Autonomous Transportation: NASA & Redstone Arsenal

1. Project Narrative and Technical Approach

1a. Introduction

Cover Letter

HUNTSVILLE

Tommy Battle
Mayor

March 13, 2019

Sarah Tarpgaard, HCFA-32
U.S. Department of Transportation (USDOT)
Federal Highway Administration (FHWA)
1200 New Jersey Avenue, SE; Mail Drop: E62-204
Washington DC 20590

Subject: Automated Driving System (ADS) Demonstration Grant

Dear , Ms. Tarpgaard.

In Huntsville, we promote ourselves as "A Smart Place."

We have smart people…the highest concentration of engineers in the nation and one of the highest overall concentrations of STEM professionals. We also have smart infrastructure. I made it a priority to become a gigabit city and ensure every home in Huntsville has access to broadband. We have recruited new providers and had significant enhancements of service from major incumbents. Our next phase of connectivity is coming in the form of the wireless infrastructure that will power 5G networks.

Serving as a demonstration site for autonomous vehicles will further advance our efforts of being a "A Smart Place" with smart transportation. The City of Huntsville's proposal is a public-private mobility partnership that will serve one of our major employment centers, NASA's Marshall Space Flight Center on Redstone Arsenal, a 38,000-acre federal installation. The demonstration project addresses a real transportation challenge while also advancing the deployment of this important emerging technology.

Best regards,

Tony Battle

Tommy Battle
Mayor

Summary Table

Project Name/Title	Autonomous Transportation: NASA & Redstone Arsenal
Eligible Entity Applying to Receive Federal Funding (Prime Applicant's Legal Name and Address)	City of Huntsville Urban Development Department P.O. Box 308 Huntsville, AL 35804
Point of Contact (Name/Title; Email; Phone Number)	Dennis Madsen Manager of Urban & Long Range Planning City of Huntsville dennis.madsen@huntsvilleal.gov 256-427-5121
Proposed Location (State(s) and Municipalities) for the Demonstration	Huntsville, Alabama (Redstone Arsenal Military Base)
Proposed Technologies for the Demonstration (briefly list)	ADS L3/L4 Taxi Service, Smart Camera Systems, HD Mapping
Proposed duration of the Demonstration (period of performance)	3 Years
Federal Funding Amount Requested	$9.97M
Non-Federal Cost Share Amount Proposed, if applicable	$2.76M
Total Project Cost (Federal Share + Non-Federal Cost Share, if applicable)	$12.73M

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1. Executive Summary

1a. Vision, Goals, and Objectives

Vision

In collaboration with NASA Marshall Space Flight Center, US Army Base Redstone Arsenal, Voyage, and other partners, the City of Huntsville (CoH) has a vision to demonstrate a safe and effective Automated Driving System (ADS) taxi service that moves individuals both on and off the base, intended to decrease the cost of both personal and fleet vehicle use and increase access to mobility for disadvantaged personnel.

Goals

The City of Huntsville, NASA, and the US Army base Redstone Arsenal will study the effectiveness of reducing the Department of Defense's motorpool vehicle fleet by replacing low-utilization General Services Administration vehicles and reducing reliance on personally-owned vehicles with fewer, highly utilized Voyage ADS taxis (addressing **NOFO Section 2: Goals, Subsection C: Collaboration**). This ADS deployment will feature Voyage autonomous vehicles, serving passengers that are looking to move both within Redstone and outside the gates to the nearby Cummins Research Park, while reducing the time it takes to move securely through the base threshold (addressing **NOFO Section 2: Goals, Subsection A: Safety**). Throughout this proposed demonstration program, the City of Huntsville and its partners will be sharing data and working directly with the U.S. Department of Transportation (USDOT) to ensure that these vehicles are integrated safely into the public road system outside and inside the base (addressing **NOFO Section 2: Goals, Subsection B: Data for Safety Analysis and Rulemaking**).

Objectives

Within the stated timeline of the proposed program schedule of 36 months, the CIty of Huntsville will work with these partners to (1) deploy a safe and effective Voyage ADS taxi service at Redstone Arsenal intended to replace government owned GSA vehicles that are used on and off base, and (2) evaluate how ADS that cross the public/private threshold can benefit from advanced smart camera systems. The ADS taxi service will be a door-to-door service, enabling soldiers, federal employees, families, civilian contractors, hospital patients, retirees, and base visitors to travel throughout Redstone Arsenal without use of their personal vehicles.

Objective (1) will utilize the Voyage second-generation ADS, a Plug-In Hybrid Chrysler Pacifica Minivan, and will address USDOT NOFO Work Areas A (**Technologies associated with ADS**), C (**Innovative mobility solutions that involve deployment of automated vehicles**), D (**ADS that enhance safety and mobility for older adults and travelers with disabilities**), and E (**Demonstration of shared interoperable fleet of automated vehicles**).

Objective (2) pairs Voyage vehicles with advanced smart camera hardware and software systems, and will address Work Areas B (**Advanced communication systems supporting safety and/or mobility**) and F (**Demonstration and validation of exchanges of data that can support and potentially accelerate the safe, efficient, and secure interoperable integration of ADS**)

1b. Key Partners, Stakeholders, Team Members, and Others

1. City of Huntsville: Dennis Madsen, Manager of Urban & Long Range Planning
2. Redstone Arsenal Garrison: Joe Davis, Director of Public Works
3. Marshall Space Flight Center: Robert Devlin, Office of Center Operations
4. Voyage: MacCallister Higgins, Co-Founder and Director of Growth
5. Smart Camera Systems: Francesco Borrelli, Ph.D

1c. Challenges, Technology, and Performance

Issues and Challenges

The first issue being addressed by this proposal is the lack of adequate transportation options currently available within military bases. Due to the secure nature of a US Army base, there is a unique lack of access to the ridesharing or public transportation options that are present outside the gates, or that are able to cross the barrier. Redstone Arsenal is a “commuter base,” where the large majority of those that work their everyday do not live within the base itself, requiring a larger percentage of soldiers and employees to own and operate personal vehicles that spend most of the day in a parking lot.

