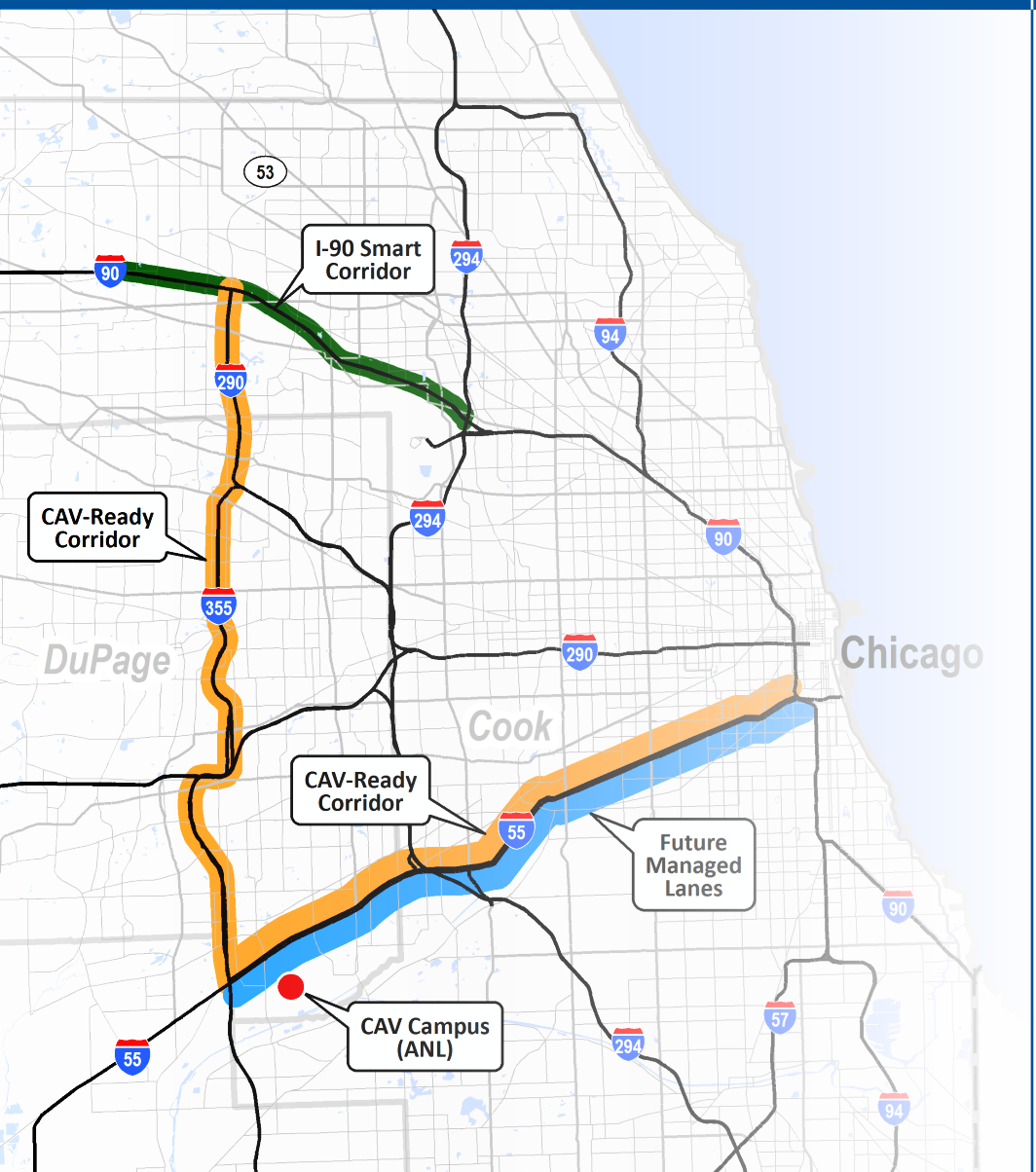
PROPOSAL



Argonne-Illinois Multi-modal Automated Freight and Mobility Testbed

December 2016

Argonne NATIONAL LABORATORY

Illinois Department of Transportation

Illinois Tollway

pace

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Introduction

A team lead by Argonne National Laboratory and in collaboration with the Illinois Department of Transportation (IDOT), the Illinois State Toll Highway Authority (Illinois Tollway), and Pace Suburban Bus Service are seeking to have the US Department of Transportation designate the Argonne campus and supplementary highway corridors (discussed in the body of this proposal) as a USDOT Automated Vehicle Proving Ground. This connected network of highway corridors and a closed campus testing facility would be identified collectively as the Argonne-Illinois Multi-modal Automated Freight and Mobility Testbed. The proposal seeks to combine the broad range of facilities and capabilities contributed by the various team members to create a forward-looking testbed and research corridor that can be used to help in the safe and effective development of Connected and Automated Vehicle (CAV) technologies, ranging from fully automated light and medium/heavy duty vehicles, including buses, to prototype sensors and algorithms, to be integrated into preexisting automated vehicle automation/connectivity package.

Participant Overview

Argonne National Laboratory

Argonne National Laboratory (https://www.anl.gov/) is a multidisciplinary science and engineering research center, where talented scientists and engineers work together to answer the biggest questions facing humanity, from how to obtain affordable clean energy to protecting ourselves and our environment. Specific to the capabilities required across a range of CAV technology development tasks, highlighted research capabilities available at Argonne include:

- Large-Scale User Facilities/Advanced Instrumentation
- Applied Mathematics
- Advanced Computer Science, Visualization, and Data
- Applied Materials Science and Engineering
- Systems Engineering and Integration
- Cybersecurity

Argonne's Center for Transportation Research (CTR) provides innovative solutions to challenges involving fuel efficiency, emissions, durability, safety, design and operating efficiency, petroleum dependence, interoperability, compatibility and codes/standards compliance and harmonization. The CTR is home to a well-balanced transportation research program staffed by world-class researchers and engineers, who are well known in the technical community and within industry, and are supported by the finest experimental facilities and high-performance computer modeling capabilities.

