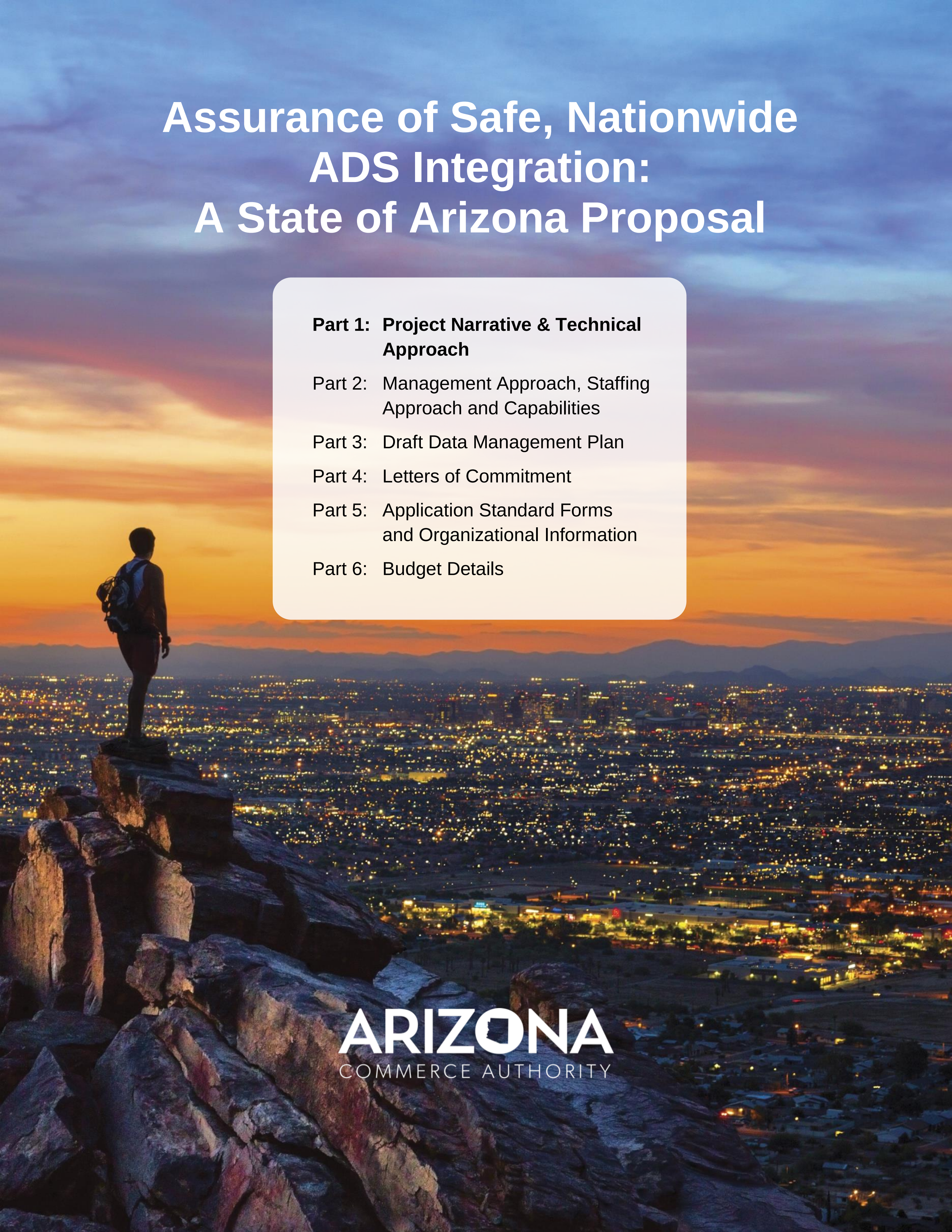

Assurance of Safe, Nationwide ADS Integration: A State of Arizona Proposal

Part 1: Project Narrative & Technical Approach

Part 2: Management Approach, Staffing Approach and Capabilities

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ARIZONA
COMMERCE AUTHORITY

Summary Table

Project Name/Title	Assurance of Safe Nationwide ADS Integration: A State of Arizona Proposal
Eligible Entity Applying to Receive Federal Funding (Prime Applicant's Legal Name and Address)	Arizona Commerce Authority 100 N. 7th Avenue, Ste. 400 Phoenix, AZ 85007
Point of Contact (Name/Title, Email, Phone Number)	Sandra Watson, President/Chief Executive Officer, sandraw@azcommerce.com, 602.845.1215
Proposed Location (State(s) and Municipalities) for the Demonstration	Arizona (Chandler, Tempe, Phoenix, Gilbert, Mesa, Scottsdale, Litchfield Park)
Proposed Technologies for the Demonstration (Briefly List)	ADS Safety Assurance Methodology (SAM); Scenario Safety Performance Assessment (SSPA) Tool; Initial Readiness Assessment (IRA) Tool; Continuous Safety Monitoring (CSM) Tool.
Proposed Duration of the Demonstration (period of performance)	3 years
Federal Funding Amount Requested	$10,000,000
Non-Federal Cost Share Amount Proposed, if applicable	$3,659,618
Total Project Cost (Federal Share + Non-Federal Cost Share, if applicable)	$13,659,618

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1 Project Narrative and Technical Approach

1.1 Executive Summary

1.1.1 Vision, Goals, Objectives

The State of Arizona's Institute of Automated Mobility (IAM), overseen by the Arizona Commerce Authority (ACA), applauds the USDOT for articulating its pragmatic strategy for the embrace of Automated Driving Systems (ADS)[1,2,3]. ADS promise a future in which dangerous human behavior is replaced by safe, steady, and consistent automated driving behavior. It is critical that the USDOT's strategy be broadly adopted to allow ADS to be developed and deployed quickly and safely across the nation. The goals of our proposal team are to develop and demonstrate the implementation of a Safety Assurance Methodology (SAM) to facilitate:

- Road testing across all 50 states to speed up ADS development;
- Assessment and maturation of safe ADS performance and behavior to promote higher confidence in ADS technology, paving the way for broad public adoption.

As highlighted in Figure 1.1, We will achieve these goals with respect to:

- **Safety:** By developing and demonstrating: a) A tool for assessing the readiness of Level 3 (and above) ADS for on-road testing with usage demonstrated on prototype ADS and b) An ADS on-road monitoring tool with usage demonstrated by up to 24 months of public/private road deployments.
- **Data for Safety and Rulemaking:** By collecting and sharing: a) Readiness assessment and on-road monitoring data and b) ADS performance and behavior evaluations.
- **Collaboration:** 1. By forging our team of State and commercial stakeholders, Arizona State University and ADS developers and 2. Implement an outreach program to educate the public and help less experienced states and municipalities embrace ADS testing.

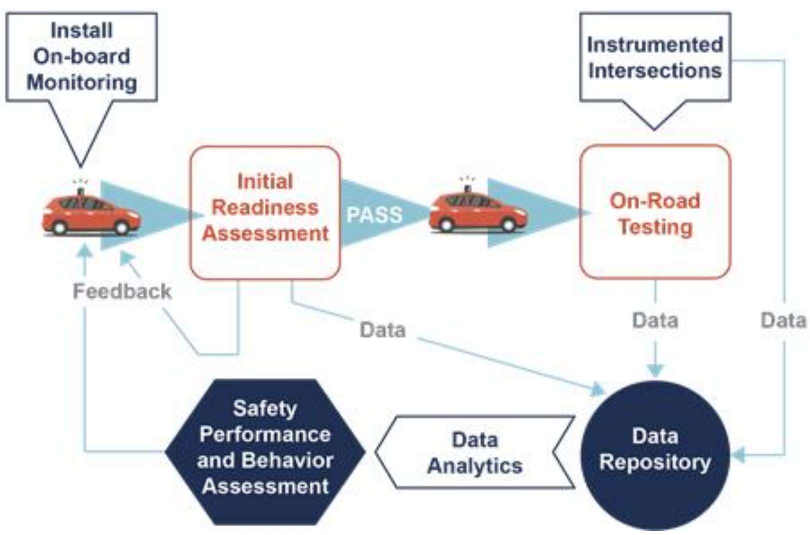

Figure 1.1: Each candidate ADS is subjected to a safety assessment process. The data collected during its testing is processed to calculate a safety performance and behavior assessment which is fed back to the developer.

The adoption of ADS will occur over many decades as consumers gain confidence in SAE Level 3-5 technology and select it to replace their aging human-centric automobiles. The USDOT promotes the following conceptual Framework[2] for the management of risk during this adoption process in Figure 1.2.

