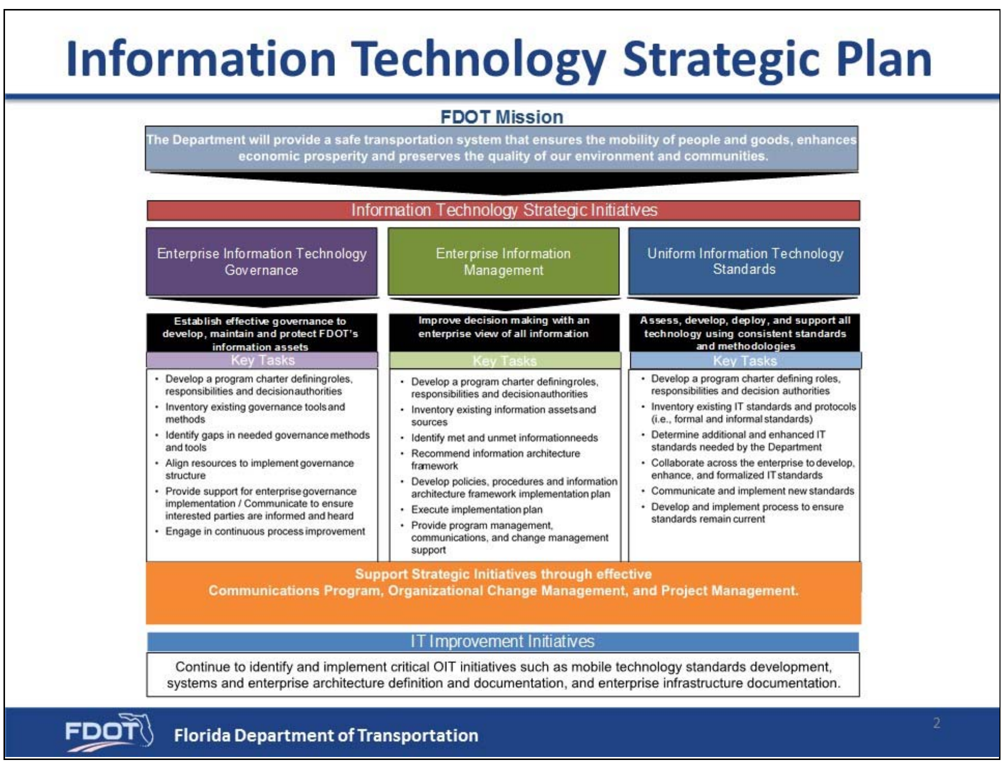

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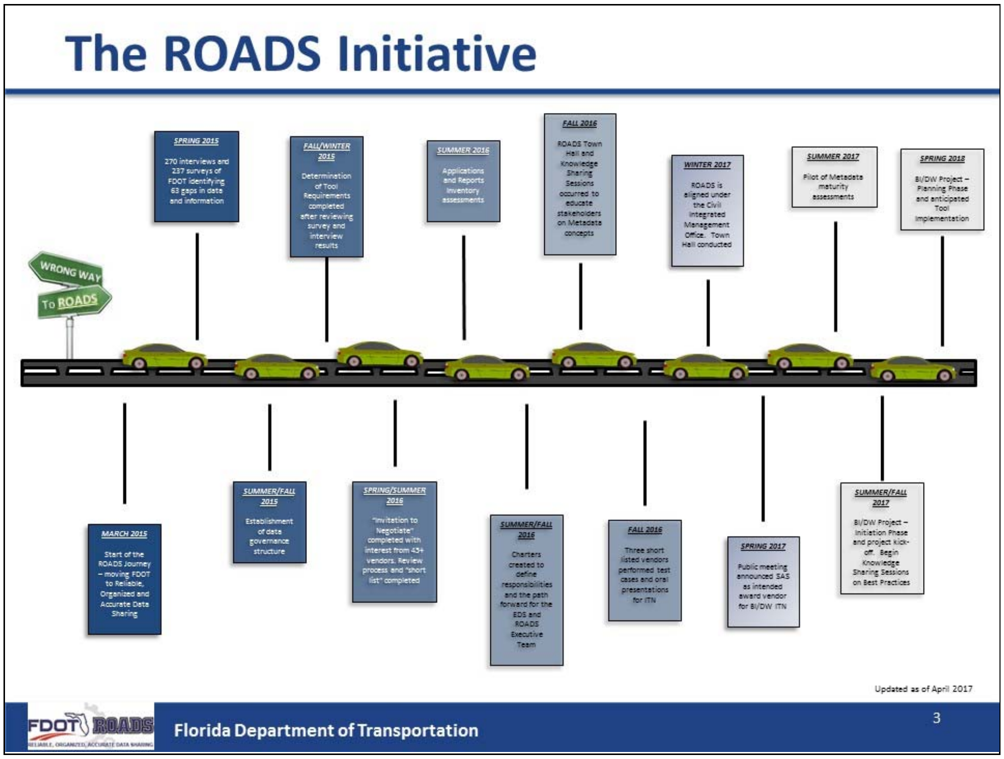


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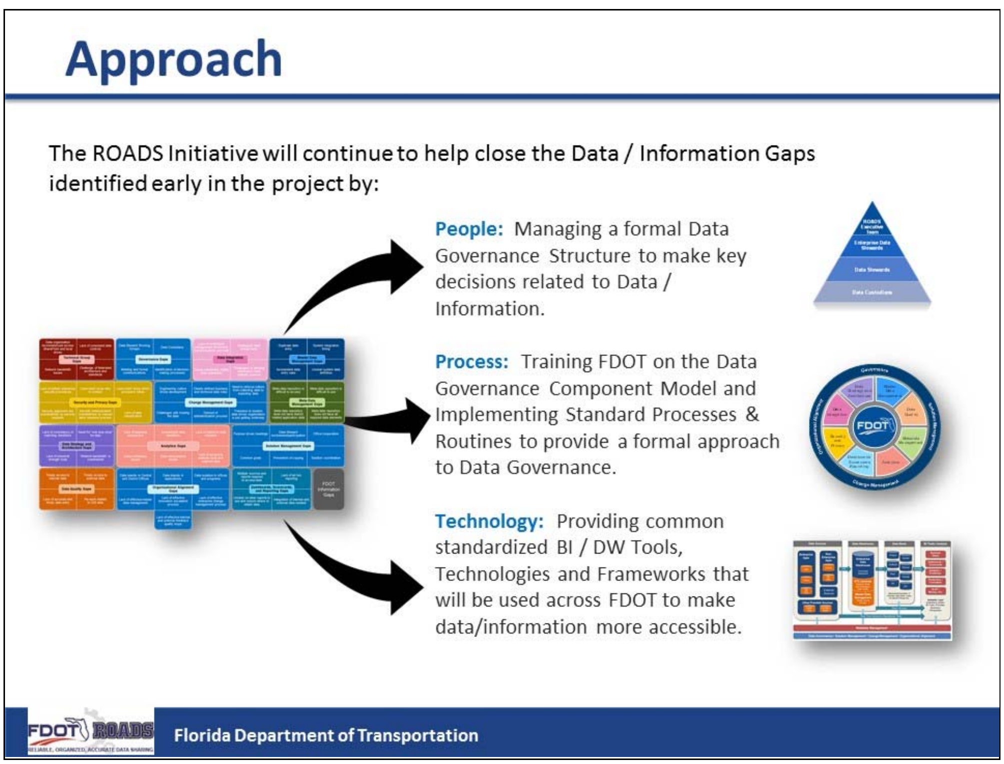

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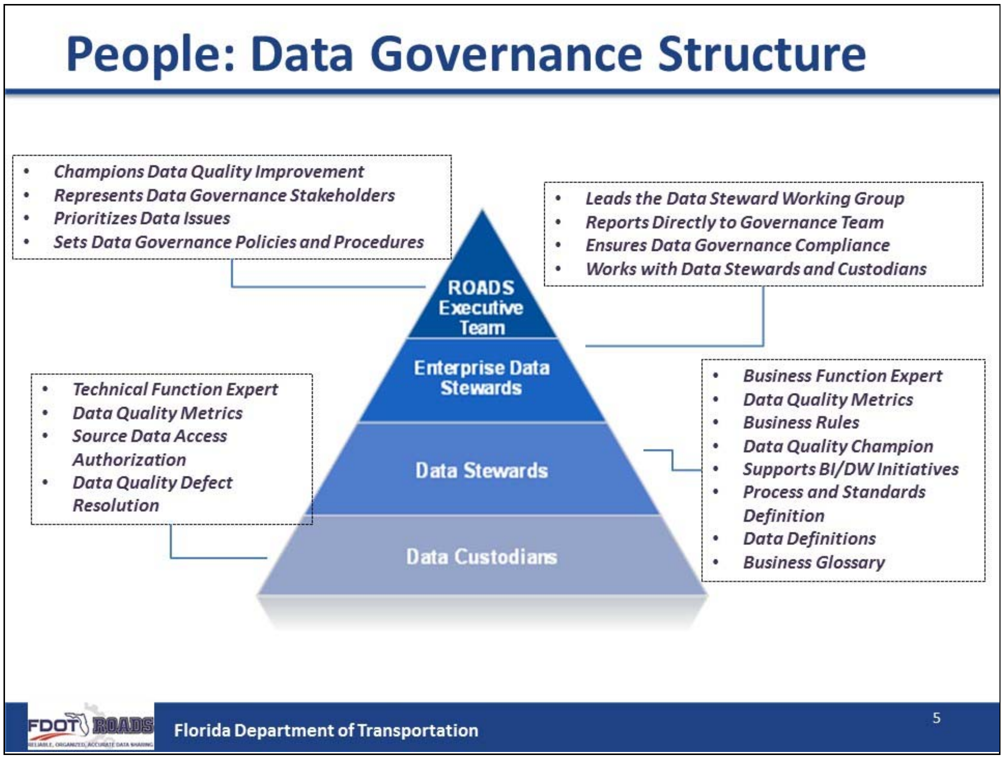