Illinois Department of Transportation

Illinois is located at the heart of the country's interstate highway system, boasting the nation's third-largest road network, including coast-to-coast interstates I-80 and I-90 and major north–south corridors I-55 and I-57. Illinois is also the freight hub of North America, with all seven class I railroads and three major rivers. With this strategic location, the State of Illinois, led by the Illinois Department of Transportation (http://www.idot.illinois.gov/), is in a prime position to be a leading voice for the advancement of connected and automated transportation. Moreover, IDOT has been a national and international leader in the development and deployment of Intelligent Transportation Systems (ITS). In the 1960s, IDOT established the Traffic Systems Center (TSC), one of the world's first real-time expressway surveillance and management systems. Since this initial deployment, the Department has

recognized the need for technological advancements to increase the safety and efficiency of the State's surface transportation system; that recognition continues to this day. Additionally, IDOT's mission is to provide safe, cost-effective transportation for the citizens of Illinois in ways that enhance quality of life and promote economic prosperity while at the same time demonstrating respect for our environment. As IDOT works to achieve this mission, it is critical that the department uphold the following principles as a hallmark of our work: safety, integrity, diversity, responsiveness, quality and innovation.

Illinois State Toll Highway Authority

The Illinois State Toll Highway Authority (Illinois Tollway, https://www.illinoistollway.com/) is a revenue bond-financed administrative agency of the state of Illinois, with its operations funded through toll and concession revenues. The Illinois Tollway consists of approximately 300 centerline miles of access controlled facilities throughout Northern Illinois, carrying over 1.5 million vehicles per day. The Illinois Tollway's mission is to provide and promote a safe and efficient system of highways while ensuring the highest possible level of service to our customers. This has been evident with the implementation of electronic tolling (I-PASS), major capital improvements through the Move Illinois Program, open road tolling and an aggressive integrated incident management program including H.E.L.P. trucks and the soon to open Active Traffic Management system. Under the leadership of the Board of Directors and Executive Staff, the Tollway is committed to achieving the following goals:

- Increase collaboration with regional transportation and planning agencies
- Promote the regional economy
- Foster environmental responsibility and sustainability
- Maintain the safety and efficiency of the Tollway system
- Further transparency and accountability
- Enhance customer service

The Illinois Tollway continues to cooperate with other regional agencies through organizations such as the Great Lakes Regional Traffic Operations Coalition and regional committees such as the MPO Regional Traffic Operations Committee. The Tollway has been on the forefront of technology including opening the new I-90 Smart Corridor including the new Active Traffic Management system opening on I-90 in 2017, and a small scale pilot deployment of Connected Vehicles technologies.

Pace Suburban Bus

Pace Suburban Bus (Pace, https://www.pacebus.com/) is the premier suburban transit provider, safely and efficiently moving people to work, school, and other regional destinations. Pace's family of public transportation services offer affordable and environmentally responsible transit options for the residents of 284 municipalities in Cook, Will, DuPage, Kane, Lake and McHenry counties. The backbone of Chicago's suburbs, Pace serves tens of thousands of daily riders. One of the largest bus services in North America, Pace covers 3,446 square miles, an area nearly the size of the state of Connecticut and about 15 times the size of the City of Chicago. Our Fleet of vehicles include 702 fixed route buses for approximately 200 routes,1233 vanpool vans and paratransit vehicles, and 696 contractor owned paratransit vehicles along with 32 passenger and transfer facilities and 25 Park-n-Ride locations.

CAV Testbed Vision and Purpose

Argonne National Laboratory seeks to identify and help solve large-scale, high-impact problems that address important scientific and societal needs of our country, which certainly includes improving transportation safety and efficiency. Similarly, IDOT and the Illinois Tollway are dedicated to the related

philosophies of “Driving Zero Fatalities to a Reality” and "Don't Be THAT Driver: Work on Safety. Get Home Safely. Every Day." emphasizing a primary focus on providing the safest transportation systems possible while simultaneously striving for high levels of mobility and efficiency. Additionally, Pace is committed to providing safe, efficient and reliable transit services to all residents of northeastern Illinois. A safe transportation system greatly reduces tragic human loss, as well as the economic costs of crashes. Illinois’ transportation system is among the safest in the world. With the projected increase in the demand for transportation in the future, identifying transformational methods and technologies across modes to keeping local, regional, and national transportation systems and citizens safe is a top priority for IDOT, the Illinois Tollway, Pace and Argonne National Laboratory. With these priorities in mind, and under the backdrop of increases in traffic related fatalities both regionally and nationally, the proposal team believes strongly that vehicle (and transportation infrastructure) automation and connectivity appear to be an enabler for dramatically increased safety, as well as offering novel means for improved transportation efficiency, congestion reduction, and mobility access.

The authors of this proposal agree with the USDOT that the safe deployment and testing of CAV technologies combined with sharing of data and best-practices is one of the most promising ways to accelerate the development of these transformation mobility technologies. Moreover, advancement of techniques such as machine learning and sensor fusion, as well as the continual progression of new sensor technologies that help vehicles and transportation systems gain a better view of their current state require the development and expansion of new safety assessment techniques and capabilities. For example, validation of a new physical sensor integrated within a large vehicle sensing and automation system will most likely require a range of assessment tasks spanning the domains of computer science (understanding and validating the mapping of sensor fusion “trust-regions” across the various sensors) to physical testing across a range environmental and situational scenarios. The ultimate vision for this pilot testbed facility is that of an aggregation of skills, capabilities and facilities to enable safe and consistent vehicle and technology evaluation from the concept to the large-scale demonstration phase.