The interior of the base shares many similarities with a city -- servicing offices, restaurants, and recreational activities. Of primary concern to the City of Huntsville is to safely address and study these transportation needs of soldiers, their families, civilian employees, contractors, hospital patients, and retired veterans within Redstone Arsenal with an ADS taxi service, a challenge that will require close collaboration and a tight feedback loop between all involved parties due to the complexity of data and physical security at military facilities.

The second issue being addressed by this proposal is the optimization of traffic flow in and out of the base, as well as reducing the number of driver interventions per mile (IPM) that occur in an ADS, which still remains higher than what is required for seamless L4 systems. This is in large part due to lack of prediction and coordination of other road agents in situations with limited sensing capabilities, such as maneuvering through a guarded gate with intricate human interactions when going on and off the base. The proposal will address this major issue by utilizing advanced smart camera systems, which will allow real-time sharing of status and motion predictions between road users, quantified and shared using real road data.

Technologies to be Demonstrated

- Voyage Autonomous Taxis (Hybrid Chrysler Pacifica Minivans)
  - Perception: LIDAR and Cameras
  - Localization: Real-Time Kinematic GPS, Inertial Measurement Unit, Wheel Odometry, and HD Maps
  - Control: Renovo Drive-by-Wire and Safety-First Architecture
  - Interface: Smartphone App for Dispatch and In-Vehicle Touchscreen
  - Smart Camera Systems: Shared actor models and coordinated maneuvers

Anticipated Quantifiable Performance Improvements

1. Achieve a number of weekly active users that exceeds 10% of the accessible user base.
2. Reduce the average time required to enter or exit the base through the main gates by 20% for weekly active users.
3. Utilization rate improvement, per vehicle, over existing GSA vehicles (7%) at NASA's Marshall Space Flight Center.
4. Reduce safety driver interventions in covered zones by 50% using smart camera systems.

1d. Geographic Area

This demonstration will occur inside Redstone Arsenal, within the Marshall Space Flight Center, and outside the base as a connector to Cummins Research Park in nearby Huntsville, Alabama. The Arsenal is a garrison for a number of tenants including the United States Army Materiel Command, Army's Aviation and Missile Command, and the Missile Defense Agency of the Department of Defense [1]. Cummins Research Park (CRP) is the second largest research park in the country and the fourth largest in the world. It is one of the world's leading science and technology business parks, with a mixture of Fortune 500 companies, local and international high-tech enterprises, U.S. space and defense agencies, thriving business incubators and competitive higher-education institutions. CRP is the home of nearly 300 companies, more than 26,000 employees and 12,500 students. The Park's major industries are aerospace, defense, engineering, biotechnology, advanced manufacturing, software development, information technology and cyber security [2].