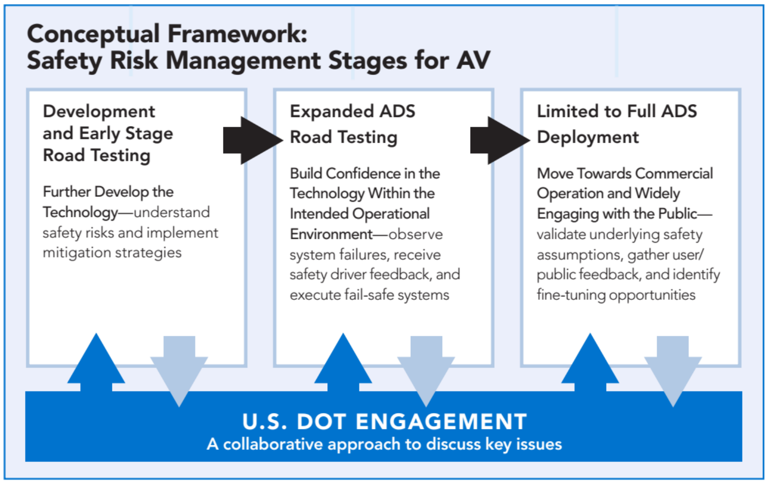

Figure 1.2: Conceptual Framework for the management of safety risk associated with the adoption of ADS technology on the nation's road infrastructure[2]

The State of Arizona is proud to have been at the forefront of **early stage road testing** with more than 600 ADS platforms operating on our roads as of March 2018. We have launched the IAM to focus our efforts on ADS safety as the nation transitions to **expanded ADS road testing**. Our leadership to date has afforded us unique experience and insights into ADS safety which we will build upon in the IAM, allowing us to accelerate the advancement of ADS Safety as our primary contribution to the nation's ADS adoption efforts. Arizona is a proven partner with the USDOT having served as a showcase for innovative transportation technology demonstration programs for more than 20 years. The AZTech partnership, one of the Metropolitan Model Deployment Initiatives selected in 1996, is an active operations partnership 22 years later, and continues to advance institutional collaboration for better system operations and public-private partnerships and to implement advanced technologies to solve real-world transportation and safety problems. Arizona has also been selected to demonstrate public safety communications interoperability to advance key goals in traffic management communications and has showcased advanced signal operations as part of a unique SmartDrive connected vehicle test bed. These experiences will be leveraged to create a successful ADS partnership and demonstration program.

ADS will have to co-exist with human-operated platforms for many decades to come. It is reasonable to expect that adoption of ADSs will be slow at first and will then accelerate as more and more owners replace their aging vehicles with ADS-equipped vehicles. Human-operated vehicles will dominate for the foreseeable future, requiring that the nation's transportation safety focus continues to be on them. As a result, ADS will instead have to adapt to the current human-centric infrastructure; they will have to master the skills and good behaviors of human drivers and blend in with these drivers so that both can safely co-exist. As time passes and the ratio of ADS to human-driven vehicles shifts in favor of ADS-equipped vehicles, then an everincreasing portion of the infrastructure budget can be applied to ADS-oriented refinements to maximize the safety benefit they provide.

One of the key tenets of the USDOT's ADS Strategy is The Voluntary Safety Self-Assessment (VSSA) approach[2] which has effectively enabled ADS developers to advance their technology efficiently. This policy allows developers to continuously improve their technology in a feedback loop which works effectively while there are few ADS operational at any given time, but as the numbers and density of ADS increase during **expanded ADS road testing**, data will need to be gathered and shared to assess ADS impact from a systems perspective. We will need to determine if their collective behavior meshes harmlessly with human-driven vehicles or if it is disruptive, causing safety challenges and/or unintended consequences.

It is critical that the VSSA be supported throughout **expanded ADS road testing** to continue to drive the pace of ADS maturation; however, it is important to note that the VSSA approach does not naturally lend itself to providing feedback to stakeholders on the behavior of AVs and how they interact with each other and human-driven cars, bikes, bicycles, scooters, pedestrians, etc., especially when it comes to the group behavior of multiple ADS, likely from different developers, operating in the same general vicinity. Further, the USDOT and ADS developers have not converged on consistent evidentiary documentation or demonstrations to support a safety evaluation of a prototype ADS intended for deployment on public (or even private) roads, nor how to ensure prototype ADS remain safe to be on the road as they evolve during development.

The pace at which the nation embraces **expanded ADS road testing** will determine the speed at which ADS technology is matured. It is critical that road testing be adopted broadly across all states so that the unique challenges that exist in individual states can all be addressed and ADS can be trusted in all corners of the nation. The IAM will use the road testing experience that has been gained in Arizona to develop and demonstrate an implementation of a Safety Assurance Methodology (SAM) to enable broader in-state testing and to help less experienced states confidently launch their own equivalent road testing programs.

The IAM will develop the following three tools to demonstrate the SAM implementation:

- Scenario Safety Performance Assessment (SSPA) Tool
- Initial Readiness Assessment (IRA) Tool
- Continuous Safety Monitoring (CSM) Tool

The SSPA Tool takes in the definition of a scenario and data collected during the execution of this scenario by an ADS and outputs a safety performance grade. The IRA Tool is an ADS test environment and procedure used to assess the readiness of an ADS for on-road testing. The CSM Tool is a data collection suite used to monitor ADS safety performance and behavior and generate the feedback required by the stakeholder community during **extended ADS road testing**.

Our proposed SAM, depicted in Figure 1.3, will provide the USDOT with a due diligence methodology that augments the VSSA to help ensure that ADS meet minimum safety performance standards. Our SAM will provide regulatory agencies with validated methods to conduct due diligence monitoring of ADS prior to and during road testing within their jurisdictions. This will help establish public confidence in the road testing of ADS, and provide these regulatory agencies with feedback on the safety performance and behavior of prototype ADS within their jurisdictions, including data on traffic impacts and near-miss incidents.

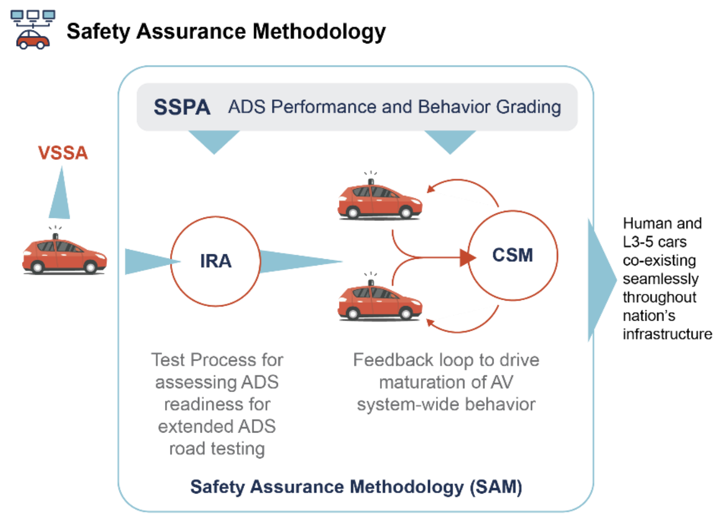

Figure 1.3: The SAM enables broadly supported, efficient **Extended ADS Road Testing** that will mature ADS behavior so that ADS seamlessly integrate with human-driven vehicles

1.1.2 Key Partners, Stakeholders, Team Members, and Others

Our team consists of the following diverse team of ADS stakeholders who are collaborating to implement or program goals. Our intent is to demonstrate an implementation of the SAM that other states and municipalities can readily reproduce. Our team is as follows:

Safety Assurance Methodology Lead: Exponent	**Team:** Lockheed Martin, State Farm
Scenario Safety Performance Assessment	ASU
Demonstrations Lead: Exponent	**IRA Team:** ASU, Lockheed Martin Maricopa County Department of Transportation (MCDOT), Arizona Department of Transportation (ADOT) **CSM Team:** ASU, State Farm, Sun Health, General Dynamics, Verizon, Cities of: Phoenix, Scottsdale, Mesa, Tempe, Gilbert, and Chandler
ADS Developers	Intel/Mobileye, Local Motors, Others (TBD)
Data Management Lead: ASU (CASCADE)	**Team:** Verizon, Amazon Web Services (AWS), General Dynamics, State Farm, Exponent

Our Outreach and Education Team will actively disseminate and interface with the public and the broad spectrum of national ADS stakeholders, including standards bodies such as SAE, to maximize the impact of our program.

1.1.3 Issues and Challenges to Be Addressed

For ADS development to proceed at maximum speed, **expanded ADS road testing** needs to be embraced broadly across our nation's infrastructure. Arizona, given the state's experience with early ADS road testing, can help other states gain confidence in ADS technology and deploy it in their unique infrastructures and environments, providing ADS developers and stakeholders with the comprehensive feedback required to mature ADS for safe, nationwide adoption. We propose to achieve this end by defining, implementing and demonstrating our Safety Assurance Methodology (SAM) and using it to validate the safety of ADS for expanded road testing and to provide the full ADS stakeholder community with the feedback required to drive the maturation of ADS system-wide behavior. The SAM will be implemented using our Scenario Safety Performance Assessment (SSPA), Initial Readiness Assessment (IRA), and Continuous Safety Monitoring (CSM) Tools.