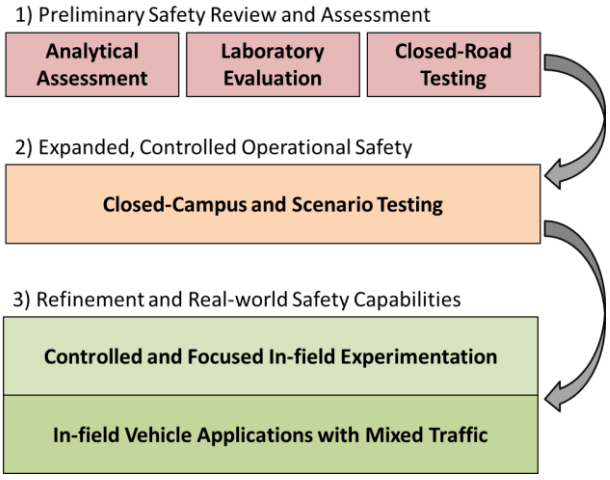

Figure 1: Proposed hierarchy of safety testing levels

To support the ability to successfully engage in a safe and effective CAV demonstration or research investigation regardless of development level or application, a hierarchy of safety testing tiers is proposed to both philosophically guide testbed operations, as well as identify the level at which a proposed vehicle or technology must be evaluated in terms of safety in order to progress to a larger-scale testing/demonstration activity. These basic tiers are parallel in spirit to the guidance and requested information provided by USDOT in the Safety Assessment Letter questions. At each level of testing, sufficient evidence must be provided to ensure that a vehicle or technology has meet the desired goals of safe, reliable, and robust operation. Additionally, these different tiers are themselves a significant research topic in terms of how to define, standardized (when possible), and incorporate best practices regarding safety assessment procedures while incorporating the technology range, rapid development pace, and cross-functional scope required to assess most CAV technologies and vehicle systems.

The combination of a closed campus and high-speed corridors is truly enabling for the rapid development of CAV technologies and safety evaluation procedures and best practices. While a closed campus is an excellent proving ground for many sensing and automation technologies, the high-speed and real-world/mixed traffic stream implications of these technologies is truly where significant development and research lies in terms of proving the fundamental safety and mobility benefits (and challenges) of any CAV technology.

Overview of Proposed Testbed

The proposed testbed seeks to combine three separate elements to form a testbed that can accommodate safety evaluation and research needs from initial prototype hardware to a full-scale demonstration at realistic speeds under real-world driving conditions. Specifically the testbed is seeking to focus on three major components:

1) A closed, low speed testing and research environment on the Argonne National Laboratory Campus able to accommodate the full spectrum of connected and automated vehicle and component technologies (i.e. sensor-to-full vehicle).

2) A connected, high-speed testing corridor comprised of the Illinois Tollway's I-90 SmartRoad which incorporates a variety of technologies to make the roadway safer and more efficient incorporating Active Traffic Management in late spring of 2017 and transit integration.

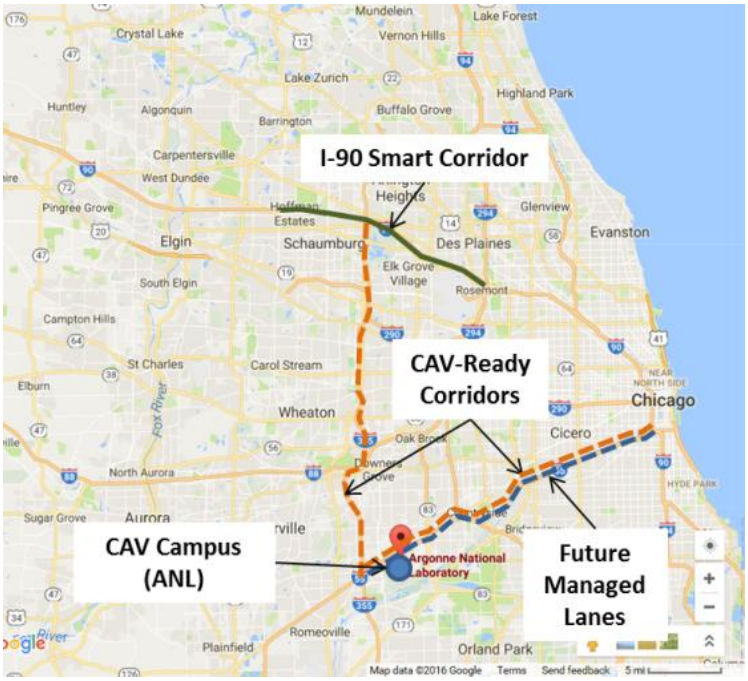

Figure 2: Overview of proposed Argonne-Illinois Multimodal Automated Freight and Mobility Testbed locations

3) A high-speed set of designated testing corridors using IDOT (I-55) and Tollway (I-355) controlled roads with limited but scalable connectivity leading toward a goal of gaining a better understanding of the added level of safety and mobility benefits that a connected approach may offer over just purely automation (in contrast to the fully connected environment in Component #2).

Argonne National Laboratory Campus Overview

Located roughly 25 miles outside of Chicago and near the intersection of several major Illinois highway corridors, Argonne National Laboratory is a closed-campus Government Owned Contractor Operated research facility spread across 1500 wooded acres. With a relatively dense inner-ring comprised of research buildings and parking surrounded by a less dense network of roadways, buildings, and parking a wide variety of on-site automation, connectivity, and mobility evaluations can take place. Additionally, a variety of road surfaces varying from pavement and asphalt to rock/dirt roads are available on-site if needed. Primary roadways on campus are two-lanes with a single lane for each direction of traffic flow. On campus speeds are limited to below 35mph across the entire campus with certain areas having lower speed limits due to specific traffic flow and traffic management features and Illinois. While technically a federally owned facility, all individuals operating vehicles on the Argonne site must obey all Illinois traffic

laws, as well as all posted road and parking signs and all additional requirements established by Argonne site policies per enforcement by the Argonne Protective Force.

The majority of Argonne's over 3,000 employees commute in their personal vehicle to work, entering though several guarded entry points handling site ID checks, visitor access, and shipping/receiving. This controlled-access offers a unique opportunity for semi-real-world evaluation on the campus while retaining some of the relevant controls and limitations relevant to early stage vehicle testing. Moreover, Argonne can temporarily close roads on-site to allow for an even more controlled testing environment. With its own Shipping and Receiving Facility, as well as semi-truck capable roadway access to most building on campus the Argonne campus can accommodate even the largest of roadway vehicles within the proposed automated vehicle pilot testbed.