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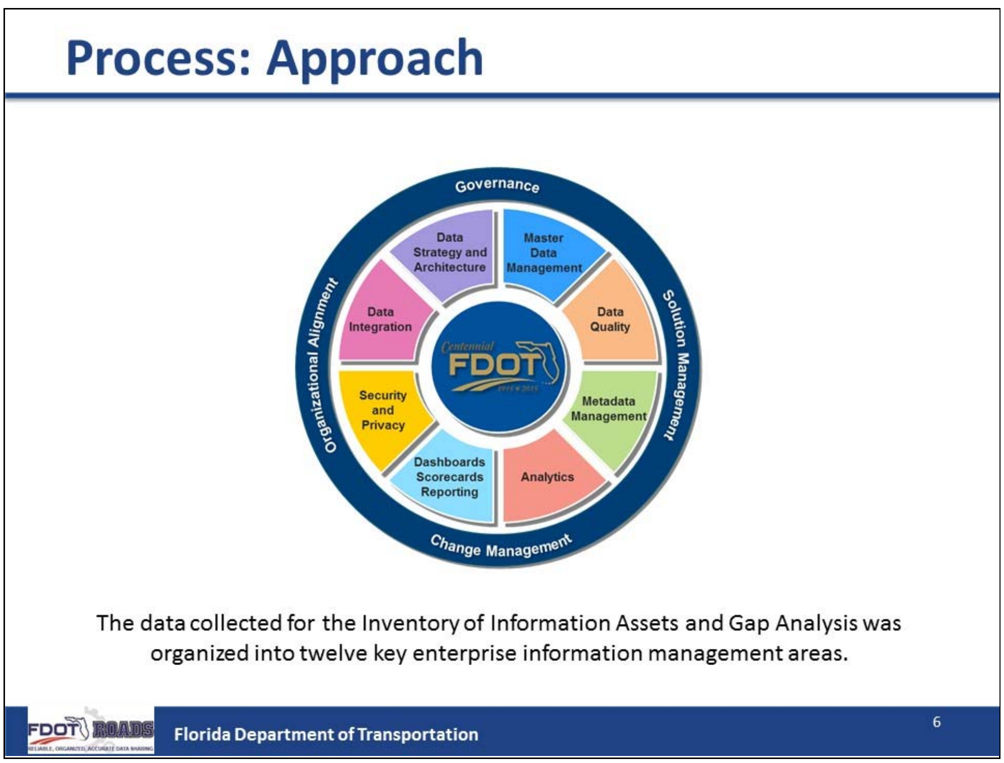

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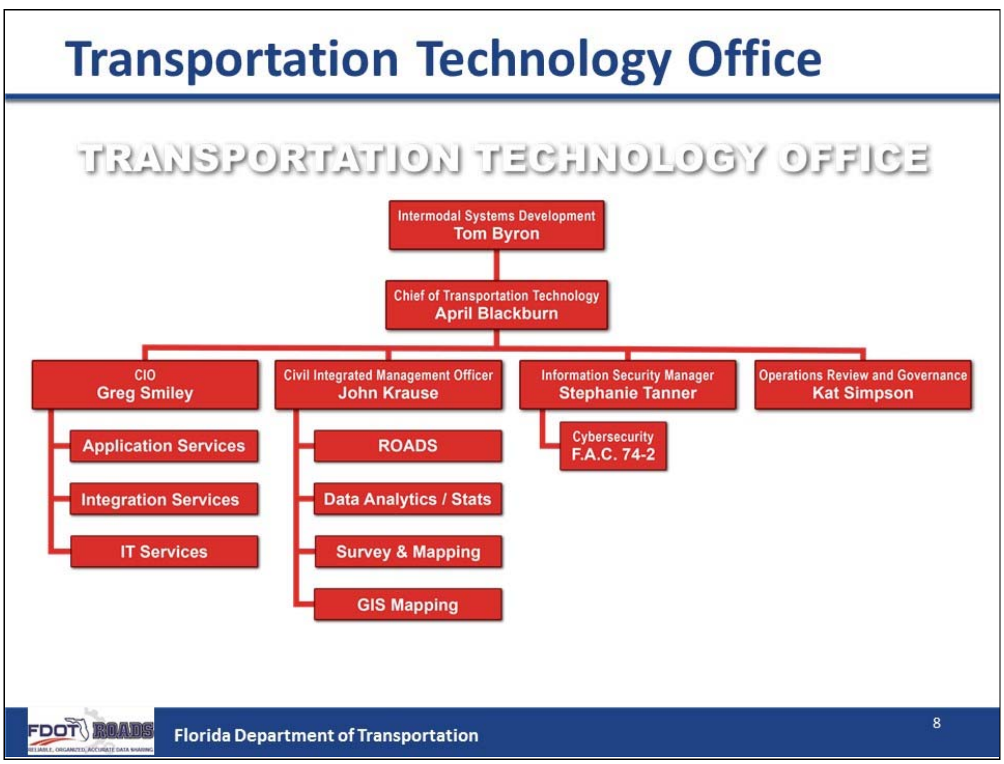

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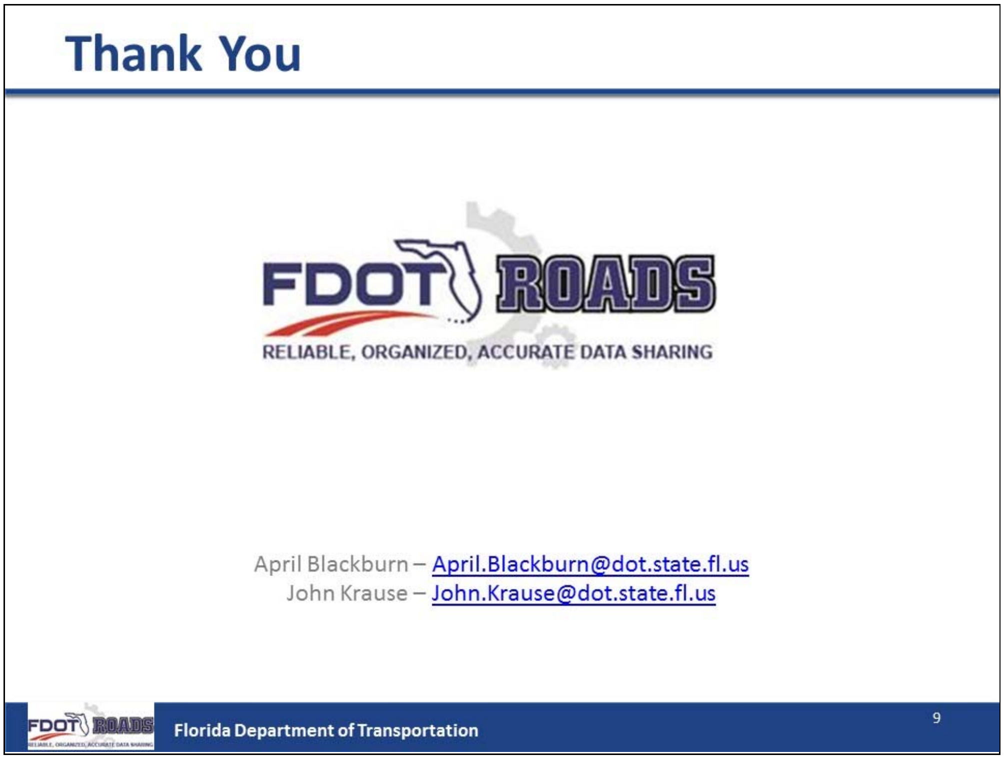

## David Sherman – Florida Department of Transportation

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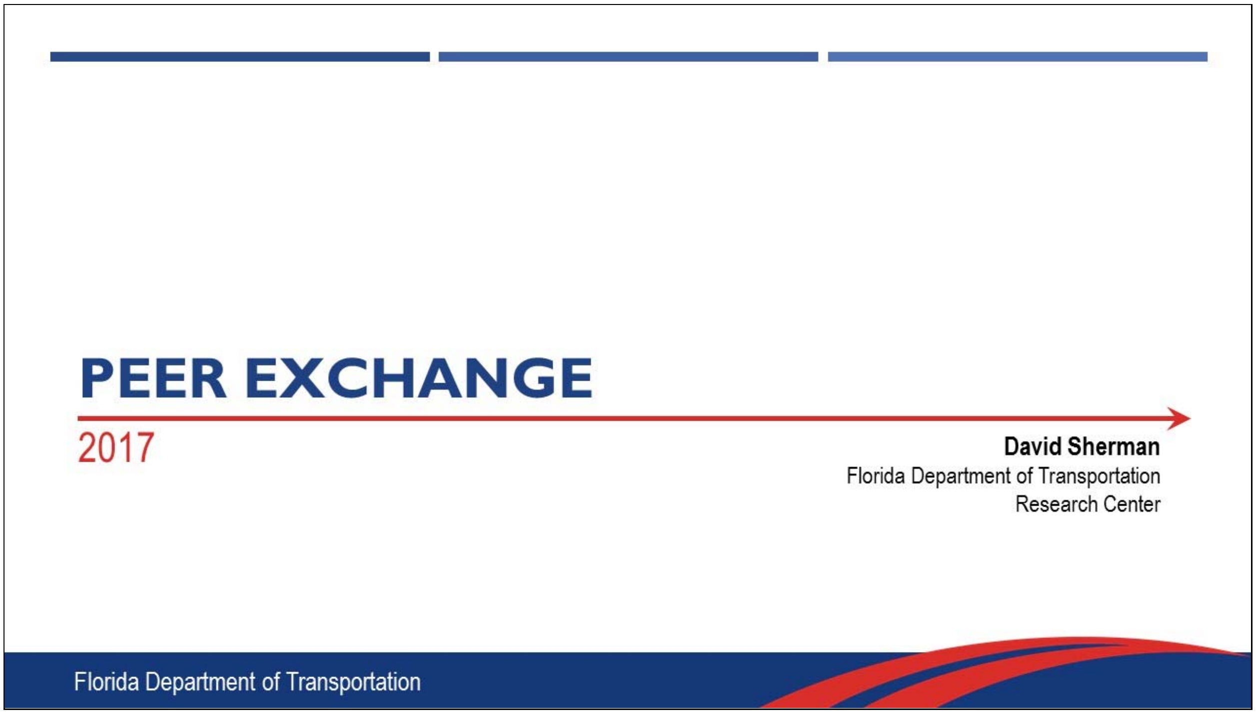