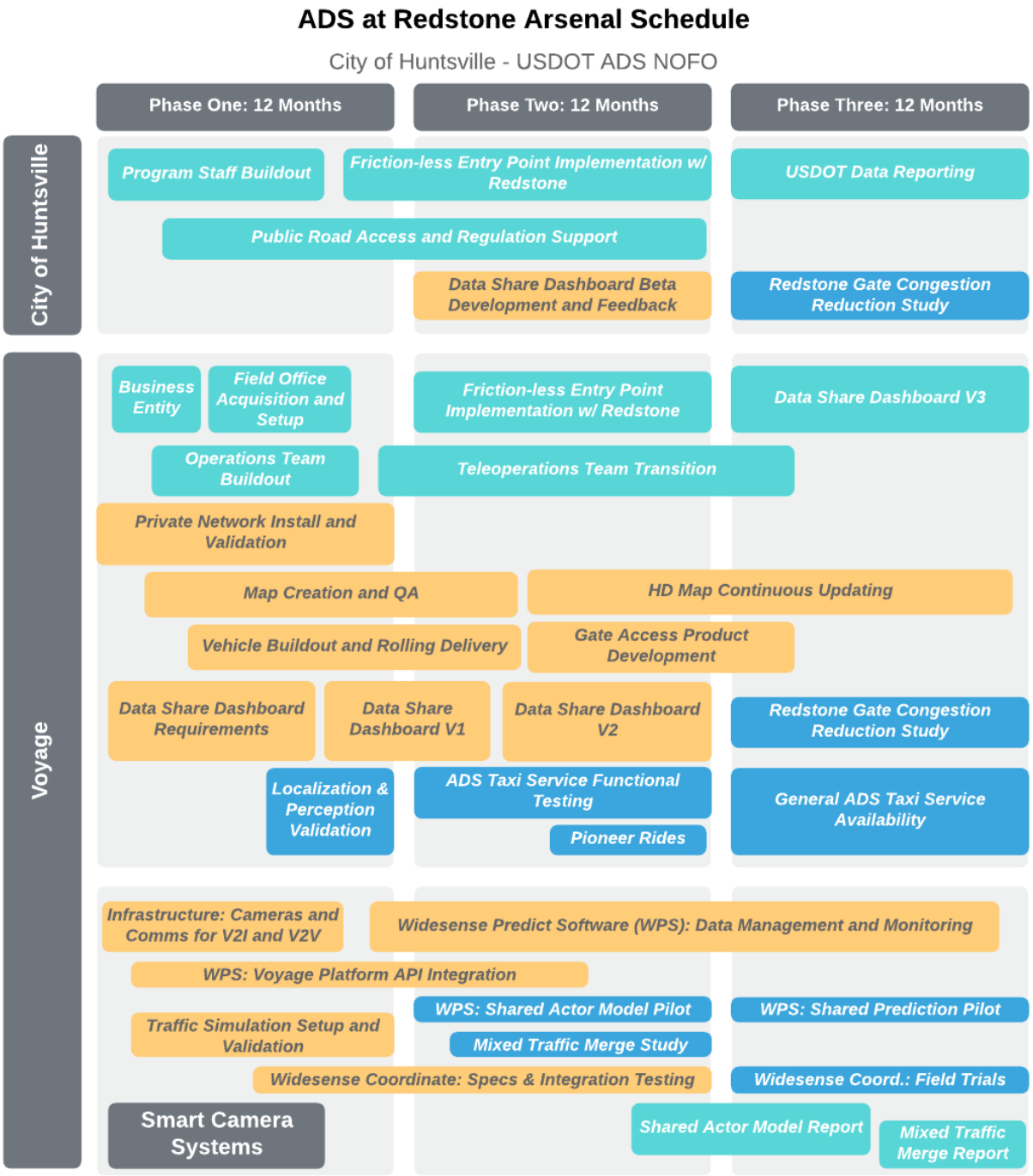
1e. Proposed Period of Performance

Over a 3 year period and multiple phases, the City of Huntsville will study (and share) the operational data from an active Voyage autonomous taxi service that addresses transportation challenges felt by active military personnel, their families, and civilian base employees. This will entail the deployment of autonomous vehicles and smart camera systems on a US military base to evaluate their effectiveness at addressing these transportation challenges.

Phase 1: 12 months with a focus on mapping and infrastructure install

Phase 2: 12 months with a focus on secure access development, testing, and validation

Phase 3: 12 months with a focus on general availability & evaluation of the ADS Taxi Service



2. Goals

The main research outcome posed by this proposal and the City of Huntsville is the reduction of congestion of personal vehicles being used by Huntsville residents to travel on base, supported by also reducing the Department of Defense's motorpool vehicle fleet. By replacing low-utilization General Services Administration vehicles with fewer, highly utilized Voyage ADS taxis, the City hopes to incentivize carpooling and other alternative transportation methods for arriving to work, while enabling seamless transportation on base and the surrounding area using Voyage taxis.

This ADS deployment will feature Voyage autonomous vehicles, serving passengers looking to move both within Redstone and outside the gates to the nearby Cummins Research Park. Throughout this proposed demonstration program, the City of Huntsville and its partners will be sharing data and working directly with the U.S. Department of Transportation (USDOT) to ensure that these vehicles are integrated safely into the public road system outside and inside the base.

2a. Safety

Voyage has invested significant time and effort in being transparent in their approach to safety, most notably in their release of the Open Autonomous Safety (OAS) program: a fully open-source library of Voyage's internal safety procedures, materials, and test code designed to supplement existing safety programs at autonomous vehicle companies.

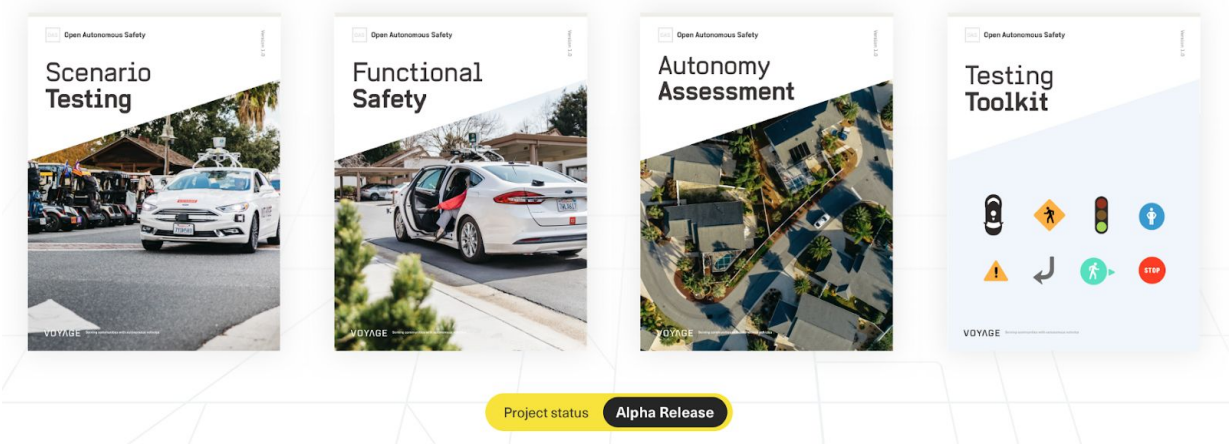


Fig. 1: Voyage's Open Autonomous Safety Program Areas

Voyage designs their technology with the fundamental principle that AVs will soon be operating in a truly driverless world, and that safety is of even greater importance when there is no

human behind the wheel. In this scenario, comprehensive safety frameworks like OAS become essential. Currently, OAS focuses on five key areas:

1. **Scenario Testing**
2. **Functional Safety**
3. **Fault Injection Testing**
4. **Autonomy Assessment**
5. **Testing Toolkit**

Scenario Testing

OAS currently contains an extensive list of custom-built scenarios, designed to evaluate the real-world capabilities of autonomous technology. These scenarios are designed for suburban environments, but are flexible and able to integrate high-speed, urban, and other unique surroundings.

Fig. 2: An Example of One of the Many Scenarios Detailed in OAS

These scenarios represent fundamental questions: How should an autonomous vehicle behave when it reaches a crosswalk and a pedestrian approaches from the right? Or when another car is backing out of a driveway? These scenarios, and many more, provide a rubric for assessing the practical capabilities of an autonomous vehicle while on the road. The scenarios also introduce a qualitative dimension to the safety program, not just asking if an ADS can complete a scenario, but also how well it performs.