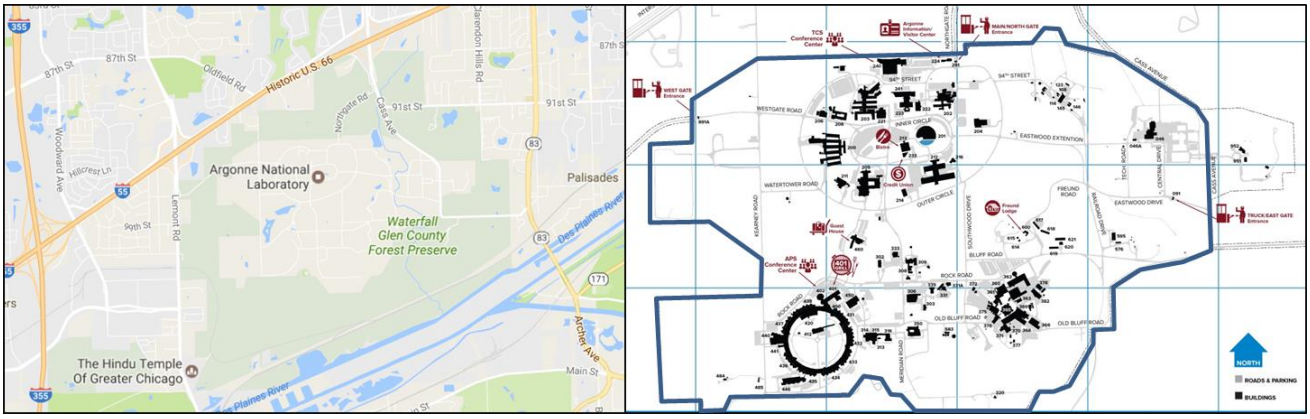

Figure 3: Overview of Argonne National Laboratory location (left) and campus map (right)

High-Speed CAV-Ready Corridors

As a supplement to the low speed, closed testing environment offered by Argonne's campus, several highway corridors are proposed to be included in this designated Automated Vehicle Testbed. These areas coincide with the "Refinement and Real-world Safety Capabilities" portion of the proposed testing hierarchy discussed in the Testbed Vision Section. Additionally, given the Chicago area's position as a major national freight hub these corridors seek to particularly emphasize research into the transformational impacts and safety implications associated with vehicle connectivity and automation in the medium/heavy duty and movement of freight sectors, while also allowing for the testbed to incorporate realistic light-duty on-highway investigations as well.

Illinois I-90 Tollway SmartRoad Corridor and I-355 Testbed

The Jane Addams Memorial Tollway (I-90) has been reconstructed to include flexible infrastructure to enable the Tollway to add new "smart" features as needed or as they become available in the years to come. Scheduled to go live in spring 2017, the new I-90 SmartRoad will be using the latest technologies to make the roadway safer and more efficient for Illinois Tollway customers. Some of the features being implemented on the corridor include the following:

- Power and communications along the entire 63 miles.
- Available cabinet space or equipment shelters and rack space every ½ mile.
- Increased density of sensors and cameras in the eastern 20 miles.

Figure 4: Overview of the I-90 Tollway SmartRoad

- Implementation of an active traffic management system on the eastern 12 miles although the eastern 20 miles are ATM ready with foundations already in place for gantries.
- Integrating transit with bus on shoulder service in the eastern 12 miles and separate transit lane.
- Delivering a 21st century corridor with flexibility for continue innovation.
- Pace Transit Signal Priority Systems at signalized intersections with ATC for I-90 access.

Leveraging the SmartRoad's wide-ranging connectivity and roadway informatics infrastructure automated vehicle testing taking place on this corridor would be capable of pushing the envelope of what is possible for a connect and automated roadway, while also identifying safety and mobility implications of these new automation and connectivity technologies.

In addition to the SmartRoad portion of I-90, this proposal also seeks identify I-355 as an additional testbed site for CAV testing and evaluation. This would help connect the SmartRoad testbed with both the Argonne Campus as well as the I-55 corridor portion of the pilot testbed, thus enabling a wide range of driving locations and scenarios to be easily accessed under a single management entity and team (i.e. this proposal team), while also still meeting the needs of each stakeholder independently.

Illinois I-55 Managed Lane Project and CAV-Ready Corridor

Illinois Department of Transportation ("IDOT") is currently developing the Interstate 55 ("I-55") Managed Lane Project (the "Project") extending from I-355 (Veterans Memorial Tollway) in the southwestern Chicago Metropolitan region (south terminus) to I-90/94 (Dan Ryan Expressway) serving the Chicago Business District (north terminus), a distance of approximately 25 miles.

Figure 5: I-55 Highway Corridor Overview

The Project includes constructing managed lanes within the existing I-55 median, with the existing three general purpose lanes in each direction remaining as free, non-tolled lanes. The new managed lanes would be configured as express toll lanes ("ETL"), available to all passenger vehicles in exchange for payment of a toll regardless of the number of passengers. Pace buses would be able to use the managed lanes without paying a toll. It is anticipated that the managed lanes would utilize congestion pricing strategies to manage congestion and travel speed in the ETL. IDOT's believes the project will (a) provide mobility enhancements and travel time reliability to the I-55 corridor and region, while minimizing adverse impacts on the adjacent communities; and (b) develop state infrastructure in a financially responsible manner that also ensures proper operations and maintenance.

While capabilities and evaluation possibilities afforded by the managed lane project will not likely be on-line for the initial Jan. 1, 2018 starting date (expected start of construction in 2018 with facility active in 2020), the I-55 corridor still represents an excellent testbed for CAV technology evaluation and development as a means to increase safety as well as reduce congestion and help better manage traffic flow. Specifically, the 25-mile corridor accommodates roughly 170,000 vehicles per day but frequently experiences severe congestion for extended periods of time on a daily basis and is unable to accommodate the existing traffic demands (regional, daily commuter and local) due to limited roadway capacity, roadway design constraints at some locations, high truck volumes and numerous interchanges. This has resulted in increasingly long and unreliable travel times, decreased safety and increased costs for delivery of goods and services. It is anticipated that vehicle automation could aid in effectively

managing and improving the performance of this corridor and thus makes it a perfect candidate for a CAV-Ready corridor component of the larger testbed environment.

Furthermore, during the construction phase of the managed lane project, the I-55 corridor affords a unique opportunity to investigate issues related to automated vehicles operating within a work-zone environment, a challenging but critical operational requirement for widespread CAV market penetration.

Figure 6: Understanding CAV safety and operation implications within a work zone environment (http://blueline2crc.com/current-construction-february-2013/)

Additional Testbed Facilities and Capabilities

As discussed in the introduction, Argonne-IDOT-Tollway group brings a wide-ranging set of capabilities to the CAV research and evaluation space. In addition to providing a testbed location for on-road testing of CAV technologies, several additional capabilities contained within the proposed testbed are highlighted regarding their relevance to evaluating the safety and mobility aspects of CAVs.