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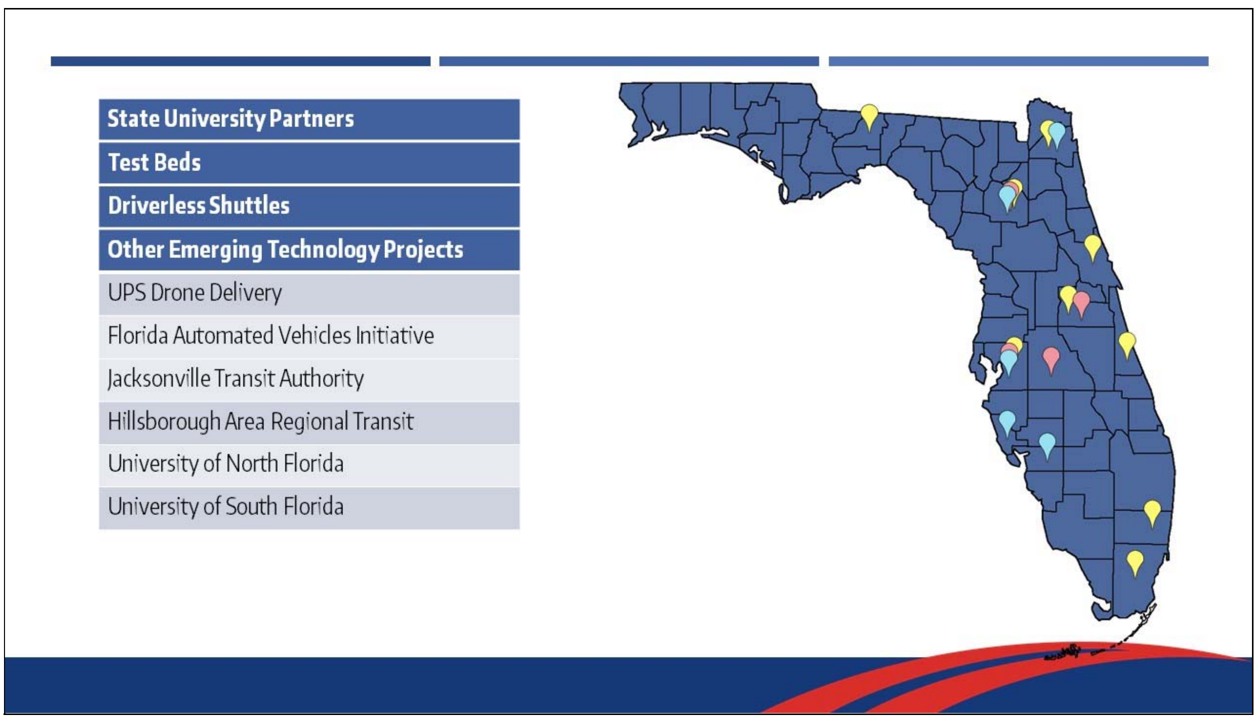

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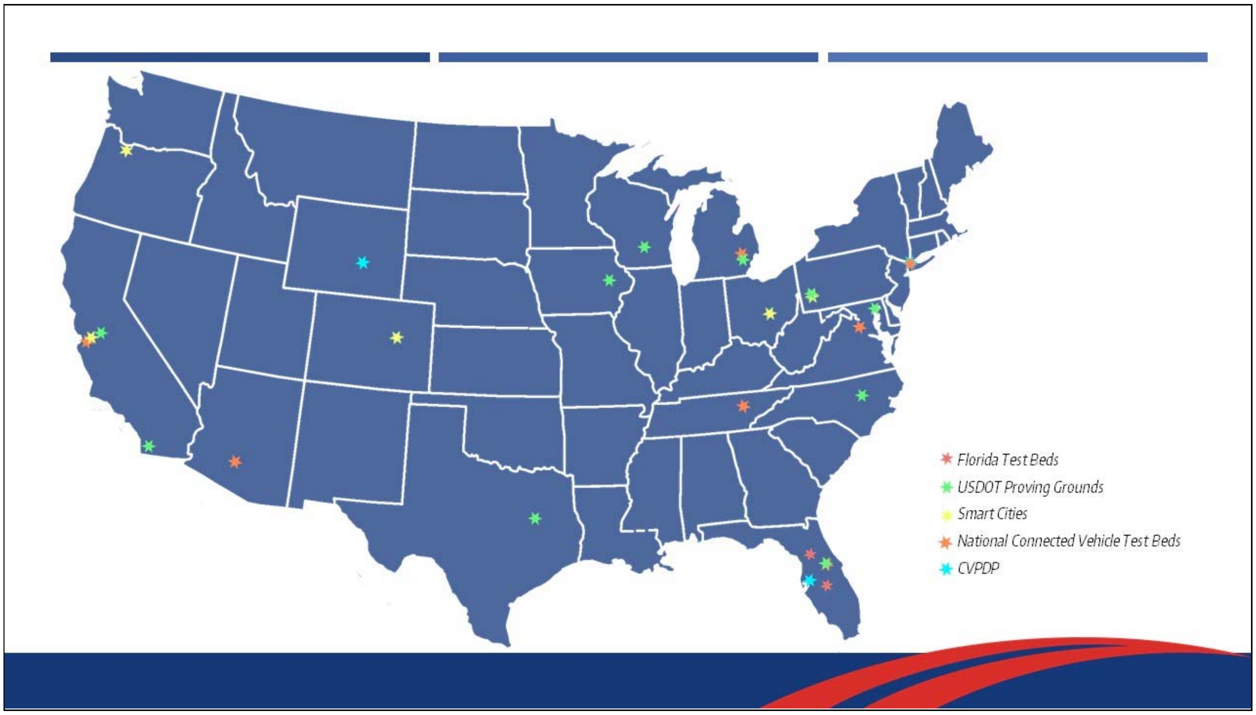


## Raj Ponnaluri – Florida Department of Transportation

*Slide 1*


*Slide 2*

# Agenda

1. Transportation Systems Management & Operations (TSM&O)
2. TSM&O Strategic Plan
3. Evaluation of Project Processes in Relation to TSM&O
4. Signal Phase and Timing (SPaT) Pilot Project
5. I-75 Florida's Regional Advanced Mobility Elements (FRAME)
6. AID Grant University of Florida (UF) Test Bed
7. Automated Traffic Signal Performance Measures (ATSPM)
8. Adaptive Signal Control Technology

TSM&O
Transportation Systems Management & Operations

**Ponnaluri, continued**

*Slide 3*

## Transportation Systems Management & Operations (TSM&O)

- TSM&O is the application of technology and communications to improve the management, operations, safety and efficiency of transportation systems.
- TSM&O involves coordination with various stakeholders ranging from all FDOT Offices to Local Metropolitan Planning Organizations and cuts across all modes of transportation.
- This program develops and applies transportation management and operations solutions that generally do not require major structural alterations of existing or planned roadways.

TSM&O Transportation Systems Management & Operations

*Slide 4*

## Strategic Plan

Executive Summary

I. Strategic Plan Development and Background

II. Challenges and Opportunities

III. TSM&O Snapshot – Where We Are Today

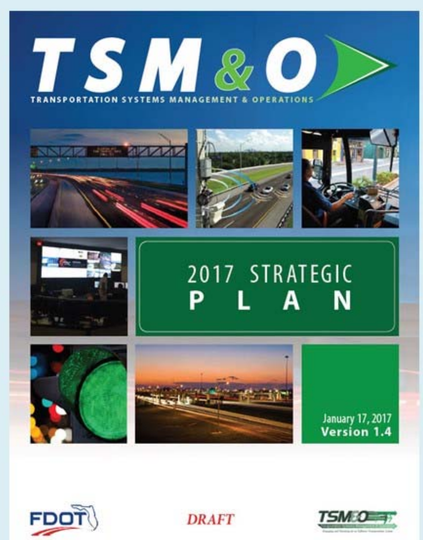
IV. TSM&O Mainstreaming

V. Vision, Mission, and Goals

VI. Roadmap to Achieving TSM&O Goals

VII. TSM&O Resources

VIII. Next Steps and Action Plans




TSM&O Transportation Systems Management & Operations

**Ponnaluri, continued**

*Slide 5*

## Strategic Plan – TSM&O Goals

- Outcome-based performance measures
  1. Mobility – travel time reliability, throughput, delay, and roadway clearance times
  2. Safety – secondary crashes
  3. System maintenance – availability and uptime
- Path to target setting
  - ✓ **Year 1 and 2:** Collect data and establish baselines
  - ✓ **Year 2:** Set targets for routes and/or critical segments
  - ✓ **Year 3 and beyond:** Set Performance Enhancement Goals (PEG) to reach targets