Our SSPA Tool will take in a scenario definition and data collected during an ADS execution of said scenario and outputs an ADS safety performance and behavior measure.

Our IRA Tool is a flexible test environment and procedure that is tailored to the particular safety assessment defined in an ADS's VSSA, to assess the readiness of these ADS for **expanded ADS road testing.**

Our CSM Tool will enable the monitoring of ADS on-road performance using on-board and off-board sensing. It will provide ADS developers with feedback on their vehicle's individual and system-wide behavior so that, in combination with their VSSA safety efforts, they can refine their ADS-equipped vehicles. This refinement can continue until such time that they become seamlessly integrated with human drivers, while addressing human driver deficiencies.

Collectively our tools, combined to implement our Safety Assurance Methodology (SAM), will provide confidence to infrastructure stakeholders that ADS candidates exceed a minimum safety performance capability before beginning operation on public (or even private) roads and maintain an acceptable level of behavioral competency and safety performance when deployed. Further, our data will be of high value to the full range of ADS stakeholders, providing them with the information required to make informed decisions about how they can best contribute to the maturation of ADS in coordination with the ADS development community.

Other challenges our development will address is that ADS developers see data captured during ADS testing as proprietary and do not want to compromise competitive advantages by sharing ADS details such as perception/classification/path-planning/actuation data. Our design team will determine what level of data needs to be collected, on observable measures of safety only and not general system performance, to effectively implement our SAM and how it can be collected without impinging on developer IP.

The IAM will actively promote the SAM as an example of how to mitigate the significant legal risk to the deployment of ADS. Our ASU Technical Law Group, which will be directly involved in the specification of the SAM, believes that the legal risk is reduced by having ADS developers all work together to drive toward a common set of safety specifications/standards, endorsed by a trusted independent organization such as the Society of Automotive Engineers (SAE). The SAM will constitute an example of such a due diligence process, developed through collaboration across our proposal's microcosm of ADS stakeholders and developers.

1.1.4 Geographic Area

The performance of the proposed project will take place in the region shown in Figure 1.4 A major advantage of the Arizona bid is that there are no restrictions on public road testing in the state after an initial consultation with the Governor's office and ADOT. The municipal testing regions (red stars) of Tempe, Chandler, Phoenix, Scottsdale, Mesa and Gilbert, Litchfield Park (Sun Health facility, green) and Exponent Test and Engineering Center (blue) are shown below.

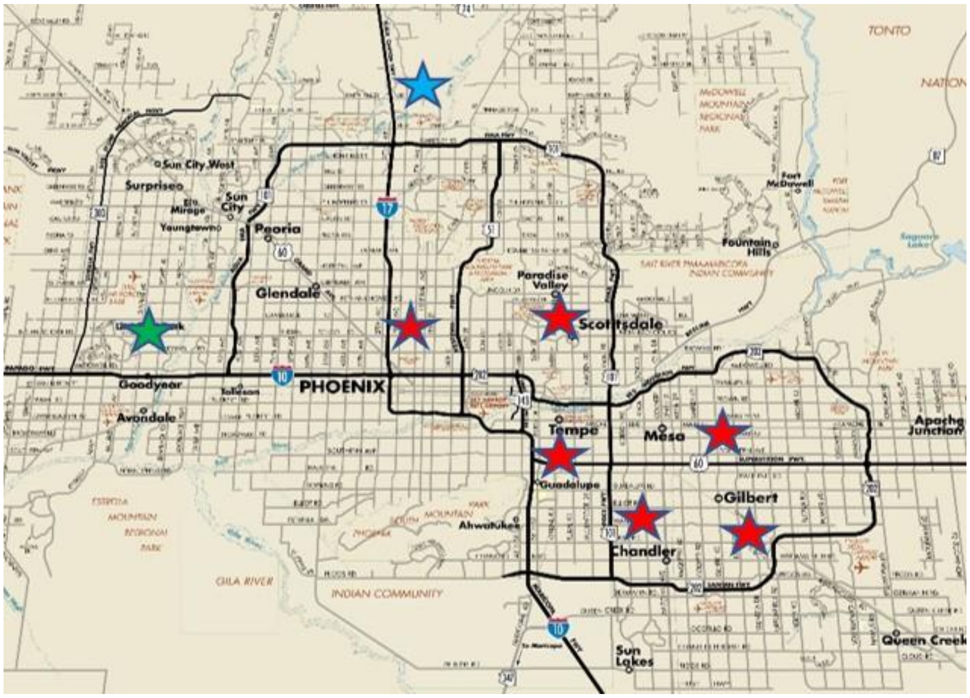

Figure 1.4: Testing regions and locations of the proposed project

1.1.5 Proposed Period of Performance

The development of the SAM, SSPA, IRA and CSM will occur over three years. Refer to the Management Plan section for more detail.

1.2 Goals

1.2.1 Safety

Our concept is strongly focused on enabling the nation to mature ADS safety as rapidly as possible. Our SAM implementation will enable us to define and demonstrate a safety evaluation capability that establishes required competency for **expanded ADS road testing** and a data collection capability that provides stakeholders with the feedback necessary to monitor and mature ADS behavior so that ADS-equipped vehicles can safely co-exist with human-driven vehicles and boost public confidence in ADS technology, paving the way for broad adoption. The goal is to dramatically reduce the death and injury rates across the nation's roadways.

1.2.2 Data for Safety Analysis and Rulemaking

Our team will research what data are needed by stakeholders during **expanded ADS road testing** to effectively monitor and evaluate the integration of ADS into our human-driver oriented infrastructure. We will demonstrate how these data can be efficiently collected while protecting developer IP and demonstrate how these data can be processed and provided as feedback to stakeholders for safety analysis and rulemaking. Our SAM will augment the VSSA approach, enabling system-wide safety and could be adopted by standards bodies such as the SAE On-Road Automated Driving (ORAD) Committee and Verification and Validation (V&V) Task Force.

1.2.3 Collaboration

Our team is a representative collection of public and private stakeholders that will work together to mature ADS so that it can be broadly embraced to allow the nation to benefit from its safety potential. We will demonstrate how collaboration across these stakeholders can be harnessed to collectively drive ADS safety maturation. We understand that it will be critical to promote ADS advancements with local leadership in Arizona, and will host several opportunities for city, county and state leaders to see first-hand ADS in action during the testing and implementation stages. Furthermore, ADS represent a significant shift for public agency operations, and our demonstration will help to highlight important strategies that support partnering and collaborating with new kinds of mobility providers and technology developers. Our intent is to help other states and municipalities that have less experience with public road testing than Arizona to embrace it and add to the nationwide feedback required to help mature ADS for broad consistent deployment across the nation's entire surface-road infrastructure. The IAM will actively promote and participate in national and international ADS safety methodology efforts, sharing our learnings with the development of the SAM, SSPA, IRA and CSM where helpful.

1.3 Focus Areas

1.3.1 Significant Public Benefits

Our proposal creates a framework for state and municipal stakeholders to embrace **expanded ADS public road testing** and to generate the data required to provide feedback to all of the stakeholders involved so that they can maintain high safety standards and contribute effectively to the maturation of ADS deployment. Ultimately, we will help to improve ADS behavior until it becomes compatible with excellent human-driven vehicles. Both will have to coexist for the foreseeable future, so ADS behavior needs to become predictable and acceptable and non-threatening to human drivers.

1.3.2 Addressing Market Failure and Other Compelling Public Needs

Our proposed methodology and tools are capabilities that individual industry stakeholders are unlikely/unable to develop on their own. ADS developers have implemented their own safety maturation processes and use the VSSA process to document them. By drawing on best practices from industry, our methodology and tools augment these maturation processes that provide a critical readiness assessment and continuous feedback on system-wide safety, something that developers cannot assess individually.

1.3.3 Economic Vitality

Our proposal brings together a breadth of U.S. companies and stakeholders that are focused on developing ADS technology that will translate into new economic opportunities. Arizona recognizes the economic potential of being able to successfully demonstrate ADS and how this will translate into attracting new industries and new services, and help to grow the regional and national economies.

1.3.4 Complexity of Technology

Our proposal will demonstrate solutions to complex challenges that need to be overcome to enable safe and effective **extended ADS road testing** and to provide feedback that will help with the modernization of local, state and federal regulations and USDOT standards. Level 3 to Level 5 ADS challenges our team will address include:

- What safety performance and behavior methodology needs to be implemented to assure system-wide safety during **extended ADS road testing**?
- What basic performance and behavior must ADS demonstrate to be trusted, within reason, during **extended ADS road testing**?
- What data need to be collected for stakeholders to be able to assess ADS behavior (individual and system-wide) and performance during **extended ADS road testing**?
- How can these data be consistently provided by the breadth of ADSs without violating their developer's right to preserve their IP?

Our proposal supports significant technical research into ADS safety methodology, testing and data capture to drive broad, consistent, and rapid technical and policy maturation. We propose to develop safety assessment tools for both pre-public road deployment and continuous safety monitoring during public road deployment.