Pace I-90 SmartRoad Expanded Operation Capabilities

Pace plans to deploy Automated Buses, CV Mobility Suite: Integrated Dynamic Transit Operations (IDTO) as part of I-90 Transit Corridor along with CV MMITS- TSP application at nine signalized intersections for buses to access to I-90 Corridor. As part of this effort pace is planning to deploy DSRC radios on portion of our fleet. Pace plans to support the test bed by providing its Fleet, OBE, RSE, other ITS infrastructure and potentially Automated Transit Vehicles within the proposed I-90 and I-55 corridors. This will supplement the extensive ITS systems already in place. Pace successfully implemented following ITS systems and infrastructure:

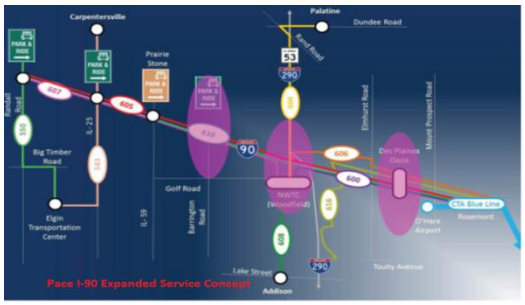

Figure7: Pace I-90 Expanded Service Concept

- Trapeze Transit Master Intelligent Vehicle Logic Unit on all buses
- Bus Depot WLAN for AVL System Data Transfer
- CAD/AVL Upgrade/Voice/Data Radio Network
- Starcom21 Radio System
- Pace Data-Only Network on 800 MHz Network
- Apollo Video Surveillance System
- Pace Wi-Fi on Buses Systems
- Transit Operations Decision Support Systems (TODSS)
- Transit Signal Priority Systems (5GHZ, V2I, V2C, I2C to be deployed at 300 signals)
- Transit Priority Timings and Signal Timing Optimization for 400 signalized intersections.

Argonne's Advanced Powertrain Research Facility – Laboratory Based CAV Testing

Since the late nineties, Argonne Advanced Powertrain Research Facility (APRF) has sought to understand and help the next generation of advanced vehicle technologies. The APRF is purpose built for automotive research and technology benchmarking. Over the last two decades, the APRF stayed in lock step with the state of the art automotive research and developments such as hydrogen powered vehicles, plug-in hybrid vehicles and modern battery electric vehicles. Furthermore, the APRF staff has provided significant leadership in the development of automotive testing standards through expertise and independent data. The APRF is recognizes that Connected and Autonomous Vehicles are the next automotive revolution and started to shift its research towards that area.

The APRF has two chassis dynamometer test cells including a thermal chamber which can replicate temperatures ranging from 0F to 95F along with solar load emulation. The APRF is in the process of upgrading a test cell to emulate some sensors inputs to CAVs (GPS, radar signal, V2I, V2V, etc.) in order test these new vehicles in the controlled test cell environment and a simulated driving environment. Furthermore, a plethora of equipment (i.e., portable emissions measurement systems, data acquisition systems, sensors, etc.) along with the expertise are available for on-road testing. Three vehicle instrumentation areas located in high-bays (capable of fitting large vehicles) with vehicle lifts enable vehicle instrumentation, adjustment, repair, and modification. Finally, it should be noted that the APRF is laid out with collaborative research in mind by including individual work spaces (with phone and high speed internet access) for visitors as well as a modern conference room right next to the instrumentation areas and the test cells. As with any vehicle-based research project, access to a capable workspace enables much greater work efficiency and is a positive inclusion for the overall testbed proposal, enabling faster iterations and repairs versus having to move to an offsite facility.

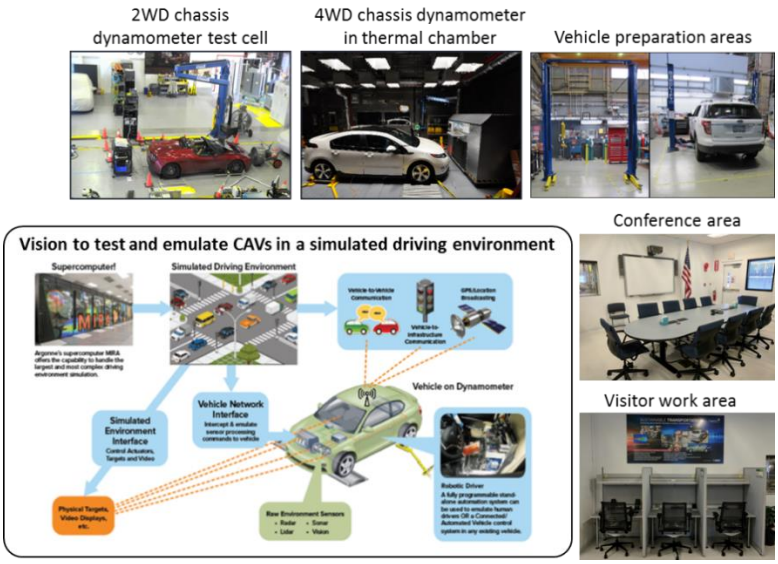

Figure 8: Advanced Powertrain Research Facility Overview

Vehicle and Transportation-System Energy Modeling

Researchers from Argonne's CTR have extensive experience in all aspects of travel demand modeling and transportation systems simulation. Over the past many years, the group has developed a set of advanced, high performance modeling tools, known as POLARIS and Autonomie, which combine these various research threads into a comprehensive system for transportation and energy use analysis enabling holistic system modelling. A core component of the POLARIS Model is the dynamic agent-based travel demand simulation, which simulates how individuals plan and schedule activity and travel. The model was designed to capture underlying fundamental processes driving activity and travel engagement in order to increase model transferability and forecasting power, and is the first model of its kind to simulate activity planning behavior. It has since been enhanced for increased computational efficiency, and has been used to synthesize populations for the cities of Chicago, Detroit and Ann Arbor

as well as the State of Illinois. In fact, CTR recently worked with the Detroit Department of Transportation (DDOT) and the Southeast Michigan Council of Governments (SEMCOG) to complete an analysis of energy benefits of "Smart Mobility" in Detroit using POLARIS and Autonomie.