TSM&O

*Slide 6*

## Evaluation of Project Processes in Relation to TSM&O

Contract Number: BDV34 TWO 977-07

Research Perspective

| | |
|---|---|
| *Principal Investigator:* | *Dr. Thobias Sando, P.E., PTOE*<br>*University of North Florida* |
| *Co-Principal Investigator:* | *Dr. Priyanka Alluri, P.E.*<br>*Florida International University* |
| *Project Manager:* | *Dr. Raj Ponnaluri, P.E., PTOE*<br>*FDOT* |
| *Co-Project Manager:* | *Melissa Ackert, P.E.*<br>*FDOT* |
| *Consultant:* | *Larry Hagen, P.E., PTOE*<br>*Hagen Consulting Services, LLC* |

TSM&O

**Ponnaluri, continued**

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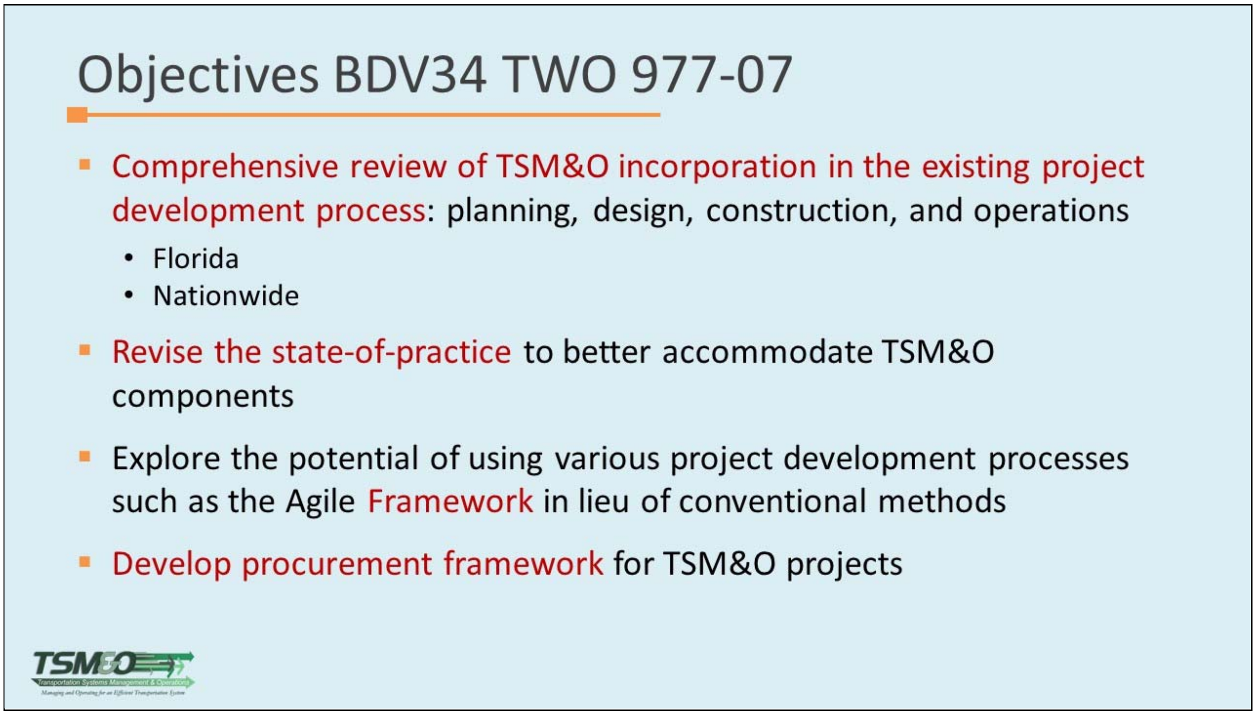


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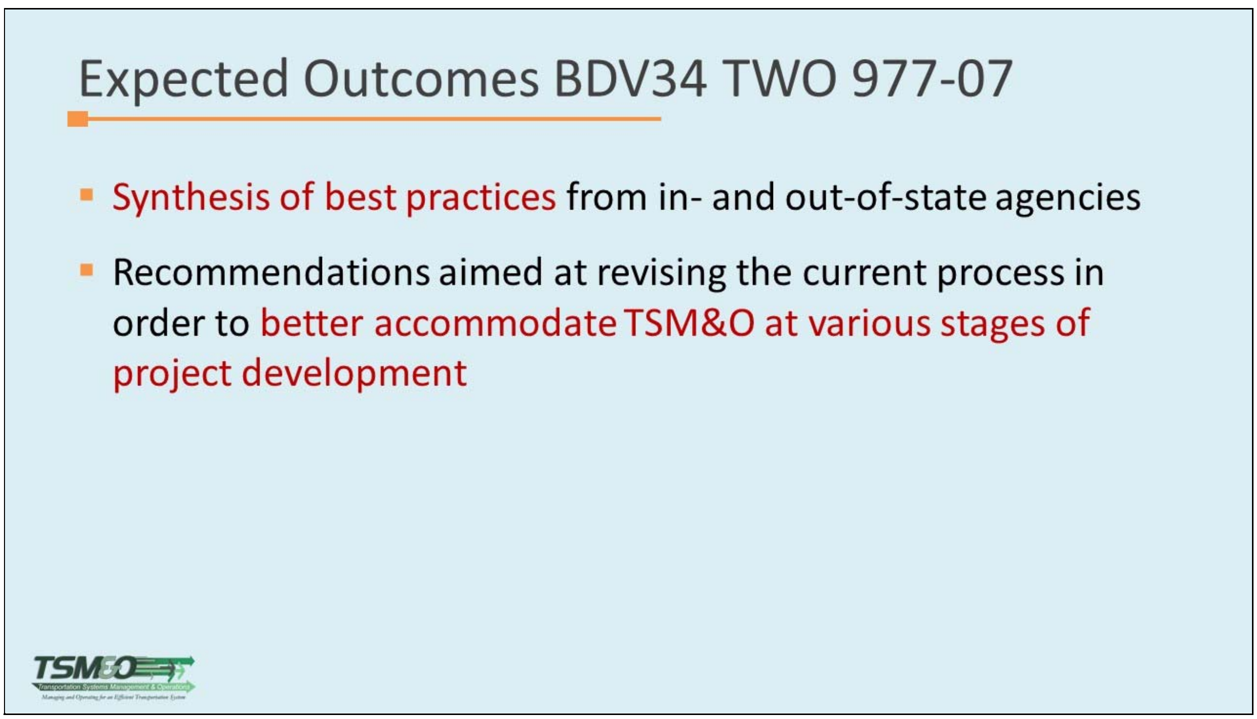


**Ponnaluri, continued**

*Slide 9*

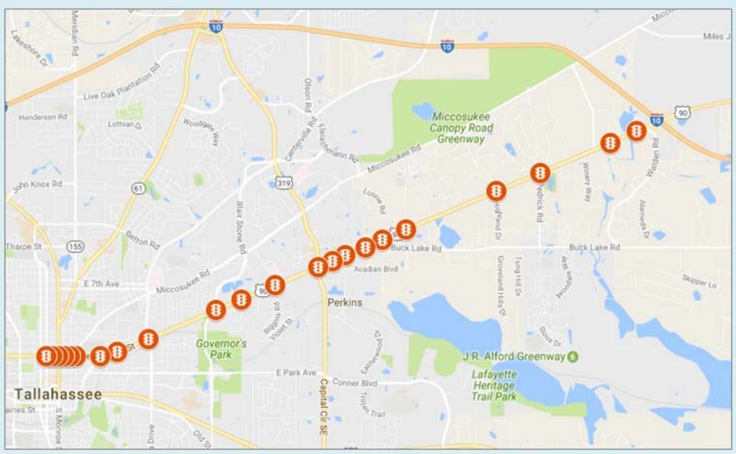
## TSM&O Innovation

- Arterial Management
  - Advanced traffic signal performance measures – part of FHWA's Every Day Counts Program
  - Advanced signal control technology – pilot projects underway; before/after studies in progress
  - FHWA workshops planned – on Business Processes and Traffic Signal Action Plans
- Connected Vehicles
  - Signal Phase and Timing (SPaT) pilot project
  - I-75 Florida's Regional Advanced Mobility Elements (FRAME) project
  - University of Florida Test Bed

*Slide 10*

## Signal Phase and Timing (SPaT) Pilot Project

- AASHTO Challenge
- 22 signalized intersections along US 90 (Mahan Drive) in Tallahassee
- FDOT and City of Tallahassee Partnership
  - City to install
- Pre-deployment testing at the Traffic Engineering Research Laboratory (TERL)
- RFP is advertised