1.3.5 Diversity of Projects

Our proposed methodology and tools are intended to enable broader **extended ADS road testing** across the entire national infrastructure, including highway, urban and rural public roads, and private roads/campuses. Our proposed region of performance for the SAM demonstration, shown in Figure 1.5, includes all of these communities.

1.3.6 Transportation-Challenged Populations

Our proposal includes the deployment of Local Motors' Olli shuttle vehicle to provide service to the transportation-challenged population within the Sun Health senior community. This deployment is discussed further in Section 1.5.1.4.1.2. In general, the SAM will enable ADS deployment to various transportation-challenged populations.

1.3.7 Prototypes

Our proposed program will demonstrate and deliver the SAM, SSPA, IRA, and CSM prototypes that will broadly enable effective **expanded ADS road testing** and speed up the maturation and acceptance of ADS technology to the benefit of the nation. In addition, we will demonstrate the Local Motors Olli shuttle vehicle that is nearing commercialization.

1.4 Requirements

1.4.1 Research and Development of Automation and ADS Technology

Figure 1.5 depicts the R&D and activities that will be pursued. Our R&D will be focused on enabling the expanded road testing of Level 3 to Level 5 ADS across the nation. Demonstration and evaluation details are provided in Section 1.5.

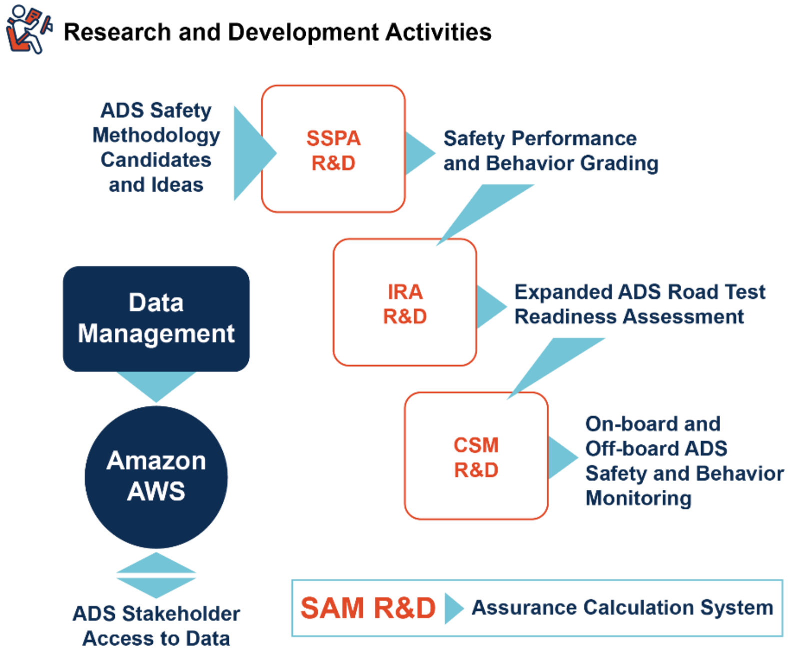

Figure 1.5: Research and Developments Activities

1.4.2 Physical Demonstration

Figure 1.6 is a depiction of our SAM demonstration. Implementation and evaluation details are provided in Section 1.5.

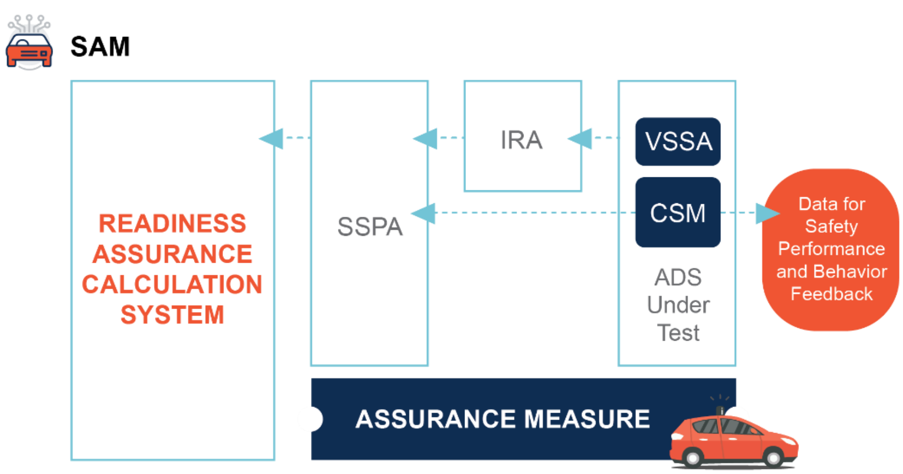

Figure 1.6: SAM Demonstration

1.4.3 Gathering and Sharing of All Relevant and Required Data

A lot of data will be generated and shared during the development of the SAM demonstration including: a) on-board and off-board vehicle data, b) novel algorithms and results from the demonstration platform; c) implementation of these algorithms into the proposed system; d) novel ADS safety assessment methodologies; and e) curricular materials for education and outreach. Where appropriate, these data will be streamed in near real-time and will be made publicly available through a user-friendly web interface to AWS. For detail, please see our Draft Data Management Plan in Part 3 of this proposal.

1.4.4 User Interfaces

Implementation of the SAM and the SSPA, IRA, and CSM Tools that feed into it will be developed with transfer to other states and municipalities in mind. As such, they will be open and will be well documented so that they can be easily reproduced. They will be implemented by commercial companies that have a national presence and can assist other states and municipalities to reconstruct them. Interface details will be defined and implemented as part of our proposed R&D efforts.

Data will be made available to the stakeholder community through AWS using standard AWS interfaces. Results of our proposed data analytics will be viewable using the data visualization approach detailed in Section 3.4.

1.4.5 Scaling the Demonstration

Our intention is to enable productive **expanded ADS road testing** broadly across the nation. We will develop and demonstrate the SAM to increase in-state road testing and to enable other states, developers and stakeholders. Through the IAM, we will actively promote the use of the SAM and our tools and assist all interested parties with their implementation and with the transfer of what we learn to standards and rule-making bodies.

Throughout the course of our testing and implementation, our team will document key steps and milestones so that lessons learned can be captured and ultimately broadly shared. We will focus on technical, policy, implementation, and performance outcomes as part of this documentation. Our team will develop project reports that are suitable for both technical and non-technical audiences that describe the process and methods used. This will integrate the perspectives of key stakeholders involved in the process, which will provide a tangible “real-world” perspective to the ADS development and implementation experiences. We know USDOT will be focused on sharing information through web updates, webinars, fact sheets, videos and other outreach tools and our Outreach and Education Team will actively partner with USDOT to develop materials to support this outreach. This information will also be valuable to promote local agency awareness and understanding of the ADS implementation process.

1.5 Approach

1.5.1 Implementation and Evaluation

1.5.1.1 Safety Assurance Methodology

The proposed approach to satisfying the objectives mentioned above first involves the development of the SAM, for which a standard process does not currently exist that a regulator can use to assess the roadworthiness of an ADS. This requirement is often framed as seeking to answer the question: “How safe is safe enough?”. As such, a framework is needed to allow for an overall assessment of the observable safety performance and behavior of an ADS as it encounters scenarios both simple and complex in simulations, closed-course testing, and on public roads, that can then be used to build the safety assessment.

The SAM is to be led by industry partner Exponent. The SAM development team will include an insurance industry partner in State Farm that currently insures 1 in every 4 vehicles in the U.S. and has extensive experience in understanding risk in automotive applications. The team will also include an aerospace and defense industry partner in Lockheed Martin with a proven track record of developing processes and systems within an industry that has the highest standards of accuracy and stringency, and Lockheed Martin has already developed assurance case methodologies in other areas of automation. The SAM development team will also be complemented by the ASU Center for Law, Science and Innovation to provide a legal perspective on risk mitigation. The SAM methodology will be open source such that it can be applied in other states and nationwide without the need for a license.

The SAM development will begin with a literature and prior art review that focuses on two main areas. First, an analysis of other industries' best practices will be performed. The cross-industry review of best practices and procedures will include (but not limited to) the Test Readiness Review system used by the Department of Defense, the stage-gate approach used by the medical device industry, the certification and HMI best practices from the aviation industry, and the approach to safety for nuclear power generation. Second, a standards mapping effort will be made to source existing standards relating to ADS, specifically V&V processes, such as ISO 26262[4] for functional safety as well as those currently in development by the SAE On-Road Automated Driving (ORAD) V&V Task Force; the Chair of the V&V Task Force is an employee of industry partner Exponent. Another key reference in testing methodology development will be NHTSA document[5] outlining test cases and scenarios specifically for establishing sample preliminary tests for ADS. The SAM may be refined after public/private road data have been captured using the CSM Tool. ADS telematics data will be used in the creation of a telematics model to evaluate the ADS and compare it to results from a subset of human drivers. Specifically, the data will be compared to human-driver data to expose behavioral differences.