Functional Safety

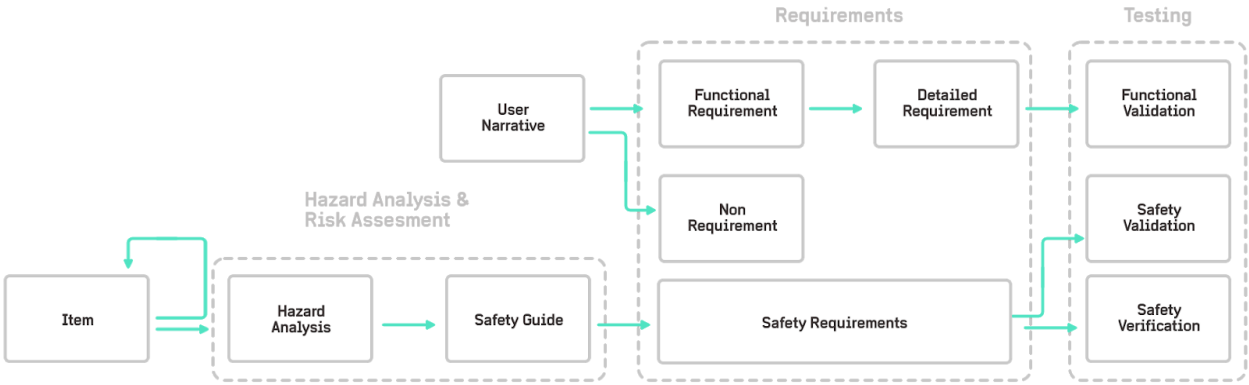


Fig. 3: Flowchart of OAS Requirements Framework

Without a driver to help identify and mitigate failures, ADS need incredibly robust safety requirements and an equally comprehensive and well-defined process for analyzing risks and assessing capabilities. Voyage models its safety approach after the ISO 26262 standard for automotive safety, taking the best practices from the automotive industry and applying them to autonomous technology.

Currently, the Functional Safety section of OAS contains two process definitions: the Safety Requirements and Functional Requirements Flows. Beyond the functional safety standards of traditional production vehicles, the goal of the safety requirements flow is to provide validation coverage and risk mitigation.

The Safety Requirements flow consists of the following steps:

1. Items of the autonomous system are identified and defined. Vehicle functions are broken down and defined as individual items so that they are better understood and isolated.
2. Hazard analysis and risk assessment is performed for each item. Safety ratings are assigned to each hazard and safety goals are determined. The Hazard and Risk Assessment (HARA) considers all potential hazards, and assigns an ASIL rating dependent on Exposure, Severity, and Controllability.
3. To ensure Safety Goals are met, safety requirements are generated that define the Technical Architecture.

4. Verification is performed on safety requirements. Test Cases are created and linked to requirements to validate all design assumptions and implementation tasks.
5. Validation plans are executed and results reported to ensure all Safety Goals and Safety Requirements are passed successfully.

The goal with the Functional Requirements flow is to define what the car should do in various scenarios, and consists of the following:

1. User Narratives are detailed.
2. High level Functional Requirements and Non-Requirements are defined to determine the scope of the functionality of the autonomous vehicle (the Operational Design Domain), and answer the question of "What" the vehicle does. Depending on the environmental needs and determined operational domain, some deployments may require different requirements.
3. Detailed Performance and Quality Requirements are created from the Functional Requirements, which are more granular and testable. These requirements shape the Architecture of the vehicle, at both the system and component level, and answer the questions of "How" the vehicle should perform.

Fault Injection Testing

Evaluating an ADS' ability to respond to rare system errors is difficult, especially if those errors only happen once every ten thousand miles. Voyage's fault injection tools enable their developers and researchers to programmatically trigger failures in both the hardware and software of critical autonomy components. This allows for the evaluation of an ADS system and its ability to handle a sensor unit that starts malfunctioning after thousands of hours of usage or system damage. Fault Injection Testing enables users to understand the response of a given ADS, design redundancies to handle such cases gracefully, and allow for the validation of:

- Ability to detect a failure
- Proper system and sensor processing and prioritization
- Correct degradation of features or vehicle functions during a fault
- Fail-Safe execution
- End-to-End latency benchmarking and monitoring
- Validation of proper acceptance criteria to pass functional scenarios

Autonomy Assessment

Autonomous technologies often result in incredibly complex systems, involving computers, sensors, custom hardware, and software. One modification can simultaneously impact a host of critical components, which makes it difficult to quantitatively measure the progress of development.

Miles Per System Fault Intervention (MPFI)

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MPFI = (Total Autonomous Miles) / (Total System Fault Interventions)
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Fig. 4: One of the metrics used within the Autonomy Assessment

The Autonomy Assessment section of OAS consists of documentation on how Voyage validates ADS performance. By collecting, processing, and evaluating operational data every single day, these consistent, well-formed metrics can be used to objectively track progress across an ever-evolving system.

Testing Toolkit

Communicating an idea for a complex test scenario can be difficult, especially with some of the unique traffic patterns that exist at Redstone Arsenal. The OAS Testing Toolkit looks to simplify this process with an open-source Sketch library of traffic, roadway and vehicle assets.

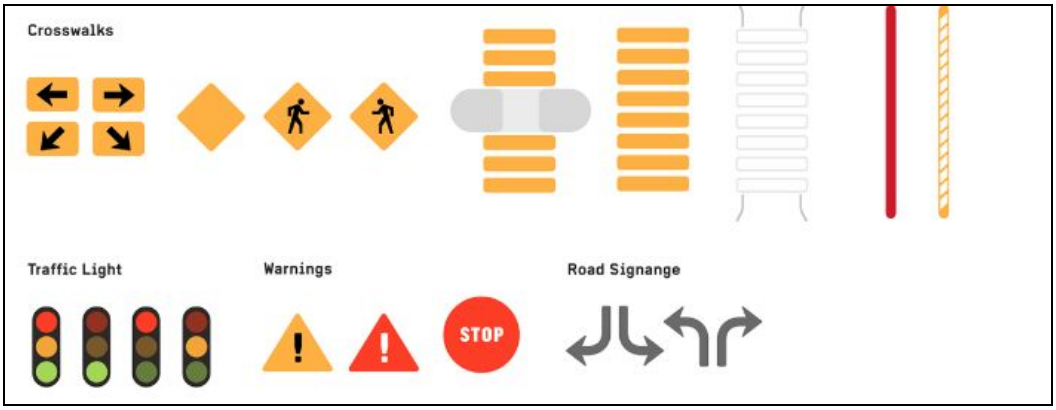

Fig. 5: Subset of OAS Testing Toolkit Assets

Speaking a consistent language across the OAS scenario library has enabled faster iteration, improved test coverage, and higher repeatability in operations testing practices and scenario definition.