**Ponnaluri, continued**

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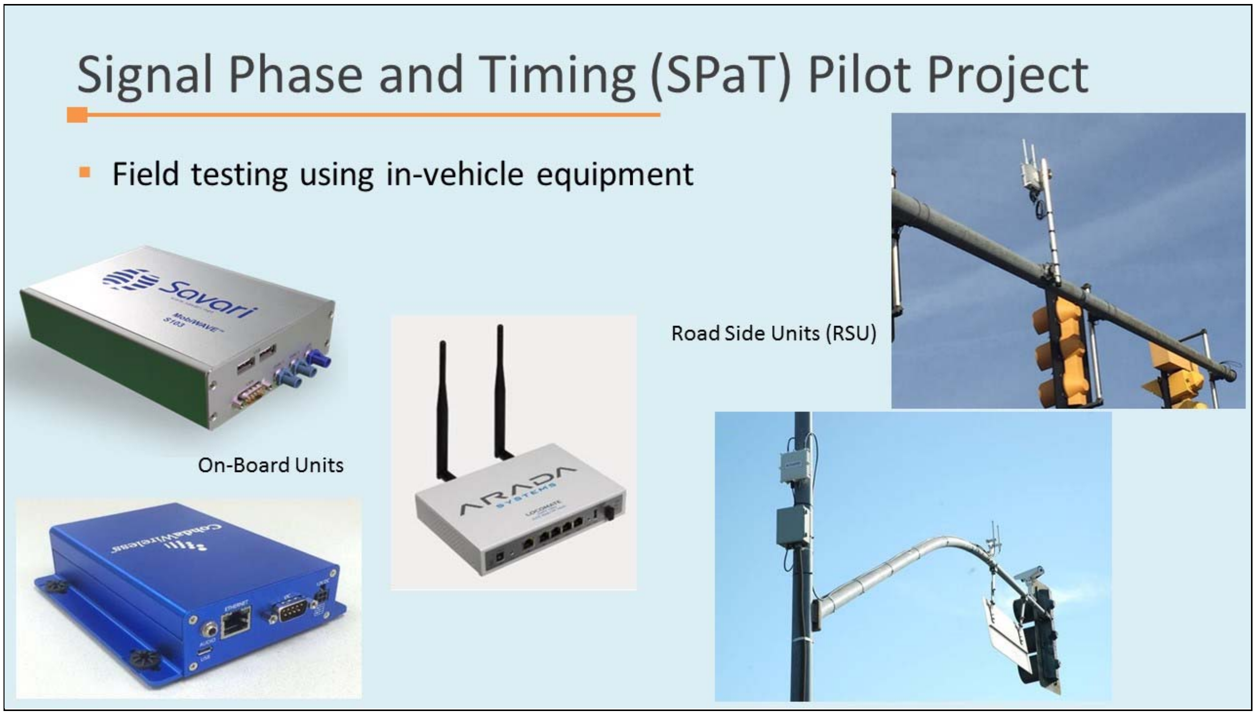


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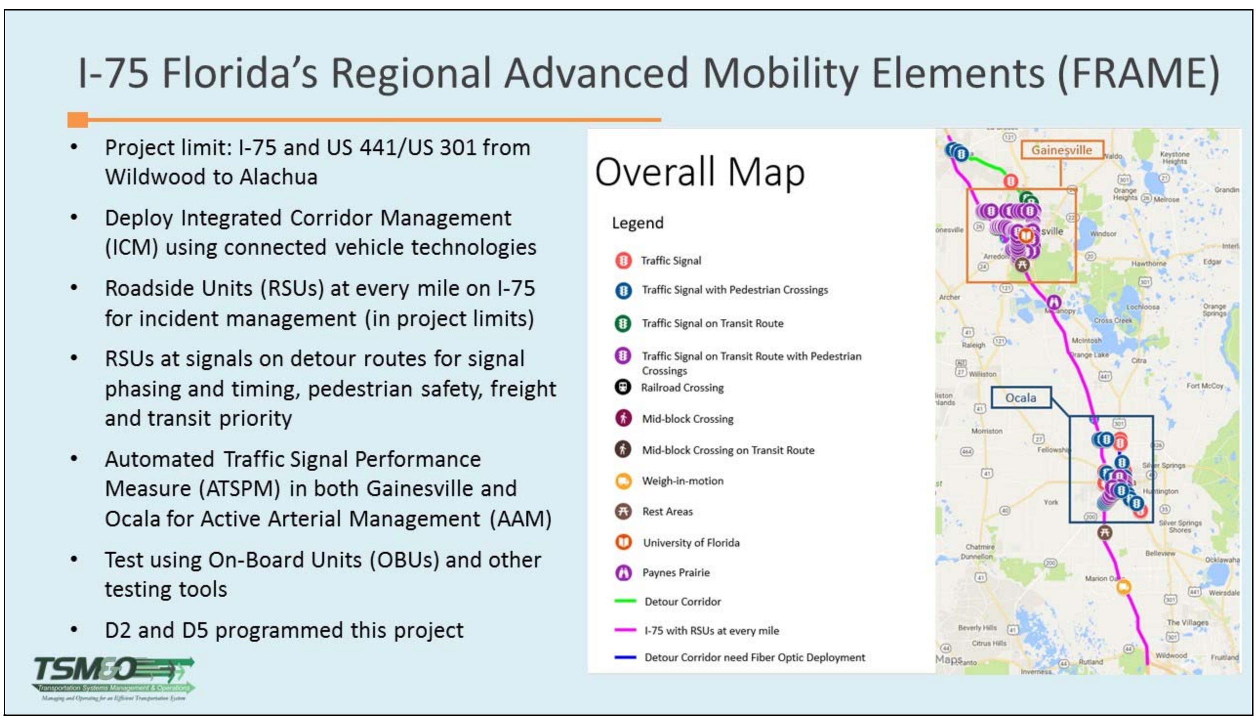

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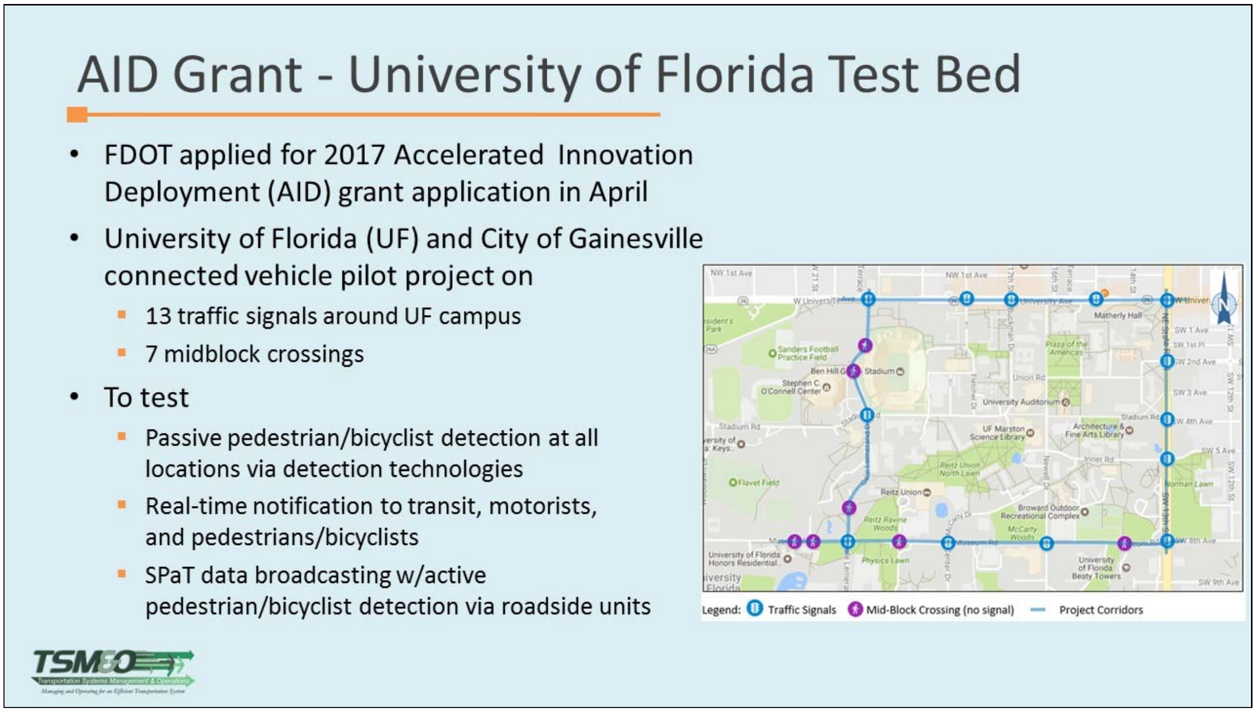


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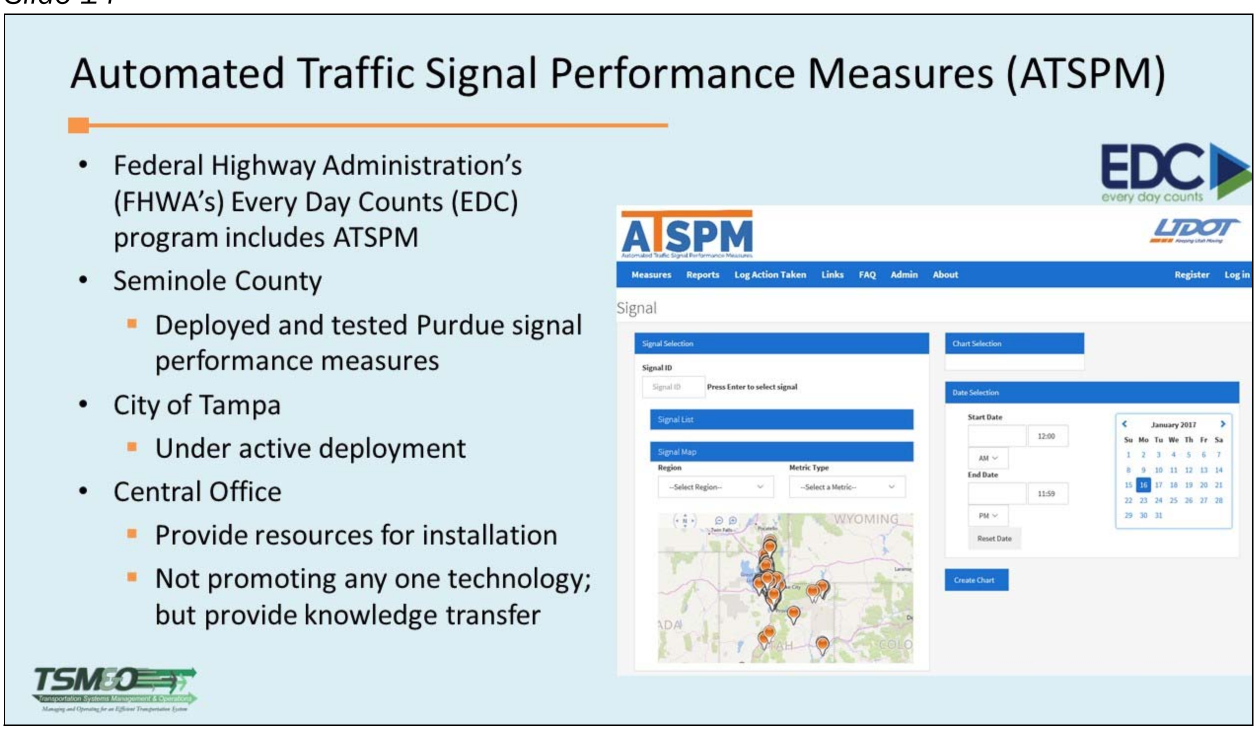