The SAM will use the results of the testing data from the IRA and CSM Tools to build the safety assessment, including for each navigation of a scenario, the safety performance and behavior data, the risk exposure of the scenario, and weighted by the type of testing conducted. The IRA will be flexible and will be informed by the safety assessment process described in the ADS developer's VSSA. ADS developers will be invited to work with the SAM implementer to define an IRA that best evaluates their ADS comprehensively across its intended ODD. Some may want to only involve closed track testing, others may also want to include simulation results they have generated, etc. However, the SAM, based on its assurance calculation system, will require that a program of testing be conducted that generates a robust assessment that is not biased towards any particular developer. In this way, an ADS that has "perfect" safety performance in simple scenarios cannot be said to have established a passing safety assessment. Likewise, a passing safety assessment cannot be made for an ADS that has poor safety performance in complex scenarios. The SAM is calculated according to the following formula for N tests:

$$\mathrm{SAM} = \sum_{\mathrm{i}=1}^{\mathrm{i}=\mathrm{N}} \mathrm{Weighting}_{\mathrm{i}} * \mathrm{Risk\ Esposure}_{\mathrm{i}} * \mathrm{SSPA}_{\mathrm{i}}$$

The weighting of each tested scenario depends on whether the testing was executed in simulation, on a closed course, or in real-world testing and how much new information it provides about the safety performance across the ODD. The weighting of the simulation testing will depend heavily on the level of validation evidence provided by the developer for their simulation tool. The closed-course testing weighting will be intermediary, and the real-world testing on public/private roads will obviously be weighted most heavily. The exact weightings will be determined during SAM research and development.

The risk exposure of a given scenario depends on the complexity of the traffic environment of the scenario. In simulation and closed-course testing, the complexity can be quantified and controlled. In public/private road testing, the complexity is determined by the data captured by the off-board sensors, described further in Section 1.5.1.4.

The safety performance of an ADS in a given scenario, whether the data collected were derived from the developer's simulation environment, closed course, or public/private road testing, is determined using the SSPA Tool, described below in Section 1.5.1.2. The SSPA interprets the testing results by assigning a safety performance and behavior "grade" for the ADS after it encounters and navigates any single scenario.

Building the overall safety assessment will be based on some combination or subset of simulation, closed-course testing, and public/private road testing, as agreed to by the ADS developer and the SAM implementer. In this framework, the SAM can help the ADS developer and the regulation authorities involved with the decision to transition between closed-course and public/private road testing. In this instance, analogous to a type of "learner's permit," the safety assessment has been sufficiently made to warrant making the transition. The safety assessment case for this transition will be made from results of the demonstration of the IRA Tool described in Section 1.5.1.3. Since ADS developers continuously modify their systems (mostly software but even hardware) during the public/private road testing phase, it is important for an ADS developer and regulator to be able to continuously assess the safety of the ADS. This continuous assessment capability will be provided by the results of the CSM Tool described in Section 1.5.1.4. If the ADS safety assessment falls below a minimum level that will be established as part of the research, the ADS developer will be encouraged to use the IRA Tool again to re-build the safety assessment until the minimum level is again met.

1.5.1.2 Scenario Safety Performance Assessment Tool

The proposed SSPA Tool will be developed by the research institution project partner ASU and include quantifiable metrics on safety performance, and integrate both state-of-the-art, data-driven machine-learning (ML) based algorithms as well as non-ML algorithms. The objective will be to provide a safety performance assessment of a specific scenario, including scenarios in simulation, closed-course, and public road testing environments.

1.5.1.2.1 Safety Principles and Metrics

The first step to SSPA Tool development is to develop safety principles and metrics for measuring conformance to the safety principles associated with driving, to be able to objectively quantify the performance and behavior of an ADS from a safety perspective. For this purpose, two robust, mathematical based, interpretable frameworks will be adopted: Responsibility-Sensitive Safety (RSS)[6] and formal languages in the form of temporal logics[7].

Responsibility-Sensitive Safety (RSS) was introduced by Intel/Mobileye in 2017. RSS provides minimum safety assurance requirements by defining unsafe situations based on longitudinal/lateral minimum safe distances that need to be maintained. The minimum safe distances can be determined at any given time using lateral/longitudinal velocities, accelerations, and decelerations (e.g., due to braking) of the considered vehicles. These RSS safety-relevant features will be automatically extracted for the SPA methodology. For example, spatio-temporal segmentation and object localization and tracking techniques can be designed and deployed to compute the velocity and acceleration from the captured video and LIDAR point cloud data.

Safety requirements formalized in temporal logics have enabled new methods for V&V in a range of automotive applications[8,9,10,11]. The RSS safety requirements using variants of temporal logic will be modeled and spatio-temporal constraints that vehicles must obey will be derived. Using temporal logics, RSS requirements can be mathematically modeled and monitored using tools developed in prior work[9,10].

Once the formal spatio-temporal constraints are defined, the designed SSPA methodology can be deployed to extract safety-relevant, spatio-temporal features that can be used as part of the monitoring logic to evaluate, at runtime, if the spatio-temporal constraints are being met (safe) or not (unsafe). One important benefit provided by the proposed logic-based formalisms[8,9] is a continuous assessment of the degree that the RSS requirements are satisfied. In other words, not only it is possible to detect when the safe driving requirements are violated, but also when the ADS comes close to violating the requirements due to its own or other vehicle actions.

The safety principles development will include the following three tasks:

1. Task 1: Are the RSS requirements proposed[6] sufficient to establish safety in typical driving scenarios? What additional requirements are needed in abnormal driving situations?
2. Task 2: What type of data are needed to monitor the RSS requirements in real time and how does noise affect the conclusions of the analysis?
3. Task 3: When it is observed in real time that the metric of the RSS requirement satisfaction decreases, what are the appropriate actions to take? This task is especially important when the RSS requirements are violated due to actions of other vehicles.

The safety principles effort will include determining other rules and spatio-temporal constraints that the ADS-equipped vehicle must meet by examining a sample of driving scenarios developed in the IRA process outlined below. The project partner research institution members have extensive experience in capturing formal requirements for automotive systems and developing monitoring tools[8,9,11,12].

In addition to the above frameworks, the participating ADS-equipped vehicles' operational safety performance and behavior will be assessed by the SSPA Tool using other agreed-upon metrics (such as safe driving metrics already in use by the insurance industry partner State Farm), and by comparing the ADS operational safety performance to average safety performance of manually operated vehicles, as well as using the rules of the road. Augmenting the above frameworks with additional safety requirements that take into account the ability of an ADS to protect its occupants, bystanders, and surroundings (even when it is not at fault) while maximizing the quality of experience will also be explored.

1.5.1.2.2 SSPA Tool Equipment

For this demonstration, data will be captured both on board and off board the ADS-equipped vehicles. The on-board vehicle equipment will be different for the two ADS developer partners:

1. Public Road-Deployment ADS Developers: Telematics device (GPS and Inertial Measurement Unit (IMU) and camera system
2. Local Motors: ADS data access (localization/perception/classification/path planning/actuation data)

For the public road-deployment ADS developers, the on-board data will be acquired using a telematics device provided by industry partner Cambridge Mobile Telematics (CMT) through their relationship with industry partner State Farm along with a camera system. The combination of GPS, IMU, and video data will provide ADS performance data from the vehicle perspective. For the Local Motors Olli shuttle vehicle, access to a subset of the ADS and vehicle data has been granted. The description of the data for both is discussed in Section 3.1.1. Further, Local Motors collects survey data from its riders and is willing to make the survey analysis reports available; however, these reports do not include personal information.

To complement the private ADS developers' ADS, a custom-built, experimental ADS-equipped vehicle, shown in Figure 1.7, from the Dynamic Systems and Control Laboratory at research institution partner ASU, will be used to help develop the SSPA methodology at the testing facility of industry partner Exponent. This ADS-equipped vehicle has been developed for other projects and its usage will be provided as an in-kind contribution. This ADS-equipped electric vehicle has four independently controlled in-wheel motors, two independently controlled steering motors, a real-time dSPACE MicroAutoBox II central controller, a RT 3003 GPS/INS system, a Delphi ESR radar, a HD camera, and other perception systems. The experimental vehicle ADS has demonstrated Level 3 and above automation[13]. The development plan for the vehicle includes the integration of a LIDAR sensor system.

The experimental vehicle provides full data access and acquisition. The on-board vehicle data includes but is not limited to vehicle longitudinal and lateral positions, velocities, accelerations, yaw rate, steering angle/rate, heading angle, and braking/driving commands. The external environment data, such as surrounding vehicles, pedestrian, traffic signs, objects, and environment, can be measured and recorded through the vehicle camera, radar and ultrasonic sensors.