Cybersecurity for Vehicles and Transportation Systems

The Cybersecurity Operations, Analysis, and Research (COAR) team within the Global Security Sciences (GSS) Division of Argonne National Laboratory is a diverse team that provides operational support for FISMA High, High, High systems, analysis products on emerging technologies, and research on innovative applications of cybersecurity. The COAR group mainly deals with sectors that lie within critical infrastructure such as energy, telecom, and emergency services. Due to the physical proximity of the COAR team to other complementary teams within GSS, collaboration between analysis and research efforts on critical infrastructure is facilitated. The COAR group's familiarity with vehicle scanning tools and cybersecurity testing frameworks provide a solid basis for research within the emerging field of vehicle security. COAR researchers have produced desirable results that confirm previous research in aspects of physical vehicle insecurity, specifically in Control Area Network (CAN) exploits and manipulation. Moreover, the research team is currently working on a myriad of facets that could provide significant contribution to the accessibility of vehicle security tools including a probabilistic model of ECU labeling by utilizing supervised machine learning. Some of COAR's recent work on vehicle cybersecurity has been published in the Center for Infrastructure Protection Report produced by George Mason University. COAR's work on vehicle security has also been presented at the Military Operations Research Symposium, NSA symposium.

Key Points of Contact

Designated Safety Officer

To meet USDOT's goal of a single safety point of contact David Shimcoski, Laboratory Manager of Argonne's Advanced Powertrain Research Facility (APRF) is selected at the Designated Safety Officer (DSO) for this testbed effort to facilitate the sharing of information and coordination between the safety agencies of Argonne, IDOT, Pace and the Illinois Tollway. Dave Shimcoski is a safety leader in Argonne's Center for Transportation Research, having started his career in automotive research in the 80ies. Though daily interactions with staff, teaching safety best-practices both internally and externally, and developing and enforcing safety procedures, he sets the tone for the safety culture at Argonne's Advanced Powertrain Research Facility (APRF). In 2011, the APRF team was awarded the Laboratory Director's Award for Team Safety which is Argonne's highest possible distinction. Over the years Dave has served in many different safety roles throughout the laboratory thanks to his reputation for hands-on safety expertise, attentional to detail, and follow through. In addition, Dave has led many facility upgrades and infrastructure development projects. The successful $5 million APRF thermal chamber upgrade to the test facility is the most prominent example for which he supervised the daily worksite and developed new operational and safety procedures.

Testbed Point-of-Contact

In addition to the DSO for the testbed site, a single POC has also been selected to help coordinate testing activities and support the needs of the testbed operations and the DSO. To these ends, Eric Rask, Principal Research Engineer at Argonne National Laboratory is suggested as the POC for the proposed pilot testbed. With a current focus on battery system-level safety research and vehicle technology assessment, Mr. Rask's work generally revolves around systems engineering, technology assessment, and development for advance vehicle components and technologies including electric machines, batteries (and their related components), engines, and transmissions. More recently, his work has expanded into assessing the energy consumption, usage, and mobility implications of connected and

automated vehicle technologies as well as the implications of expanded vehicle sensing and location awareness. In addition to his research work, Mr. Rask also leads the Connected and Automated Vehicle portion of DOE's SMART Mobility Multi-lab Consortium. Mr. Rask will coordinate directly with IDOT, the Illinois Tollway, and Pace.

A Shared History and Culture of Safety Excellence and Outreach

The combined proposal team brings to bear a diverse and expansive set of safety expertise to the development and operation of the proposed automated vehicle test pilot. The mix of practical and theoretical safety expertise spread across Argonne, IDOT, Pace and the Illinois Tollway alongside a strong commitment to push the state-of-the art through outreach, accelerated development of best-practices, and open and accessible data sharing related to CAVs is one of the strongest aspects of the proposed testbed facility.

Argonne National Laboratory - As a leading U.S. Department of Energy multi-program research laboratory, Argonne's our obligation to the American people demands that we conduct our research and operations safely and responsibly. As a recognized leader in safety, we are committed to making ethical decisions that provide a safe and healthful workplace and a positive presence within the larger Chicagoland community. Argonne's Integrated Safety Management (ISM) program is the foundation of the laboratory's ongoing effort to provide a safe and productive environment for employees, users, other site personnel, visitors and the public. This safety leadership and safety management program would be the foundation of any Automated Vehicle Testbed on-site or affiliated with Argonne. Furthermore, given a research scope that encompasses nuclear engineering to nano-materials and beyond, Argonne's safety experts and programs are well versed in the challenges and requirements related to developing safety management plans for dynamic and emerging research areas.

Illinois Department of Transportation - IDOT has a long history of providing safe roads for the traveling public and construction workers alike. Traffic safety is an integral part of all aspects of IDOT's operation. The recent increase in traffic fatalities has highlighted the need for the advancement and early deployment of CAV. IDOT believes that the work accomplished in the designated test facilities, and consequently the early introduction of CAV in car production, will greatly reduce crashes and fatalities, as NHTSA has presciently indicated. To achieve targeted safety on roadways, IDOT, in collaboration with other entities, will develop a Strategic Highway Safety Plan and implement a Highway Safety Improvement Program. Similar to the roadway safety for CAV, the stakeholders buy-in and a shared vision on safety will be the guiding principles.

Illinois Tollway - As stated previously, the Illinois Tollway's mission statement leads off with "Safety." The Illinois Tollway has aggressively pursued integrated incident management over the years. This includes the following:

- One of the nation's first integrations between Computer Aided Dispatch and a traffic management center
- The implementation of a dedicated highway service patrol
- Annual training of all maintenance personnel in incident management and empowering all field staff to leave maintenance activities and respond to proximate incidents
- Supporting a monthly interdisciplinary committee that reviews all operational issues including crashes and other incidents
- Installing over 50 Dynamic Message Signs around the system to keep travelers informed

In order to provide the best service, the Tollway also provides annual training to all 59 fire protection districts that respond to crashes on the Tollway system. The Tollway supports two safety focused activities each month. The safety subcommittee includes staff from Illinois State Police District 15 (responsible for patrolling the Illinois Tollway), traffic engineering staff, and legal staff to review monthly crash statistics and discuss operational concerns. The Traffic Operations Safety Committee (TOSC) also includes staff from toll services, risk management, and other departments within the Tollway. The TOSC is chaired by the Tollway's General Manager of Maintenance and Traffic, Wayde Tabor. Mr. Tabor will serve as the safety contact for the Tollway in all matters related to CAV.