**Ponnaluri, continued**

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## FDOT Traffic Signal Performance Measures (TSPM) Study

- Final report published in 2/28/2017
- Report highlights
  - Benefits of TSPM
  - Challenges of TSPM
- Benefits
  - Enhanced system intelligence and remote signal monitoring
  - Travel time savings and reduction in delays
  - Public safety
  - Maintenance cost efficiencies
  - Additional verification of signal performance
  - Public information
  - Low-cost implementation


TSM&O Transportation Systems Management & Operations

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## Adaptive Signal Control Technology

- Advanced systems automatically adapt to changing traffic demands
- More responsive to unexpected incidents such as weather and traffic crashes
- More responsive to unscheduled events such as holiday traffic

Traffic Signal Controller - cabinet and hardware

Traffic Signal

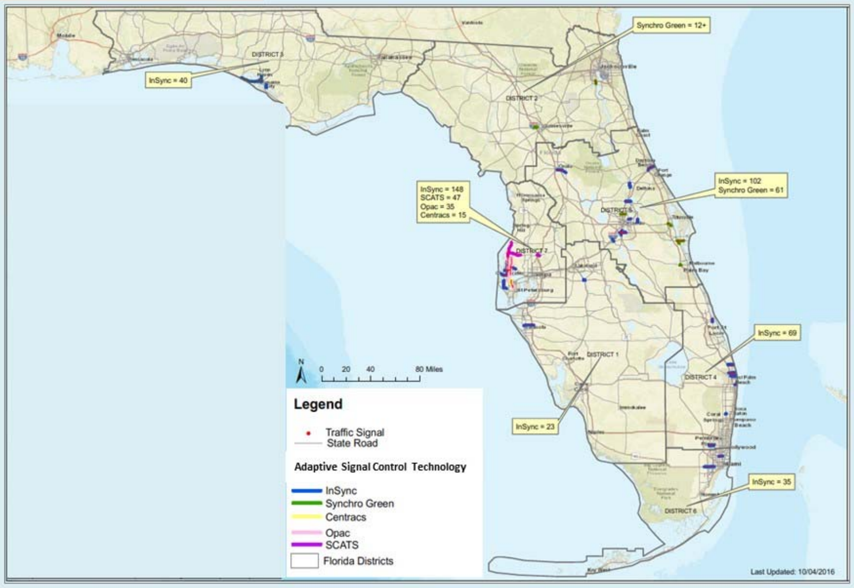
TSM&O Transportation Systems Management & Operations

**Ponnaluri, continued**

*Slide 17*

## Adaptive Signal Control Technology

- Deploying pilot projects
- Before and after assessments by University of Florida
- Does not work everywhere
  - Low effectiveness on fully saturated corridors during peak periods
- Additional deployments planned on Strategic Intermodal System corridors




TSM&O Transportation Systems Management & Operations

*Slide 18*

## STREET Challenge

- **STREET Vision:** To draw from the Department's vision and TSM&O Strategic Plan of pursuing innovation and deploying emerging technologies which focus on transportation safety and mobility.
- **STREET Mission:** To conceptualize, accelerate deployment, and evaluate emerging TSM&O technologies.
- **Wok Plan / Objectives:**
- Identify regional needs and pilot locations
- Identify deployment-ready connected vehicle and/or emerging technologies (CVET) consistent with the STREET vision
- Develop potential use cases and develop cost estimates
- Prepare a Request for Information (RFI) package to solicit CVET service providers and vendors

TSM&O Transportation Systems Management & Operations

**Ponnaluri, continued**

*Slide 19*

## Work Plan

- **Wok Plan / Objectives:**
- Choose about 3 to 4 technologies for implementation, deployment, testing and evaluation
- Identify regions for deployment and seek matching funds from federal, state, and local agencies, if feasible from a process and time-perspective
- Select vendors and implement the technologies in the selected regions
- Deploy
- Field test and evaluate the implemented technologies
- Conduct before and after studies to gauge the benefits and deployment challenges
- Prepare documentation as *lessons learned* effort

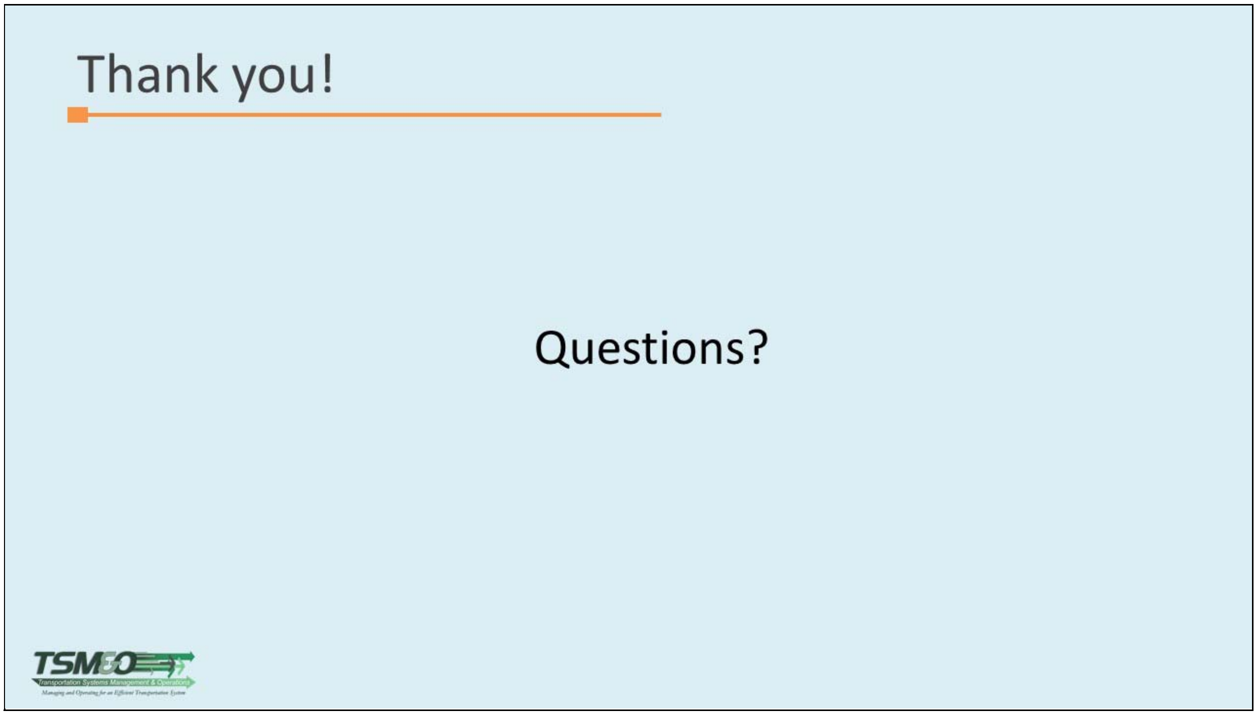
*Slide 20*

## Potential CVET Applications

- Bike-Ped detection and/or safety including priority phasing for pedestrians (Ped-Sig)
- Pedestrian Alert Systems – alert vehicles when pedestrians are in a crosswalk (Ped-X)
- Forward Collision Warning (FCW) to warn drivers of an impending collision
- Intelligent Traffic Signal (I-SIG) for optimizing traffic flows though signal timing adjustments
- Vehicle Data for Traffic Operations (VDTO) – use Automated Traffic Signal Performance Measures
- Signal Phase and Timing (SPaT) deployment enhancements
- Basic Safety and Info messages for vehicle to infrastructure (V2I) support to industry
- Use of Unmanned Aerial System (UAS) in Traffic Engineering
- Grade Crossing Notification System (GCNS) at highway-rail grade crossings
- Traffic Signal Central System Software (CSS)
- Data Analytics and Decision Support Systems (DSS)

**Ponnaluri, concluded**

*Slide 21*



# Appendix C: Request for Information

**I-Street Testbed at the University of Florida (Implementing Solutions from Transportation Research and Evaluation of Emerging Technologies)**

**Request for Information (RFI)**

## Intent

The intent of this Request for Information (RFI) is to invite industry partners, private sector developers, research entities and transportation innovators (hereinafter referred to as I-STREET Partners) of emerging technologies and transportation solutions (hereinafter referred to as I-STREET Solutions) to express implementation interest and provide deployment-oriented approaches for real-world demonstration and testing with the anticipated outcome of assisting the I-STREET Partners to transition from development to realization of transportation safety and mobility benefits as quickly as possible. The I-STREER Testbed is a collaboration of the University of Florida (UF), the Florida Department of Transportation (FDOT), and the City of Gainesville (CoG) (hereinafter referred to as the I-STREET Team).

I-STREET intends to leverage the several ongoing efforts at FDOT, UF and CoG, including the use of the hardware and software solutions being deployed for realizing the benefits from connected vehicle (CV) technologies to improve the safety and mobility of road users. This initiative plans to provide I-STREET Partners with data and any other output obtained from the ongoing projects at FDOT.