To enable off-board ADS operational safety performance and behavior data collection, off-board data will be acquired using off-board multi-modal sensors paired with data transfer equipment. The multi-modal sensors include visible and IR cameras from Verizon and General Dynamics Mission Systems, and ASU custom-designed multi-modal data acquisition integrating cameras and LIDAR. This diversified network of sensors will provide timely and reliable operation. The on-board and off-board captured data will be sent to the cloud-based platform for further processing, feature extraction, and analysis.

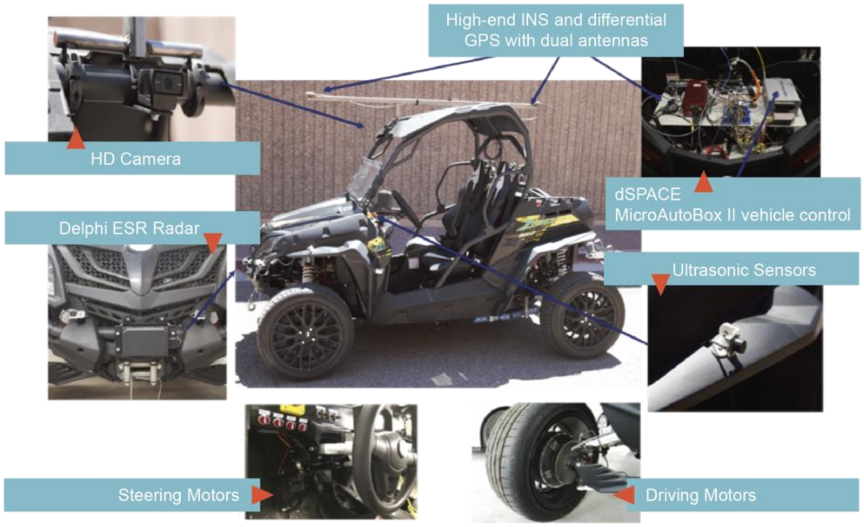

Figure 1.7: ASU Experimental ADS-Equipped Vehicle

1.5.1.2.3 SSPA Tool Development

SSPA Tool development will be carried out in three phases. In the initial phase, the captured data will guide the development of a robust SSPA methodology that can perform under various conditions and scenarios. For the on-board and the off-board data, these algorithms include de-noising, dimensionality reduction, feature extraction, predictive analytics, and classification. In addition, for the rich spatio-temporal off-board data captured by the off-board sensors, advanced spatio-temporal data processing, computer vision, and deep learning based machine learning algorithms will be designed and implemented for (a) spatio-temporal segmentation, (b) background reconstruction and change detection, (c) object (e.g., vehicles, pedestrians, cyclists, road obstacles, etc.) localization (e.g., position, depth), classification, counting, and tracking approaches, (e) safety-relevant feature extraction (e.g., velocity, acceleration, environmental/lighting conditions, context, etc.) for automated safety performance assessment wherein the extracted features are used to verify whether safety principles are met (safe) or are violated (unsafe) and to detect events of interest such as near-miss incidents, collisions/crashes, and other factors that can help in traffic incident management.

In the second phase, the performance of the developed algorithms in terms of generalization to unseen events, efficiency, and robustness to changes in environmental and road conditions as well as adversarial attacks, will be tested and improved upon if necessary in a lab setting using the roadside units' real-time captured and streamed data.

In the third phase, the tested and refined algorithms will be deployed online on the industry partner AWS cloud to process and analyze the captured data in real time. Edge computing (implementing parts of the algorithms as part of the off-board sensors) and cloud computing (running the algorithms or parts of the algorithms on the cloud) tradeoffs and which configuration would maximize the desired performance (e.g., efficiency, accuracy, reliability, and cost) will be explored.

1.5.1.2.3.1 Multi-Modal Sensor Fusion

In addition to designing algorithms and optimizing them for each sensing modality (e.g., video and LIDAR), the proposed approach includes an exploration of how to maximize the performance through multi-modal sensor fusion. Two different fusion approaches will be considered: 1) through mixtures of deep neural networks (MixDeepNet), and 2) through the aggregation of sensing modalities as channels that are all fed to a deep neural network.

For the first approach, an ensemble method, MixDeepNet, is proposed. The ensemble members (also called "experts") in the model are each a deep network trained for a particular type of sensing modality. The output of the model is a weighted sum of the expert models, where the weights are determined by a separate gating network. The gating network is trained to predict weights so as to optimize the classification performance under varying environmental conditions and various driving scenarios using a regularized loss function (e.g., cross-entropy loss function with regularization on the gating network weights).

For the second approach, inputs from different sensors will first be aggregated to form a concatenated input that is fed to a deep neural network. Various deep learning architectures including Convolutional Neural Network (DCNN), Residual Neural Network (ResNet), and Recurrent Neural Network (RNN) architectures will then be explored.

The expertise of the ASU team in the design and development of robust computer vision, machine learning, and deep learning systems[14,15,16,17,18] will also be harnessed for the development of robust perception and data analytics systems that can operate reliably under varying conditions and are robust to changes in environmental conditions. In prior work on obstacle detection for automated driving, an Inverse Perspective Mapping (IPM) camera-based obstacle detection and collision warning system that can operate reliably under various illumination conditions and for various types of road obstacles was developed. The previous camera-based work with other sensor modalities will be augmented. For example, safety-relevant features extracted from the LIDAR data will be explored and incorporated. To this end, algorithms to process and analyze 3D LIDAR point cloud data will be developed. Further, features (e.g., point cloud density, point cloud temporal flow, point cloud clusters, to name a few) that are relevant to safety monitoring and that can reliably quantify the vehicle driving performance under various conditions will be determined.

1.5.1.3 IRA Tool

IRA Tool development will be led by Exponent. ADS candidates must demonstrate basic behavioral competencies and scenario navigation capabilities in closed-course testing before deployment. The IRA Tool process will consolidate best practices for defining the program stages for ADS development and safe testing and deployment. Core behavioral competencies will be based on prior research and exposure data derived from naturalistic driving database and crash databases, and input from project participants including ADS developer partners.

The test results provided by the implementation of the IRA Tool is an input to the SAM. ADS developers will be encouraged to meet an established minimum safety assessment in the IRA Tool implementation before proceeding to the implementation of the CSM Tool, i.e., being deployed outside of the closed-course environment.

1.5.1.3.1 Scenario and Behavioral Competencies Taxonomy and Curation

The first step in the IRA Tool process development will be to develop a library to be hosted by industry partner Exponent for use by the ADS developers of simple-to-complex operating scenarios that an ADS might encounter with accompanying, appropriate behavioral competencies that the ADS must demonstrate in interactions with other road users including pedestrians, cyclists, human-operated vehicles (under various levels of automation) in multi-modal scenarios, as well as different ODDs for different ADS. Research will begin with entities engaged in scenario curation such as the PEGASUS project and also with the partner ADS developers. The sheer number of variables and possible states of each give rise to a practically infinite number of plausible scenarios that ADS could encounter on public roads. It will therefore be impossible to test ADS under all possible scenarios. However, it is important to identify, characterize, and classify scenarios of interest based on criteria to be defined by this research.

For human-operated vehicles, crash statistics and facts have traditionally provided data to inform the development of novel safety technologies and eventually regulatory actions. These data are not yet widely available for ADS as deployments are still limited and sparse; however, the ADS disengagement and crash data that do exist will be sourced and examined. It should be noted that even if a data set exists, it may be dependent of the specific implementation of the automated function. The crash databases containing information on human-operated vehicles can provide an initial methodology framework; however, analysis is required to determine the relevancy to scenarios ADS are likely to encounter. For example, national statistics on human-operated vehicle crashes show that rear-end collisions are the most frequent. However, the cause for this collision type is often lack of driver attention, which will not be applicable in the ADS case. Therefore, elevating this type of scenario would not be appropriate. Meanwhile, scenarios that are seen to be challenging for ADS, and especially when multiple ADS encounter the same challenges, would be ranked higher in the testing priority. The scenario curation effort may also leverage the scenario library already developed by ADS developers. Concurrently, the scenario database will also host a crash/incident database so that scenarios analytics can be continuously informed by in-field performance.

The scenario curation effort includes constructing a rational and harmonized curation of scenarios relevant to ADS and it is intended to grow and expand over time as testing, field data, and collective knowledge develop. The scenario curation includes a comprehensive classification of operating environment scenarios by identifying all the variables and parameter space that characterize a scenario. For example, a scenario is characterized (at a minimum) by road type, road conditions, lighting conditions, weather conditions, traffic pattern, traffic control devices layout (including lane markings), etc.