Pace Suburban Bus Service - Pace's innovative approach to public transportation gives the agency a national reputation as an industry leader. Pace has worked with Intelligent Transportation Systems (ITS) in our fleet of vehicles and on-street infrastructure for over past 25 years. Pace staff continues to participate and coordinate with the Argonne Labs, IL Tollway and IDOT teams and other regional agencies on several ITS projects. Mr. Taqhi Mohammed, Supervisor – ITS and Transportation Engineering, will serve as contact for Pace in all matters related to CAV. Pace continues to look for new ways to improve the services we provide to the public in northeastern Illinois.

Adherence to Laws, Regulations, and Federal Policy

Given that both IDOT and the Illinois Tollway are directly included in this testbed proposal, it is hopefully obvious that state and local laws will be followed for this proposed testbed. Additionally, IDOT and the Tollway are extremely familiar and well versed in working with local and federal regulations, thus providing strong leadership in this area for the proposed testbed.

As discussed in the Testbed Vision Section, the proposed hierarchy of testing also helps facilitate compliance with the newly developed USDOT guidance related to CAV technologies. Specifically, each tier of testing seeks answer (and support with data and testing) the questions raised in USDOT's Safety Assessment Letter before moving to the next tier of testing, at which the same set of questions will be revisited before ultimately moving to the next tied of testing possibilities.

Supporting a Safe Mobility Future

Proposed Contributions

As discussed earlier in this proposal, all four members of the proposal team have longstanding commitments to providing public data, best practices, and supporting the large community of researchers and stakeholders interfacing with the challenges related to vehicle connectivity and automation. For example, Argonne researchers and engineers have lead a large range of test procedure and standards document working groups for a variety of organizations (IEEE, ISO, SAE, etc.). Along with IDOT, Pace and the Illinois Tollway, Argonne anticipates again providing leadership in the emerging research area of vehicle connectivity by not only contributing to development and evaluation efforts, but also strongly supporting the unbiased exchange of information, safety practices, and data to help accelerate the state-of-the-art and acceptance of the transformative transportation technologies. In addition to the USDOT desired contributions to meetings, joint research efforts, and submission of significant activity reports, the proposal team suggests holding at least one yearly working group meeting/conference to discuss results and analysis across the network of pilot laboratories and including wide range of industry, government, and academic stakeholders. Argonne's campus is particularly well suited to this since there are a variety of auditoriums and conference spaces availed. In fact, a NHTSA/Argonne/SAE sponsored working group meeting to discuss Battery Stranded Energy and

Safety used the Argonne facilities to help host a very successful gathering of experts in a single location over the course of two days.

Research, Application and Data Sharing

For the past 20 years, Argonne National Laboratory's Center for Transportation research has led efforts to advance future mobility solutions through research into advanced vehicle technologies. These efforts have been directed at an array of technologies from alternative fuels (gaseous and biofuels) to electrification (hybrid to full EVs), with results and analysis distributed through multiple means including development of industry critical codes and standards, academic publications, direct distribution of data, and the development of tools for modeling and simulation- many of which are used throughout the international automotive community. The proposed testbed will offer facilities for automated vehicle testing with a range of safety considerations from a closed, controlled environment with a vehicle stationary on a chassis dynamometer to restricted on-road testing on campus at ANL, to populated public roadways in the Chicagoland area under direction from the Illinois DOT and Illinois Tollway.

Insight gained from autonomous vehicle operation in this wide variety of conditions will be shared with the greater research community to the greatest extent possible. To execute the distribution of this data, and in addition to regular updates across the newly formed network of pilot testbed facilities, the project team anticipates frequently distributed data through research publications, chairing of committees of internationally recognized codes and standards development working group, directing public discussion through activities such as the Clean Cities Coalition, administering Advanced Vehicle Technology Competitions such as Ecocar, and openly distributing of testing data and analysis results through sites such as the APRF's database or dynamometer testing data (www.anl.gov/d3). Additionally, the Illinois Tollway and IDOT currently share a wide range of data through the LMIGA Gateway system and these contributions are only expected to grow with the data generated from the prosed testbed.

Demonstrated Investments

Through past research efforts, Argonne has led many relevant research projects relating to automated vehicles. These efforts will continue to advance, and would be greatly benefited from the real world testing data of vehicle and transportation systems operation generated from this testbed. This real world evaluation requires an environment in which a safe, quantifiable, and repeatable testing may be conducted. The testing system must capture all components of the operational system, including not only sub components, but the software for interfacing of the different components of the system.

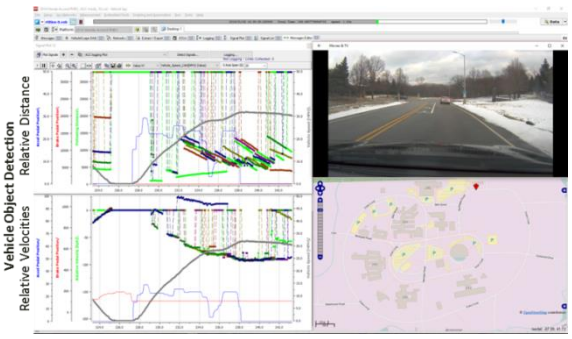

Figure 9: On-campus data collection and basic automated vehicle operation (modified Adaptive Cruise Control)

Over the past several years, the APRF at ANL has leveraged an existing fleet of research vehicles to advance an understanding of driver assistance systems enabling varying levels of vehicle automation, such as camera and radar based adaptive cruise control, and lane detection technologies with manufacturers varying from Mobileye to Fujitsu. These research vehicles have been further instrumented and equipped with additional data logging systems, and their operation captured both on road and on dyno in order to assist in the advancement of testing methods for automated vehicle technologies. An example of vehicle data captured from a radar based system, overlaid with time aligned video and vehicle location on one of these research vehicle while operating on the closed road systems at ANL can be seen in the

corresponding figure. Additional investments have been made within the laboratory in the form of Savari DSRC V2V in-vehicle radio sets and multiple V2I DSRC road-side units, with both the vehicle and infrastructure systems made portable to enable use on campus, on dynamometer, or in the field on-corridor.