2b. Data for Safety Analysis and Rulemaking

Voyage will expose a web-based interface to the USDOT that acts as a data sharing portal. In much the same way that simulation testing is used to perform continuous integration testing at the software level, this dashboard will monitor the actual, real-life performance of Voyage vehicles operating in Huntsville and Redstone Arsenal. This system will monitor for the occurrence of OAS functional testing scenarios, either from natural traffic interactions or contrived testing, and immediately evaluate the performance of the ADS with pass/fail metrics.

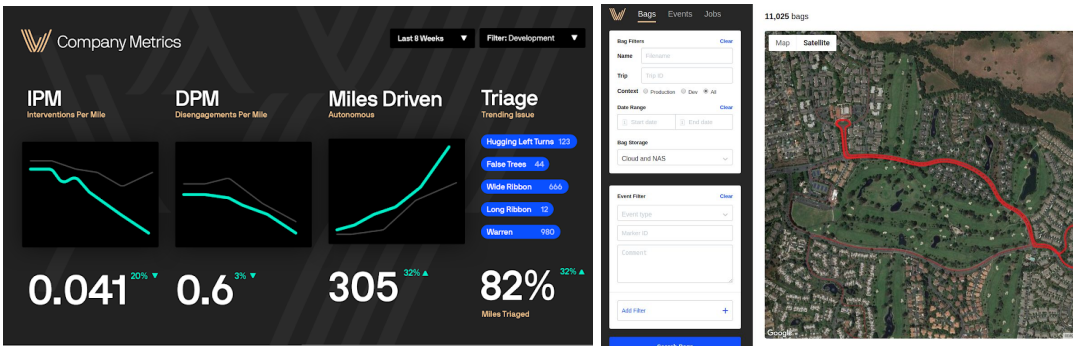

Fig. 6: Existing Internal Voyage Data Dashboards

Additionally, all sections of the Open Autonomous Safety program are completely public on the OAS website and repository (located at http://oas.voyage.auto) under its current open-source MIT License, allowing all interested parties to review, improve, repurpose, and expand, in conjunction with other parallel efforts by Voyage to expand the scope and utility of the existing program.

2c. Collaboration

As smart cities continue to expand, the US military will need to adapt to remain an attractive option for potential recruits who have become accustomed to a certain quality of life afforded as a civilian in the private sector. As with any organization or community, the US Army's installations have a responsibility to use its limited resources prudently and to minimize its impact on the environment. In response to these emerging threats, opportunities and values, the US Army has developed its Smart and Resilient Installation (SaRI) framework, which organizes installation elements and activities into six domains and 17 focus areas.

Redstone has been tapped to pilot this concept and serve as the Army's flagship installation of the future. These domains and focus areas provide a comprehensive view of an Army installation, though by the connected nature of a smart community, there is overlap in the scope and impact of some areas. For example, intelligent traffic signals (Traffic Management) are fed by data collected and analyzed by smart cameras anchored on base infrastructure, enabling them to "green light" the route for first responders dispatched to an incident (Emergency Services), providing an incredible opportunity to integrate ADS into this vision of the future military base.

Huntsville and Redstone Arsenal have a long history of being a test bed for innovation, all the way back to its inception in 1941 as the Huntsville Arsenal chemical weapon plant during World War II, and taking a lead in developing the Army's ballistic missile program in the 1950s and the first NASA space launch vehicles in the 1960s. Today, Redstone remains a center for testing, development and doctrine for the Army's missile programs and several DoD and DOJ organizations, including the Missile Defense Agency (MDA), Missile and Space Intelligence

Command (MSIC), the Federal Bureau of Investigation (FBI) and the Bureau of Alcohol, Tobacco, Firearms and Explosives (ATF).

Army installations are vital members of the local community, partnering with municipalities, universities, and private sector companies to drive economic and social development and well-being. The installation of the future / SaRI initiative is an opportunity to strengthen these relationships with organizations and stakeholder groups in the surrounding community by inviting them to play a role in the design and implementation of the new installation platform, and this grant proposal is no exception. By working together to utilize ADS to expedite moving employees from Huntsville to Redstone, we are truly reinforcing the goals of the Smart and Resilient Installation framework.

By fostering collaboration between federal organizations at Redstone and municipal or private organizations in the greater Huntsville area, the City and Redstone intend to capture synergies, share development costs, procure services at competitive prices, take advantage of special funding mechanisms (such as UESCs, ESPCs, OTAs, PIAs, and USDOT grants), access research and development sources in the private sector (e.g., the University of Alabama in Huntsville), and ensure that enhancements to Redstone meet the needs and desires of its neighbors in the community. Transforming the 5,000 acre Redstone installation into a technology-enhanced connected community will require several years of concerted efforts and investment on the part of the US Army, Redstone tenant organizations, and other stakeholder groups like Voyage.

3. Focus Areas

3a. Significant Public Benefits

Traffic Management at Redstone Arsenal

An effective traffic management system that relies partially on ADS and smart camera systems can help reduce the average commute time for citizens of the installation, improving productivity, quality of life, and improving air quality by reducing emissions from idle vehicles. In addition to the transportation of their occupants, ADS are also able to “greenlight” the route for emergency services, allowing first responders to more quickly respond during emergencies by immediately vacating certain routes. Optimizing traffic flow will require current traffic volume and pattern studies, evaluation and deployment of these ADS technology solutions for frictionless entry at gates, smart cameras with analytic capabilities, and adaptable traffic signals.

Redstone’s Strategy:

1. Perform traffic study (in progress)
2. Deploy friction-less entry points with analytics (currently in the design phase)
3. Install smart camera systems with analytical capabilities (this proposal)
4. Explore on-base shuttle/rideshare service to reduce motorpool reliance (this proposal)

5. Deploy ADS for private use (this proposal)

By partnering with Redstone Arsenal, NASA's Marshall Space Flight Center, Voyage, and others on implementing the Army's SaRI initiative partially through this USDOT grant, the CIty of Huntsville is prepared to help cities across the country learn how to interface more effectively with their local base counterparts, while helping define local and national integration and regulation for ADS.