The mission of the I-STREET Team is:

- To collaborate with and provide every possible assistance to I-STREET Partners to demonstrate and test a wide range of I-STREET Solutions that have the potential to increase the rate of delivery of fatality-free and congestion-free transportation systems for all transportation system users. Included are software, hardware and any other solution for review by the I-STREET Team.
- To provide I-STREET environs ranging from freeways to high-pedestrian volume arterials. Each of the environs is or is planned to be equipped with Intelligent Transportation System (ITS) and/or CV infrastructure.
- To provide technical, evaluation, and financial resources to assist I-STREET Partners to transition I-STREET Solutions from the laboratory and design to wide-scale field deployment.
- To cooperatively share the results of successful I-STREET Solutions demonstration and testing with the various industry groups to which the I-STREET Partners belong. (Any proprietary information will not be shared outside of the I-STREET Team without prior consent from the respective I-STREET Partner.)

## Options and Selection of I-STREET Solutions for Demonstration and Testing

The following general options are available to I-STREET Partners for engaging with the I-STREET Team:

1. Testing and Evaluation of Equipment/Hardware/Software: This option is most suitable for I-STREET Partners with a fully developed concept which is ready for installation and testing in a real-world environment. Under this option the I-STREET environs may be used to test and evaluate the effectiveness of the new device or software on transportation safety or mobility. The evaluation may be conducted by an I-STREET Partner using the facilities, or in collaboration with the I-STREET Team.

2. Equipment Loan and Collaboration: This option is most suitable for Developers with equipment that has already been installed in a real-world environment but could be used for research, education, and technology transfer purposes by the I-STREET Team. Under this option the I-STREET Partner may enter into an agreement to loan equipment over a pre-specified time period or under a pre-specified set of conditions.
3. Research and Development: This option is most suitable when desiring to collaborate with the Team to develop or refine an existing concept or device. In this case, a research-type agreement may be developed.

The options above are provided for illustrative purposes and to describe the range of options currently explored. Additional options may be explored by the I-STREET Team if requested through the RFI process. The I-STREET Team website provides examples of agreements for each of these categories. These are provided for illustrative purposes and will be revised and finalized with I-STREET Partners on a case-by-case basis.

The I-STREET Team will select candidate I-STREET Solutions for further discussions and/or moving forward with demonstration and/or testing based on information requested in "Response to RFI", below. If a I-STREET Partner requires financial support, the I-STREET Team may use a Request for Proposals (RFP) to further define and quantify roles and responsibilities. UF will manage any necessary contracts and agreements between the I-STREET Team and I-STREET Partners.

## I-STREET Facilities

FDOT is investing in various emerging technology projects within the CoG area on several corridors in partnership with CoG and UF as shown in Figure 1. These corridors and proposed emerging technologies can be made available to I-STREET Partners to test their proposed I-STREET Solutions. All these corridors (including I-75) are connected to the CoG's Smartraffic Center[1] using the City's communications network. CoG has several ITS deployments such as traffic cameras, travel time data collection devices, and arterial dynamic message signs on a few corridors. CoG also manages and operates signals for the Gainesville and surrounding areas including the City of Alachua. The traffic signal controllers are Naztec 980 version and run on ATMS.now central system software at CoG's Smartraffic facility.

Detailed information regarding the specific equipment available at a particular location or corridor may be obtained from the City of Gainesville (see contacts at the end of the RFI). The summary details for projects shown in Figure 1 are:

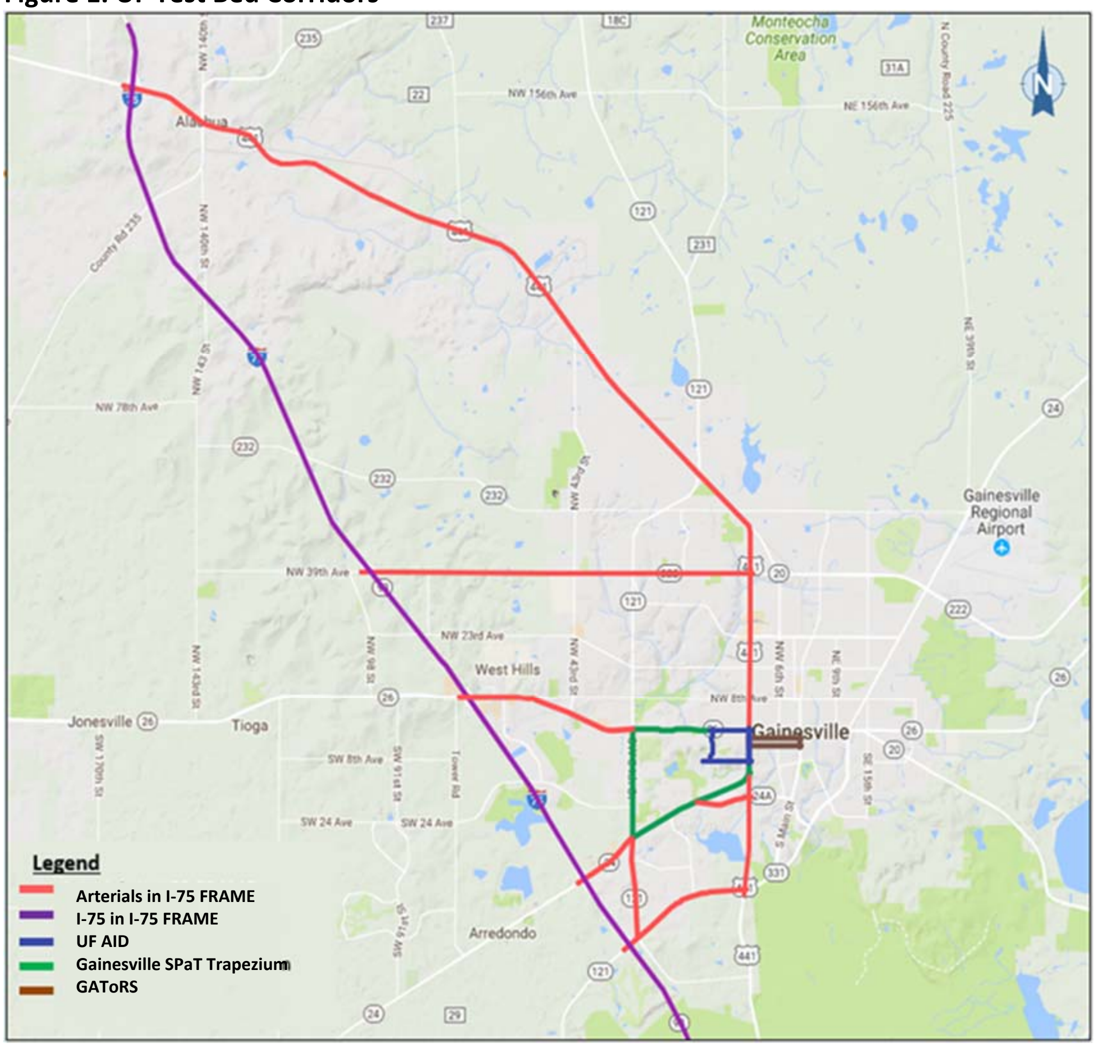
1. **I-75 Florida's Regional Advanced Mobility Elements (FRAME):** This project will deploy Automated Traffic Signal Performance Measures (ATSPM), ITS and CV technologies to better manage, operate, and maintain the multi-modal transportation system and create an Integrated Corridor Management (ICM) solution on I-75 and state highway systems in and around Gainesville. The goal of the project is to reduce crashes on I-75 and reduce impact of diverted traffic on the arterial roadways. I-75 FRAME routes are: I-75 and US 441, US 301, SR 24, SR 24A, SR 26, SR 121, and SR 222. Approximately, 150 roadside units (RSUs) are planned for installation.
2. **UF Accelerated Innovation Deployment (AID) Demonstration project**: This project plans to deploy and test pedestrian and bicycle safety applications (active or passive) at 13 signalized

[1] http://gac-smartraffic.com/

intersections and seven (7) mid-block crossings using CV technologies within the core of the UF campus. The goal of the project is to reduce pedestrian and bicycle crashes and conflicts. The routes are SR 26 (University Avenue), US 441 (SW 13th Street), Museum Road and Gale Lemerand Drive. Approximately, 20 RSUs and passive pedestrian detection are anticipated to be deployed.

3. **Gainesville Trapezium**: This project plans to deploy and test CV technology and applications along four corridors forming a trapezium surrounding the UF main campus. The goal of the project is to improve travel time reliability, throughput and traveler information. This project plans to deploy pedestrian and bicyclist safety applications. The routes are SR 121, SR 26, US 441, and SR 24. The approximate number of RSUs installed on this project is 45.
4. **Gainesville Autonomous Transit Shuttle (GAToRS):** This project will deploy an autonomous transit system to connect the CoG Innovation District and downtown with UF student housing and campus by means of frequent transit service. The goal of GAToRS is to maintain a maximum headway of 10 minutes or less for the GAToRS buses. GAToRS routes include SW 4th Avenue, SW 13th Street, SW 2nd Avenue, and S Main Street (shown in brown).

**Figure 1. UF Test Bed Corridors**



I-STREET Partners may opt to use these corridors to test their Solutions or may request other corridors within CoG City Limits[2]. Developers may identify opportunities to improve existing and proposed systems in this region to support demonstration or testing of their proposed I-STREET Solution(s). Such recommendations should be submitted to the I-STREET Team along with the RFI response or identified after the proposed solution is selected for further discussion, potentially leading to demonstration or testing.