The scenario taxonomy would also include traffic incident management (TIM) scenarios, and work with the unique partnership between the ADOT and Arizona Department of Public Safety (DPS), Maricopa County Regional Emergency Action Coordination Team (REACT) (the only multi-jurisdictional incident response team in the U.S.) and other AZTech TIM Coalition partners to develop TIM-related scenarios that help ensure that an ADS can navigate a situation where an incident has already occurred, and the ADS must not cause a secondary incident or put a first responder on the scene in jeopardy. Such scenarios include, but are not limited to:

- Temporary road construction zones
- Traffic incidents and crashes that result in unplanned road closures
- Manual traffic control by police, using hand gestures, at malfunctioning traffic signals
- Traffic breaks created by DPS to slow down traffic upstream of an incident scene
- Diversions in response to Wrong-Way Driver notifications via Dynamic Message Signs

The TIM scenario work will also be an input and advancement to the USDOT Cooperative Automation Research Mobility Applications (CARMA) platform project that has identified TIM as one of the focus use cases for Level 1 and Level 2 Cooperative ADS. The proposed project will focus on TIM scenarios for Level 3 and above. Through collaboration between ADOT and Arizona DPS, Maricopa County Regional Emergency Action Coordination Team (REACT) and other AZTech TIM partners, a step-by-step process for TIM first responders for ADS-related incidents and also how ADS-equipped vehicles can assist in incident information conveyance will be developed. It should be noted that AZ first responders have unique experience already with ADS-equipped vehicles in serious crashes, with two of these occurring in the Tempe, AZ region.

A comprehensive taxonomy of operating environment scenarios will help decompose complex scenarios into fundamental building blocks that can be then re-arranged and combined to generate even more complex scenarios and ultimately "edge" cases. The main benefit of this research is to provide a structured database of operating environment scenarios. These databases will include scenarios generated by both real-world drive data and also synthetic stimuli inserted into otherwise real scenarios. Further, parallel to the scenario database, an ADS crash/incident database will be maintained so that field data can be continuously used to update and inform the scenario database.

A review of the work on behavioral competencies for ADS developed thus far will be researched from sources such as California Partners for Advanced Transportation Technologies (PATH). Subsequently, an effort will be made to link the appropriate behavioral competencies to the scenario. The competencies will also be linked to exposure and risk. For instance, being able to signal to another driver at a 4-way stop is not a competency that carries the same risk as the competency of being capable to merge on the highway during rush hour. Driving scenarios will thus be analyzed to establish the risk they pose and evaluate what specific behavioral competencies are expected to be demonstrated by the ADS when negotiating the scenario. This task will lay the foundation for the testing methodology development.

1.5.1.3.2 IRA Tool Development

The IRA Tool developed by industry partners Exponent and Lockheed Martin will be flexible according to the individual ADS developer situation, so it can be adapted to their safely methodology defined in their VSSA and to their ODD. Thus, the IRA Tool demonstration will be different, for example, for the ADS developers that will be deployed on public versus private roads in the CSM Tool demonstration. The next input to the bespoke IRA Tool implementation will be to analyze (where applicable) the VSSA prepared by the ADS developer. The level of detail and comprehensiveness of the VSSA will be judged according to determined metrics to result in an objective assessment of the starting point of the safety assessment.

The ADS developer will then have the option of providing simulation tool results. Industry partner Exponent will collaborate with the ADS developer to adapt the SSPA Tool and risk exposure metric to the simulations and ensure a uniform format for output.

The next step in the IRA Tool demonstration will be to determine the set of scenarios against which the ADS will be tested. This set will be determined in collaboration between the ADS developer and industry partner Exponent using the hosted scenario library. If the simulation results are to be provided, the scenario set for simulation testing will be modified iteratively, depending on the simulation results. For example, scenarios where the ADS was assessed by the

SSPA Tool (regardless of the risk exposure metric of the scenario) in simulation to be closer to failure will be of particular focus. The ADS developers will be encouraged to make attempts to find edge cases in their simulation testing, in part by including perturbations to a single scenario to test the robustness of the ADS response. Whether the simulation results are provided or not, the scenario set may also include common scenarios for all ADS (with the same ODD) to establish a baseline and method for comparison. Finally, scenarios will be chosen through a process leveraging, in part, Lockheed Martin's methodology used in its Independent Research and Development (IRAD) projects. The IRA Tool development will include a collaboration between the IRA team and ADS developers to ensure an open methodology while also respecting individual IP. The scenarios will be selected for the ADS, based on its ODD and taken from the scenario library, and conducted in the closed course testing. Edge cases will be identified and marked for priority in the closed-course testing.

In either case of whether the simulation results are to be used as an input or not, the key purpose of the closed course testing will be to grade the ADS safety performance for a given scenario with associated risk exposure metric. Each scenario tested for which the ADS safety performance is satisfactory helps build the safety assessment and move the ADS closer to meeting the minimum safety performance and the progression to the CSM Tool demonstration.

1.5.1.3.3 Closed Course Testing

Closed course testing will occur at the Exponent Test and Engineering Center (TEC) in Phoenix, AZ. The TEC has 147 acres of indoor and outdoor testing facilities, including a 2-mile oval track. To be able to test scenarios that ADS will encounter in real-world driving, modifications to the TEC are required to allow for a wide variety of driving scenarios to be assembled.

The main proposed modification to the TEC facility is to build a Programmable Driving Scenario Assembler (PDSA), to be designed and developed by research institution partner ASU and industry partner Exponent, for additional testing capabilities specifically designed to accommodate ADS testing. The PDSA will have the capability to:

1. Create various roadway interactions, e.g., pedestrians, pedestrians, jaywalkers, deer on a highway, etc. Programmable scenario actors will be mounted to rail-propelled bases and/or robotized bases that will be controlled by the infrastructure control system.
2. Create multi-vehicle scenarios, e.g., lane merging, traffic intersections, roundabouts, multi-way stop signs, etc. The traffic lights, speed limit signs, and other roadway signage such as billboard warning systems will be controlled by the infrastructure control system to make each traffic control device dynamically reconfigurable.

The most important feature of PDSA will be that it will be programmable, so it will allow for configuring the driving scenario on the test track, including traffic device and signage and roadway interactions, from a script. The PDSA will allow for configuration of both the events on a test track, as well as their timing from a script. This will enable repeatable experiments, which is the key to systematic and fair testing of ADS. For example, it will be possible to create repeatable test scenarios in which the car in the lane next to the ADS-under-test changes lanes and moves in front. Even more interesting, it will be possible to tune the timing of the lane change of the other car in a systematic and deterministic manner, so as to be able to comprehensively test the safety of the ADS-under-test in this scenario.

The second main modification to the TEC will be to build the CSM off-board data equipment consisting of visible and IR cameras and LIDAR sensors, as outlined in Section 1.5.1.2.2. This will allow for both development and validation of the SSPA Tool and validation of the CSM Tool sensor suite design. For the IRA Tool, the off-board data equipment will capture data on ADS performance from outside of the ego-vehicle perspective.

1.5.1.3.5 IRA Tool Deliverables

The IRA Tool deliverables include a methodology for assessing the safety performance of an ADS before the ADS-equipped vehicle is deployed on public/private roads. In this way, the IRA Tool is really a subset of a larger V&V process that would be used to build the safety assessment required for ADS commercialization. The IRA Tool will be developed for the specific Arizona testing environment that has drawn so many ADS developers to the state, namely wide, well-marked roads with little precipitation or snow. The IRA Tool is extrapolatable to other locations and potentially nationwide; the additional environments and scenarios would simply need to be added to the closed-course testing, and the principles of the IRA Tool would remain the same. The IRA Tool process can also be an addition to the USDOT VSSA process as an optional method for ADS developers to follow a common method of due diligence assurance. Once a sufficient safety assessment has been built for the ADS in the implementation of the IRA Tool, the ADS developer will be advanced to the implementation of the CSM Tool.

1.5.1.4 CSM Tool

The CSM Tool is another input to SAM to build the safety assessment for an ADS deployed in public/private road testing that the safety performance that was verified in the implementation of the IRA Tool has been maintained (or even improved). The purpose of the CSM Tool is to develop, validate, and demonstrate methodologies for ensuring reliable and sustained safety performance assessment for ADS that are being deployed and/or tested on public or private roads. Ultimately, the CSM Tool will generate feedback on ADS system-wide behavior that can be used by stakeholders to mature this behavior. Participating ADS will have first undergone an implementation of the IRA Tool to assess readiness for the public road testing of the implementation of the CSM Tool. The implementation will elucidate the assessment fidelity using on-board vehicle data, off-board vehicle data, and a combination of both, to illustrate how the CSM Tool can be used in other states or by the USDOT in other locations around the country. Implementation of the CSM Tool will inform the USDOT on what kind of data (and the data source) and methodologies are needed for the agency to monitor the safe behavior of ADS on public roads, to be able to effectively manage traffic incidents in a mixed traffic environment with ADS, and ultimately allow for the safe integration of ADS to public infrastructure.

The normal operations of the ADS developers will be impacted as little as possible as evidence that the CSM Tool can be employed by regulatory agencies around the U.S. without unduly intruding on the ADS development. The ADS developers will be encouraged to pass the off-board sensor-equipped locations as frequently as possible, and potentially at specific times where, for instance, a police officer is directing traffic due to either traffic-light malfunction or temporary road shut-down for a large, pedestrian-rich event.