Taxpayers, the Federal Government, and the Department of Defense

The biggest beneficiaries of ADS technology will be those with the largest vehicle fleets, especially those with fleets that have low daily utilization rates. At the top of this list is the US federal government, which owns and operates more than 600,000 vehicles [3], according to extensive research completed by Marine Corps Lieutenant Colonel Brandon Newell [4]. The Department of Defense is responsible for 175,000 of those, with an annual operating cost of $435 million [3]. These vehicles are not tanks or armored personnel carriers, they are cars, trucks and other vehicles designated as NTVs (non-tactical vehicles), and are utilized less than 7% of the time (less than 100 minutes a day, according to a study conducted by the Army at Fort Hood), spending the majority of their service life in a parking spot [5].

As part of this grant, Redstone Arsenal and NASA Marshall Space Flight Center are looking to understand how many of their motor pool vehicles could be removed from their fleet, as the downtime of a vehicle sitting in a parking lot waiting for a user can be drastically cut. This leads to more efficient and resilient bases, a reduced environmental footprint, and an overall better deal for the US taxpayer.

3b. Addressing Market Failure and Other Compelling Public Needs

End-Users of the ADS Taxi Service

Redstone Arsenal supports nearly 44,000 military, civilian, retiree, and reserve personnel. Without traditional ridesharing options and no circulator busses, individuals living and working on the base have extremely reduced options for travel, especially when considering families living on base that only own or lease a single vehicle. At one point, the Marshall Space Flight Center operated a 10 car on-base taxi service, but it was eliminated during federal budget cuts in 2006 at the peak of its popularity, breaking 5,000 miles of monthly utilization in June of that year. The demand for better on-base transportation exists, yet the funding for a manned taxi system does not.

More broadly, vehicle ownership itself is a burden on young enlisted soldiers, as costs average nearly $9k a year [6]. This cost becomes untenable with active duty enlisted soldiers in the Army making between $20k - $40k, especially combined with the inefficiencies of personal vehicle ownership [7]. However, since military personnel are not required to pay for housing, and since existing transportation options on base are inconvenient, young enlisted soldiers are

regularly incentivized to make such purchases (sometimes with the use of predatory loans aimed specifically at service members). Direct, door-to-door ADS taxi services can directly address and reduce this incentive to purchase a vehicle by providing a convenient option for on-base transportation.

In addition, the Department of Defense is exploring ways to mitigate the safety risks associated with traditional vehicle ownership. Pulling again from research completed by Marine Corps Lieutenant Colonel Brandon Newell, the US military suffered 1,923 automobile fatalities and 806 motorcycle fatalities between 2000 and 2009 [8]. Of these fatalities, many involved alcohol, lack of seat belt usage, speeding, and other identified high-risk behaviors more prevalent in this demographic.

3c. Economic Vitality

The City of Huntsville is committed to reinforcing the development of critical military and space technologies at Redstone Arsenal, a US military base that supports nearly 44,000 active-duty military, family members, reserve component soldiers, retirees, and civilian employees, as discussed in Section 2c (Collaboration) of this proposal. In addition to the local economy, proposal partners Voyage, Carmera, Renovo, Velodyne, Ericsson, and AV Connect are all US corporations, looking to solve transportation challenges at Redstone Arsenal.

3d. Complexity of Technology

Voyage currently operates an autonomous taxi service in two US locations (San Jose, CA and The Villages, FL), with the intention of transitioning to SAE L4 within the timeline of this grant. Voyage will be replicating these existing service platforms at Redstone Arsenal and in the City of Huntsville in support of the grant objectives.

3e. Diversity of Projects

Through this proposal, we are looking to gather data on personal mobility, and public transportation. Redstone Arsenal has many restaurants, commercial stores, recreation centers, and even food trucks, and consists of a blend between commercial office centers, manufacturing warehouses, and individual campuses. Outside of the gate, Cummins Research Park is a large commercial facility that is visited daily by nearly 22,000 employees.

3f. Transportation-Challenged Populations and Accessibility

The nature of the demographic of retirement communities (Voyage's current operating domain) has necessitated a focus on developing accessible technology. Their second generation vehicle was chosen largely for ease of access for those with mobility challenges or physical disabilities, with their very first passenger being a blind individual who was able to summon a Voyage ADS on her smartphone using vision-impairment features. Redstone Arsenal is home to Fox Army Health Center, a comprehensive primary care facility dedicated to serving both the base, and is utilized by the same transportation-challenged demographics as Voyage's existing deployments.

Military bases have hospitals with disabled service members, as well as families with restricted transportation options. To address this population directly, the City of Huntsville and Voyage will be including retired veterans as our first target demographic for our Pioneer pilot program, as the taxis themselves begin servicing passengers moving between Redstone and the immediate surrounding Huntsville area. Taxis, Uber, and Lyft are generally not allowed on base with current security protocols (unknown drivers going on and off base), so individuals needing to get to the base exchange (retail shopping) or the commissary (grocery store) are left with few options.

The complexity of serving military personnel and their families within a base comes from both the difficulty of a commercial service getting access to the base itself, along with the increased costs and complexity associated with data locality and security. Military bases remain underserved in the general transportation economy as it stands now, even before the added difficulty of AV technology is included. Additionally, military funding is generally tied to existing, traditionally under-utilized options such as circulator buses, creating a barrier to entry for new technology.

3g. Prototypes

Voyage as a company has built and deployed several driverless vehicles, and is currently working to enable L4 capability on their second-generation Chrysler Pacifica platform. These vehicles are already moving passengers autonomously in retirement communities, utilizing tools and services from our partners listed in this grant proposal.

4. Requirements

4a. ADS Technology Level

Voyage currently operates an autonomous taxi service in two US locations (San Jose, CA and The Villages, FL), with the intention of transitioning to SAE L4 within the timeline of this grant. Voyage will be replicating these existing service platforms at Redstone Arsenal and in the City of Huntsville in support of the grant objectives.