## Desired Technologies/Applications

The I-STREET Team is specifically interested in the following categories of emerging transportation I-STREET Solutions, but is open to receiving information on other Solutions as well. Each I-STREET facility has specific transportation safety and mobility needs such as increasing the throughput, addressing recurring and non-recurring congestion, mitigating traffic crashes, providing detours, supporting multimodalism (pedestrians, bicyclists, skateboarders, scooters, transit), parking solutions, addressing at-grade train crossing issues, high truck volume and freight delivery aspects, and road weather information needs.

1. **Safety Applications** for improved public safety through connected vehicle systems; smart work zones using CV systems; improved bicyclist, skateboarders, scooter, and pedestrian safety; enhanced rail-road crossings notification and improved at-grade crossings; road weather notifications; and the use of Unmanned Aerial Systems (UAS) in transportation management.
2. **Mobility Applications** for improved traffic flow throughput and travel-time reliability for all modes through efficient and intelligent traffic signals; intelligent parking systems (cars and trucks); freight delivery applications; and improved first- and last-mile connectivity.
3. **Data Management Applications** for cost effective data sharing and management through use of vehicular data for fleet management and public safety; the use of traffic data for predictive analytics, decision support systems, dashboard applications, and third-party dissemination using cellular/Wi-Fi/Dedicated Short Range Communication (DSRC); and improved data sharing agreements between private party and local/state agencies. The use of Internet of Things (IOT) elements can also play a role in I-STREET.

## Response to RFI

The Interested I-STREET Partners are requested to submit the following information for consideration:

1. **I-STREET Solution Description(s):** Describe the I-STREET Solution(s) proposed by the Developer for demonstration and/or testing. Discuss the innovative aspects of the I-STREET Solution, in what way it improves on previously available solutions and implementations, and the proposed location(s) or types of locations where it is expected to be deployed.
2. **Implementation Roadmap**: Describe the path to wide-scale implementation and how the path to development and/or implementation of the proposed I-STREET Solutions will benefit from demonstration and/or testing in partnership with I-STREET. Describe the estimated timeframe

[2] http://gainesvillefl.maps.arcgis.com/apps/webappviewer/index.html?id=0a0a533b105040819877c82cbe5a091d

for technology prototype availability for testing and for field deployment. Implementation-readiness is an important objective of I-STREET.

3. **Deployment Benefits:** Discuss the types and magnitude of the potential safety and/or mobility benefits relative to a specific or range of transportation needs.
4. **Implementation Resources**: Describe resource requirements for wide-scale field development, implementation, operations, and maintenance of your proposed I-STREET Solutions.
5. **I-STREET Outcomes**: Describe goals, objectives and expected outcomes of collaboration with I-STREET for demonstration and/or testing of the proposed I-STREET Solutions.
6. **I-STREET Team Financial and Technical Support Needs:** Describe level of support required or desired from the I-STREET Team to accelerate bringing Solution(s) to the marketplace, including:
   - Infrastructure elements: provide as much detail as possible on preferred location(s) for installation of the proposed technology.
   - Technical resources: provide details on resource needs for design, implementation, testing, integration, or other support that may be available from the I-STREET Team.
   - Evaluation resources: provide details on resource needs for monitoring, data collection, data analysis and reporting that may be available from the I-STREET Team.
   - Financial resources: provide details on financial resource needs for procurement of hardware/software or other elements of the proposed Solutions that may be available from the I-STREET Team.
7. **Standards and Specifications:** The intent of this section is to merely identify and describe current and planned level of compliance with applicable standards/specifications for the safe mobility of road users. The I-STREET Partners are invited to explore technology options for deployment-readiness. Of particular interest to the I-STREET Team is the ease of integration and compatibility with the CoG's Smartraffic software, FDOT's SunGuide® software, and FDOT's Data Integration and Video Aggregation System (DIVAS). If applicable, the Security Credential Management System (SCMS) elements may be described.
8. **Risks**: I-STREET Team may be consulted while identifying potential risks that could limit either a successful technology test or potential full scale implementation if the test is highly successful. Identity potential safety or security risks to road users and ITS infrastructure, and provide a risk mitigation or management plan for use during I-STREET Solutions testing/operations.
9. **Confidentiality**: Identification of any portions of the proposer's RFI response that are confidential or proprietary information protected by copyright, trademark, or patent.
10. **Other Information**: I-STREET Partners may request the I-STREET Team of any other information to develop the I-STREET Solution(s) for demonstration and/or testing.

## Receipt of RFI Responses

I-STREET Team will review the RFI responses received at any time until _________. RFI responses shall be submitted to Dr. Lily Elefteriadou at elefter@ce.ufl.edu. The RFI response date may be extended at UF Partners' request and/or I-STREET Team's discretion. Submission of an RFI response does not commit UF or the I-STREET Team to award any work to the I-STREET Solution proposers either directly or through response to a future RFP. If the UF or FDOT chooses to advertise an RFP, all qualified I-STREET Partners will need to submit proposals for consideration in accordance with the terms defined in the RFP.

## Contact Information

**Clark Letter**
Testbed Manager
University of Florida Transportation Institute
ClarkLet@ufl.edu

**Emmanuel Posadas**
Traffic Operations Manager
City of Gainesville
PosadasEP@cityofgainesville.org

**Raj Ponnaluri**
Arterial Management System Engineer
Florida Department of Transportation
Raj.Ponnaluri@dot.state.fl.u

# Appendix D: Advanced Technologies Campus Testbed – Semiannual Meeting

**9 am – 5 pm**

# Tentative Agenda

**Morning Session:**

| | |
|---|---|
| 9:00 am – 11:00 pm | Individual Project Overview. The PI for each respective project will give an overview of progress made during the previous six months. This overview will include the following:<br>• A status report detailing the progress made on each specific task, and what progress is expected in the next 6 months.<br>• If any testing was performed, it is expected that a summary of performance measures be presented. |
| 11:00 am – 12:00 pm | Review of Overall Project Schedule and Modifications. The schedule of each project will be updated to reflect the current progress made, and the projected completion of each task. This will then be updated into the overall project schedule by the testbed manager. |
| 12:00 pm – 1:00 pm | Lunch. |
| 1:00 pm – 2:00 pm | Industry Partnerships. Discussion on current and planned industry partners for the next six month period. Current partner involvement will be outlined and their continued involvement will be discussed. |
| 2:00 pm - 4:00 pm | Review of Outside Testbed Activity. Discussion and presentation(s) related to the activity of related testbeds around the country. Representative(s) from other testbeds may be invited to present on current and planned projects. |
| 4:00 pm - 5:00 pm | New Projects and Suggested Changes. Scopes of work for new research; adjustments to existing scopes of work. |

# Appendix E: Communications Plan

**Communications Plan for I-STREET Activities**

Objective: To showcase UF's innovation leadership in working with the Florida Dept. of Transportation City of Gainesville to test emerging transportation technologies. These technologies are aimed at improving safety, mobility and data management strategies. Current projects are related to autonomous vehicles, connectivity between all modes of transportation, data management and analytics, advanced traffic management strategies and infrastructure enhancements. Ms. Elaine Khoo will update the communications plan to address press releases and upcoming opportunities to promote I-STREET activities.

Spokespeople

- Charlie Lane, senior VP and COO
- Dr. Lily Elefteriadou, Director of UF Transportation Institute
- Dr. Clark Letter, I-STREET Manager
- FDOT Representatives
- City of Gainesville

Messages

*Innovation*: UF Transportation Institute, part of the Herbert Wertheim College of Engineering, has been conducting research on autonomous vehicles since xxxx.

Gainesville as a "living laboratory."

*Partnership:* UF has partnered with FDOT and City of Gainesville to conduct research on autonomous vehicles and advanced communications systems. The ultimate goal is to improve the user's safety and mobility. This is accomplished by collecting, analyzing and disseminating data from advanced sensing and communications technologies.

*Safety*: Important to message parents and students before autonomous vehicles go live on campus: Need to release information through media about the safety of these vehicles as they are tested on campus.

Status:

An RFP will be released by the end of August, seeking to secure a vendor whose vehicles can be engineered for self-driving testing. A selection will be made in the fall semester, and vehicles projected to be on the road by the end of Spring semester.

An RFI will be released at a similar time to the RFP requesting interest in collaborating on research and demonstration of advanced technology. The anticipated result is partnership with multiple partners on research solutions.

Next steps include coordinating a launch event for the testbed. This event will include demonstration of current research projects and an open Q&A session with invited media outlets.

UF Testbed has been named "I-STREET," short for Implementing Solutions from Transportation Research and Evaluation of Emerging Technologies

In October the WTS student chapter will be hosting the WTS Symposium with the theme "smart cities."

In November UFTI's STRIDE will be hosting the UTC Conference at the Reitz Union – there will be an Automated Vehicle demonstration

An initial draft of a promotional logo for the University of Florida has been created:

I-STREET

Transportation Institute
UNIVERSITY OF FLORIDA

Website pages have been drafted, and a general brochure has been created.

Audiences:

- Transportation industry
- Engineering industry
- Business statewide and national
- City/government newsletters
- Students, parents, alumni, potential students

Past coverage: a Gainesville Sun editorial from April (4/27/17): http://www.gainesville.com/opinion/20170427/editorial-uf-driving-toward-city-improvements

-Was picked up in several publications, including the ITS America Smart Brief newsletter (5/2/17), and: http://www.govtech.com/fs/University-of-Florida-to-Use-Gainsville-as-a-Living-Laboratory.html

Traffic Technology Today: http://www.traffictechnologytoday.com/news.php?NewsID=85168

WUFT https://www.wuft.org/news/2017/04/28/uf-gainesville-announce-partnership-to-test-self-driving-vehicles/

Other media interested: CBS4 Brooke Rayford