During the implementation of the CSM Tool, the ADS developer is free to make changes to its ADS from both a hardware and software perspective. If these changes are such that the safety performance as determined by the SAM is deemed to fall below the minimum safety bar, the

ADS developer will be encouraged to re-implement the IRA Tool.

1.5.1.4.1 CSM Tool Demonstrations

There will be two types of CSM Tool demonstrations as part of the SAM:

1. Public road deployment
2. Private road deployment

1.5.1.4.1.1 Public Road Deployment

The public road deployment will involve ADS developers with whom discussions are currently underway. Locations for the off-board sensors must be chosen that minimize the impact to the operations of the ADS developers while also providing interesting traffic and ODD environments. In choosing the locations of interest for off-board sensor installation, the following criteria will be considered:

- Areas that have been mapped by an ADS developer
- Locations with fiber optic cable access (for cheaper data transfer)
- High-congestion areas
- High-accident areas
- Areas with stadia or large crowds that often have normal traffic diversions (and potentially police-directed traffic)
- Areas that will be known to be under construction during the demonstration
- Have transportation-challenged populations
- Areas that ADS developers report are difficult for their ADS to navigate
- Rural and urban diversity
- Freeways and arterials diversity

A diversity of captured entity types will be desired. Examples are:

- Cars
- Cyclists
- Pedestrians
- Micro-mobility
- Transit
- Construction
- First responders
- Garbage trucks
- Delivery trucks
- Freight
- Highway
- City
- Mixed
- Campus

The municipalities chosen for the public road deployment in which locations will be identified are Phoenix, Chandler, Scottsdale, Mesa, Gilbert and Tempe. Several of these municipalities have extensive experience with ADS testing within their jurisdictions and have intersections and roadways that satisfy the criteria listed above. The CSM Team will coordinate with the municipalities on the planning/installation/maintenance of the off-board sensors and data transfer equipment.

1.5.1.4.1.2 Private and Public Road Deployment

The private road deployments involve ADS developer partner Local Motors that is developing the Olli ADS-equipped shuttle vehicle, designed for first/last mile use cases, that does not currently have federal approval for public road deployment. The Olli design includes efforts to accommodate transportation-challenged populations such as elderly, wheelchair-bound, and visually impaired passengers. The off-board sensor equipment will be placed at selected locations along the specific route(s) that the shuttle service accommodates. Two very different deployments are being considered for this vehicle:

- Remote retirement and wellness community shuttle service: The property developer partner (Sun Health) is in the beginning stages of developing the La Loma Village community in Litchfield Park, AZ for retirees that will include social, entertainment, and wellness services, shown in Figure 1.8. The Olli shuttle vehicle would convey community residents and employees between administrative buildings, residences, community centers, and commercial establishments. Many of the community's residents are considered part of a transportation-challenged population.

Figure 1.8: Sun Health La Loma Village site map

- Maricopa County juror shuttle service in Central Business District (CBD): The county DOT partner (MCDOT) has the need for a juror shuttle service in Phoenix's CBD to convey passengers from a juror parking lot to the court building, as shown in Figure 1.9. The speed limit for the road portion of the route is 25 mph and stop signs provide the required traffic control. The secure shuttle storage facility is located nearby. The two drop-off points for the jurors are located on a single-purpose pathway that will be designated for Olli operations. This Phoenix CBD deployment would occur only after Local Motors has secured federal approval for public road deployment. The case for this approval will be based, in part, on the results from the IRA Tool Demonstration as well as the Sun Health deployment. The project will demonstrate a model process for agencies like MCDOT to safely integrate low-speed ADS shuttle services on a public road. A diverse juror stakeholder group will be surveyed to solicit feedback on the user experience.

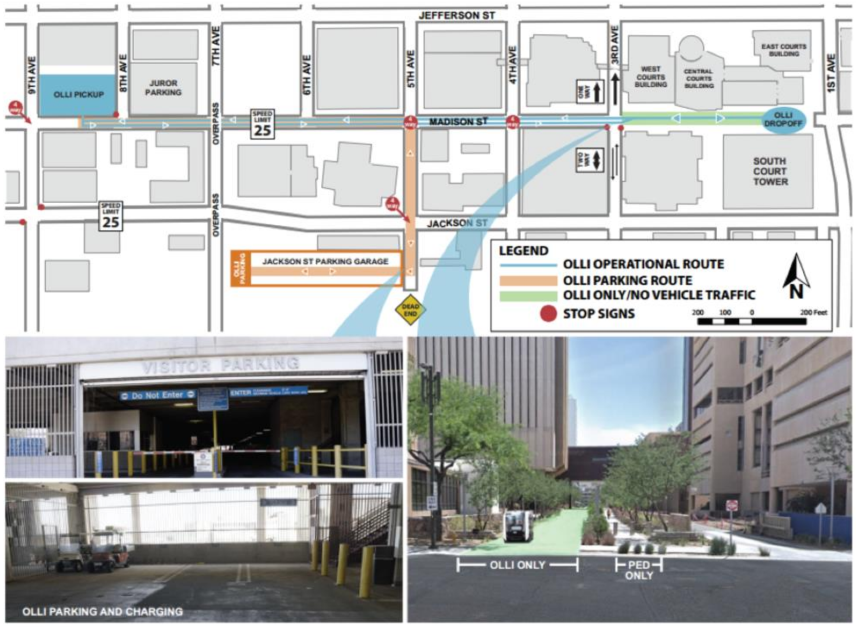

Figure 1.9: Proposed Maricopa County juror shuttle route

1.5.1.4.2 CSM Tool Deliverables

The CSM Tool deliverables include a methodology for continuously assessing the safety performance of an ADS as it is deployed on public/private roads. The CSM and IRA Tools are a subset of a larger V&V process that would be used to build the safety assessment required for ADS commercialization. Unlike the IRA Tool that may require additions to be applied elsewhere, the CSM Tool is immediately extrapolatable to other locations and potentially nationwide.

The CSM Tool will be used to identify ADS safety-critical scenarios and collect data to substantiate those. The collected data about these safety-critical scenarios and edge cases will be used by the ADS developer partners to create solutions to help mitigate such cases as part of the feedback loop process described earlier. The CSM demonstration will collect infrastructure data that will inform the USDOT, state and local DOTs on the infrastructure asset needs to support ADS; these data will also support in future updates of Manual of Uniform Traffic Control Devices (MUTCD) and provide agencies valuable input for future road infrastructure planning.

1.5.2 Regulatory and Environmental Compliance

Our intention is to demonstrate our SAM implementation on public roads. In particular, our demonstration includes testing a Local Motors Olli vehicle to provide a juror shuttle service in the Phoenix CBD. We will need exemptions from FMVSS and the FMCSR to carry out this testing. We are in discussions with other ADS developers who are testing within the Phoenix area about their participation (negotiations will not be complete by the NOFO deadline). We will define the details of our demonstrations during the execution of our program and will apply for the appropriate exemptions once we have a clear understanding of exactly what is required.

We will adhere to the Buy American Act. All participants in our program are U.S. entities and we will not be purchasing any vehicles or any significant, foreign-built technology, so we do not anticipate the need for any exemptions.

We do not anticipate any environmental compliance issues.

1.5.3 Safety Evaluation

Our proposal is focused on the safety assessment of ADS. Our stakeholders are all experts in safety management and will apply their best practices to the development, implementation and demonstration of the SAM, IRA and CSM.

1.5.4 Risk Mitigation and Management

The primary risks associated with the development of the SAM, SSPA, IRA and the CSM and their mitigation are (color coded by level of risk: high, medium, low):

SAM:

- Assurance measure accuracy and variance too large to provide confidence in assurance grade.
  Mitigation: Continue to iterate on the inputs to and structure of the assurance calculation process to better identify the key safety contributing factors and rework the IRA, SSPA, and CSM tools to focus on them.

SSPA:

- Too computationally expensive.
  Mitigation: There are many algorithmic approaches available to calculate the SSPA. Explore alternate combinations of algorithms that improve computational efficiency.

IRA:

- Closed course facility test capabilities too limited to properly assess readiness.
  Mitigation: Our initial assumption is that the Exponent facilities are robust enough to support the testing required. If this assumption turns out to be incorrect, we will reach out and involve some of the many other Arizona test facilities.

CSM:

- Testing environment too limited to comprehensively evaluate ADS behavior.
  Mitigation: Expand number and variety of testing locations. The municipalities involved in our program will work with us to identify and assist in instrumenting more intersections so that we establish more diversity in our data gathering.
- ADS candidates not road worthy – cannot use for CSM.
  Mitigation: Engage additional ADS candidates. We intend to reach out to the full list of ADS developers operating in AZ throughout the execution of or program to explore opportunities to engage them to improve the robustness of our R&D and demonstration.
- Off-board and On-board data collection not adequate to fully evaluate ADS behavior.
  Mitigation: Work with ADS developers to tap missing data from their ADS.

1.5.5 Contributions to and Management of Non-Federal Resources

Refer to the cost share management description in Part 6.

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