In terms of roadway investments within the proposed corridors, the Illinois Tollway has already significantly invested in the I-90 smart corridor with items such as power, fiber, cabinets, a CV pilot study, and ATM. Once active, the I-55 managed lanes will also provide a significant amount of additional functionality and use cases to be evaluated within the context of the proposed testbed.

Readiness

While efforts are currently on-going to finalize more generalize safety management plans (versus the current vehicle-by-vehicle basis) regarding testing a wide range of CAV technologies , the project team feels extremely confident that the Argonne Campus, I-90 SmartRoad, and CAV-Ready Corridors will be open and ready for testing by the desired start date of January 1st, 2018. A vehicle with a limited set of automation capabilities has already be used on Argonne's campus in addition to other vehicle DSRC communications experiments and the I-90 SmartRoad has already performed a Connected Vehicle pilot study. Through their on-going development projects, both IDOT and the Illinois Tollway have and continue to engage the impacted communities along the various project corridors and these relationships are expected to grow and expand as the area begins to see more and more automated vehicle testing and evaluation. Additionally, given Argonne, IDOT, Pace and the Tollway's commitment to public outreach and widely available resources and data, the USDOT should not have any concerns that this testbed would become restricted to a subset of select users or that only very limited data would be publicly released. Moreover, Argonne frequently works with private companies and is quite familiar with the balancing act between accessing emerging technologies and providing publicly useful data in collaboration with industry.

Conclusions

Argonne, IDOT, Pace and the Illinois Tollway feel strongly that vehicle connectivity and automation offer transformative possibilities for the future of transportation safety and efficiency. Given the benefits afforded by these technologies and the team's various missions, we feel that the proposed Argonne-Illinois Automated Freight and Mobility Testbed offers a unique set of capabilities enabling CAV technologies to be evaluated at a scope ranging from individual sensors to full vehicle demonstrations. The data, safety best practices, and knowledge developed over the course of creating, managing, using and improving the testbed is expected greatly accelerate the development and adoption of CAV technologies. Given Illinois's location as a nexus point for the national transportation network, it only seems fitting that the state plays a key role accelerating the development of these innovative technologies.

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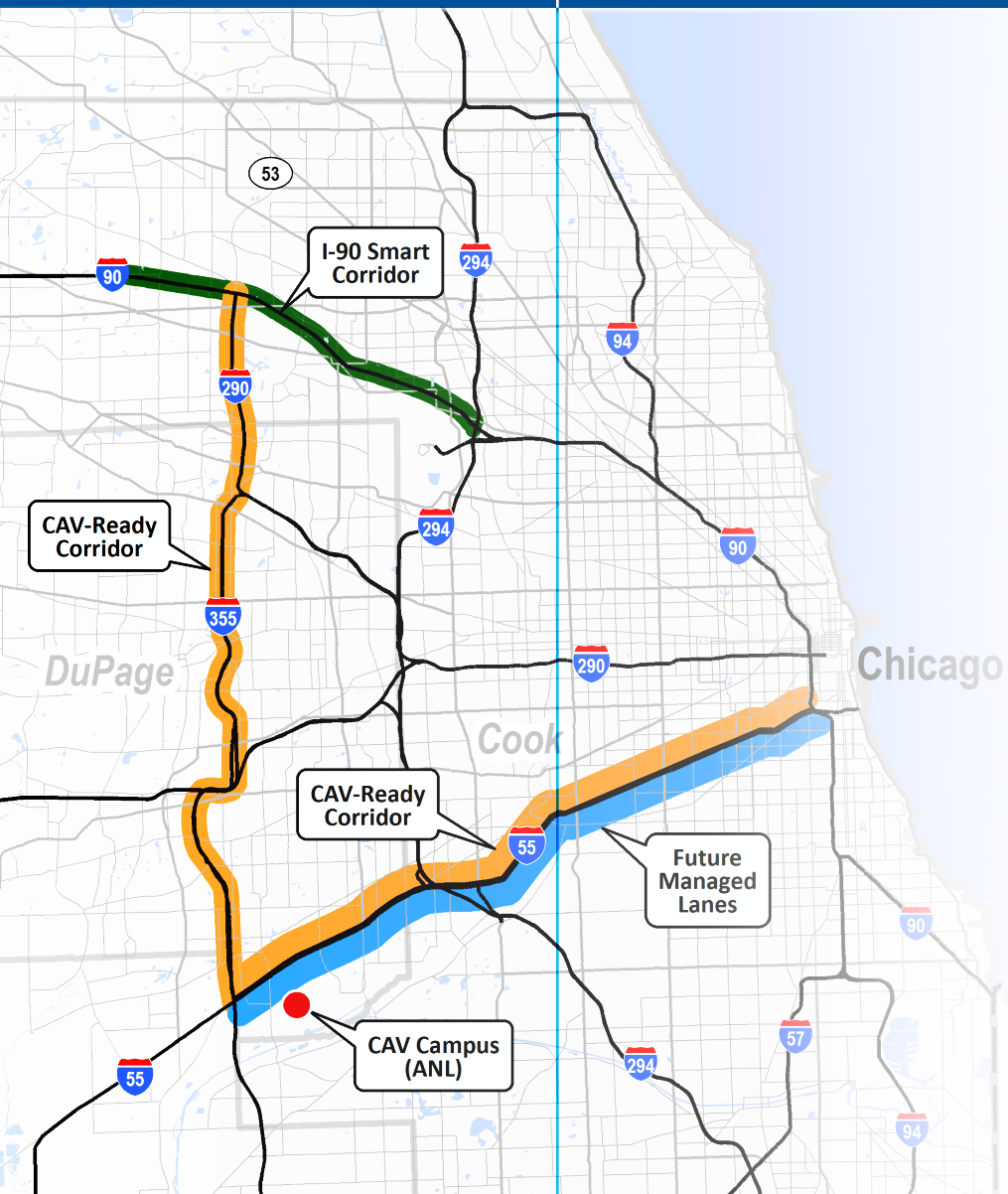
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