4b. Physical Demonstration

As described in 4a, this demonstration will include an operating door-to-door taxi service within Marshall Space Flight Center, the larger area of Redstone Arsenal, and the immediate surrounding areas of Huntsville outside the main transit gates.

4c. Data Sharing

Specific Data Shares through the Data Dashboard (described in 2b):

- Measured performance evaluation of the Voyage ADS in all listed OAS scenarios relevant to the Redstone Arsenal environment.
- A functional safety analysis breakdown of the operational service including Safety Verification, Safety Validation, and Functional Validation.
- Smart camera systems data:
    - Unified total merged actor (road user) models (prediction of actor behavior) for the duration of the evaluation.
    - Data and Analysis and on the effectiveness of shared models, including differential analysis of the ego-only view actor model to the merged model.
    - Data and Analysis evaluating coordinated maneuver efficiency, including plan graphs for each coordinated maneuver.
    - Data and Analysis of mixed traffic interaction effectiveness, including usage statistics on the number of emergency yield requests from mixed traffic.
    - Data and Analysis on the percentage of time each vehicle is in reliable communication with both other vehicle actors, and with intersection prediction devices.
- All reported data will be made available for a minimum of 5 years after the award period of performance expires through the analysis dashboard.

4d. Accessibility: User Interfaces

In addition to the discussed general accessibility features of the ADS smartphone application, Voyage has spent considerable time and product iterations improving their in-car interface, allowing for a simplified selection of destinations to popular locations with the option of manual address input. The smartphone application itself has also been simplified, having evolved from the more traditional ridesharing style to the current “press and go” flow.

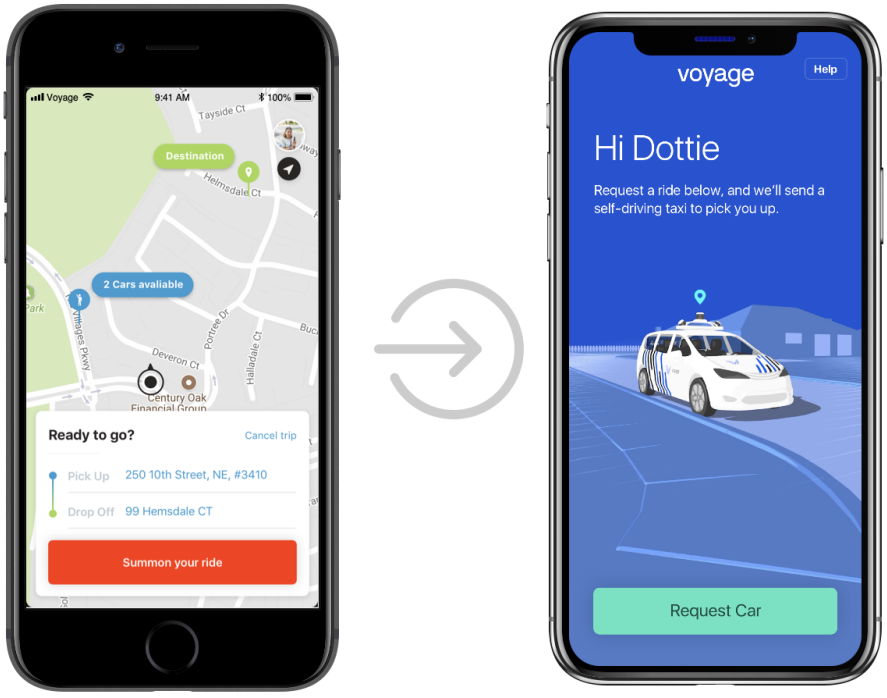

Fig. 7: Simplified user flow of the new Voyage ride hailing application

4e. Scalability

Voyage has approached the vehicle scaling problem by establishing a first-of-its-kind partnership with the leader in commercial fleet leasing and maintenance: Enterprise. This leverages decades of fleet management experience to procure, lease, and service the Voyage fleets, while allowing for retrofitting vehicles with self-driving hardware. When the lease term is up, Voyage is able to return the vehicle to Enterprise, and recycle any vehicle equity back into expanding the fleet.

In addition, all data from this demonstration project is intended to be shared with the Department of Defense, military bases, and federal installations across the country that share similar transportation and security challenges, through the same interface that will be provided to the USDOT.

5. Approach

5a. Technical Approach

Operational Domain

The City of Huntsville and Voyage both feel strongly that the best first application of ADS is in communities that consist of simpler, slower environments. The operational environment is the

single biggest factor in determining the development timeline of a self-driving car, and its corresponding evaluation framework. The environment dictates every key technical challenge, most importantly in terms of speed and complexity.

Within Marshall Space Flight Center, one of the many campuses inside Redstone Arsenal, (as well as retirement communities, the current operational domain of Voyage ADS), traffic is often speed-limited to 25 MPH, and although there exists a variety of cars and pedestrians, it's infinitely less chaotic than a typical city or suburb. The roadway itself is easier to navigate, thanks to simpler traffic patterns and incredible maintenance. Vehicles are able to operate for miles while avoiding complex lane merges, or even traffic lights.

Environmental Mapping

Currently, Carmera provides all mapping services for Voyage ADS systems. Their biggest deployment (The Villages in Florida) consists of 750 linear miles of highway, major arterial and residential roads, and is home to over 125,000 residents, three fully developed downtowns, and thirty-eight golf courses. Carmera also provides continuous updates of localization and navigation data for Voyage self-driving cars, which is critical when covering more road-miles than almost any urban center in the US. Carmera will be responsible for collecting and annotating the HD mapping data at Marshall Space Flight Center during Phase 1 of this ADS project, and will continue to monitor and upgrade maps as required.

Vehicle Platform and Sensors

The Voyage G2 vehicle is based on the widely acclaimed Chrysler Pacifica Hybrid minivan, and features next-generation sensor technology from Velodyne, best-in-class safety systems, and Voyage's ADS software and technology.

Fig. 8: The Voyage G2 ADS Vehicle and a Resident Customer

LIDAR: Multi-Channel Velodyne Sensors

With 128 channels (or lines) of resolution and 300m of range, the Velodyne 128 is an exceptional sensor that enables the Voyage ADS algorithms to process a dense, 3D view of the world in 360 degrees at all times. The Velodyne VLS-128 produces more than 3x the number of points of any commercially-available ultra long-range LIDAR sensor, and is paired with 4 other lower-resolution lidars to cover blind spots around the perimeter of the vehicle.

Safety Systems

Voyage will continue to invest an immense amount of energy into safety systems. Some examples of the results of their safety first development platform include:

- Hardware-enforced limitations on speed and steering. The Voyage ADS stack is limited, via firmware, to a maximum speed.
- Extensive fault injection testing to test real edge cases.
- A deeply integrated diagnostics module that monitors our systems and vehicle for abnormalities and degradations, with the ability to trigger a safe stop on an independent system if necessary.
- Monitoring of computers and sensors for abnormalities in temperature and output.
- Heartbeat monitoring to ensure all systems are communicating properly.
- Redundancy in key hardware, software and algorithms.
- Redundant, server-grade computer, complete with air cooling and state-of-the-art processing power.
- Hardware-level vehicle state machines
- Real-time execution of safety-critical procedures
- System diagnostics and configurable fault handling
- Automatic, configurable telemetry, logging, and local storage
- A flexible, time-series query language for on-vehicle data (e.g. camera frames or telemetry events)

This platform also enables Voyage to intelligently off-load and store data when the vehicles return to base each night, ensuring that the most important data from the day is collected and processed immediately, without unnecessarily waiting to off-load terabytes of redundant data from each vehicle.

5b. Legal, Regulatory, and Environmental Approach

5bi. FMVSS and FMCSR

As we are not selling a vehicle to a consumer, we are not subject to the Federal Motor Vehicle Safety Standards. Additionally, we do not trigger any of the applicable criteria for being subject to the Federal Motor Carrier Safety Regulations, as our vehicles will only carry a maximum of four passengers.

5bii. Buy American

This grant proposal will not require an exception. The second-generation Voyage vehicle is a leased (not purchased) Chrysler Pacifica, as explained in section 4e.

5c. Data Commitment

The City of Huntsville is committed to work with all partners and the USDOT to share operational and safety data generated from and specified in this project proposal. In addition to just providing data, the City is committed to participate in the evaluation of developed safety outcomes with the USDOT, and study particular measures of effectiveness in other arenas, such as mobility, as arises naturally throughout the course of this proposal.

5d. Risks

Many aspects of ADS technology are currently in heavy development across several industries, creating technical milestones that will be reached during the performance period of this grant proposal. Our goal is to fully understand and estimate the work needed to reach these technical challenges, in close collaboration with our partners, to present a clear understanding of inherent risk in any ADS deployment. The major technical challenges that we anticipate are listed below, together with the proposed approaches to mitigate the connected risks.

Military Data Security

Operating ADS on a military base comes with a complex set of data challenges. A significant aspect of this USDOT NOFO is the sharing of relevant data to inform the creation of standards and regulations, but there is a significant segment of sensor data that will be generated from Voyage vehicles and smart cameras that will not be able to leave the confines of the military installation due to security concerns. While the analytical value of raw LIDAR and camera imagery is minimal for the purposes of understanding and studying an ADS deployment, where operational and safety data is far more useful to all parties, a unique challenge is presented when training data cannot be removed from the facility for perception purposes. To mitigate this risk, Voyage is working directly with their partners to enable onsite data storage and processing for annotation and algorithm training, as well as exploring the use of federated learning techniques that maintain data privacy.

Military Base Deployment

Deploying Voyage vehicles and smart camera systems is critical to ensure program success. While these types of sensors and networks are currently providing similar functionality in use cases around the world, a military deployment presents unique challenges in interfacing with the Risk Management authoritative bodies. Voyage vehicles will need to be evaluated under the Department of Defense's (DoD) Risk Management Framework (RMF), and Voyage will need to secure an Authority to Operate (ATO) on the base. For this, we have identified an advisor regularly referred by the DoD to help setup contractors and move them through this process, as well as met several times with base stakeholders to preliminarily understand any potential blockers. As such, we are confident that this ADS technology aligns with the desires of Redstone

Arsenal to modernize transportation, connected vehicles, and wireless technology, paving the way for the base of the future.

Speed Increase to Handle 35 MPH Roadways

Currently, Voyage vehicles are restricted via software to 25 MPH. Redstone Arsenal contains many connector roads that have a speed limit that exceeds this restriction, potentially creating paths that their vehicles are initially unable to utilize. To mitigate the risk of not reaching certain users, Voyage has identified alternative routes that enable connecting these areas initially without traversing the high speed roadways, even if the route itself becomes slightly longer. Voyage's internal technical roadmap indicates that these speeds will be reached during the performance period of this proposal, using OAS program to build upon existing functional testing for verifying vehicle performance at higher speeds. Additionally, other deployments have had their vehicles operate at lower speeds on these routes, which also remains an option while working closely with the NASA Operations office, who has indicated that speed limits can also be adjusted within the confines of the base during segments of this grant program.

Traversing Public Roadways and Access Gates

With no current supporting state level legislation in Alabama enabling ADS systems on public roadways, there is a risk with stating conclusively that we will be able to operate this technology on Huntsville roadways. To mitigate this, in the worst case scenario, Voyage vehicles will be confined to Redstone Arsenal and Marshall Space Flight Center. Additionally, and as part of the value of this proposal, the City of Huntsville intends to document our process for pursuing legal framework change to support ADS locally and within the state, utilizing our relationship with the USDOT through this program to create a repeatable process for other municipalities to follow when seeking to allow ADS on public roads.

5e. Cost Share

Voyage and the proposal partners are committed to cost sharing, with specific values and percentages indicated in the Budget Detail section. Voyage will be contributing staffing costs for engineering and operations, the incurred cost for the middleware platform for their vehicles, and the annotation of the captured sensor data used to train their perception systems.

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