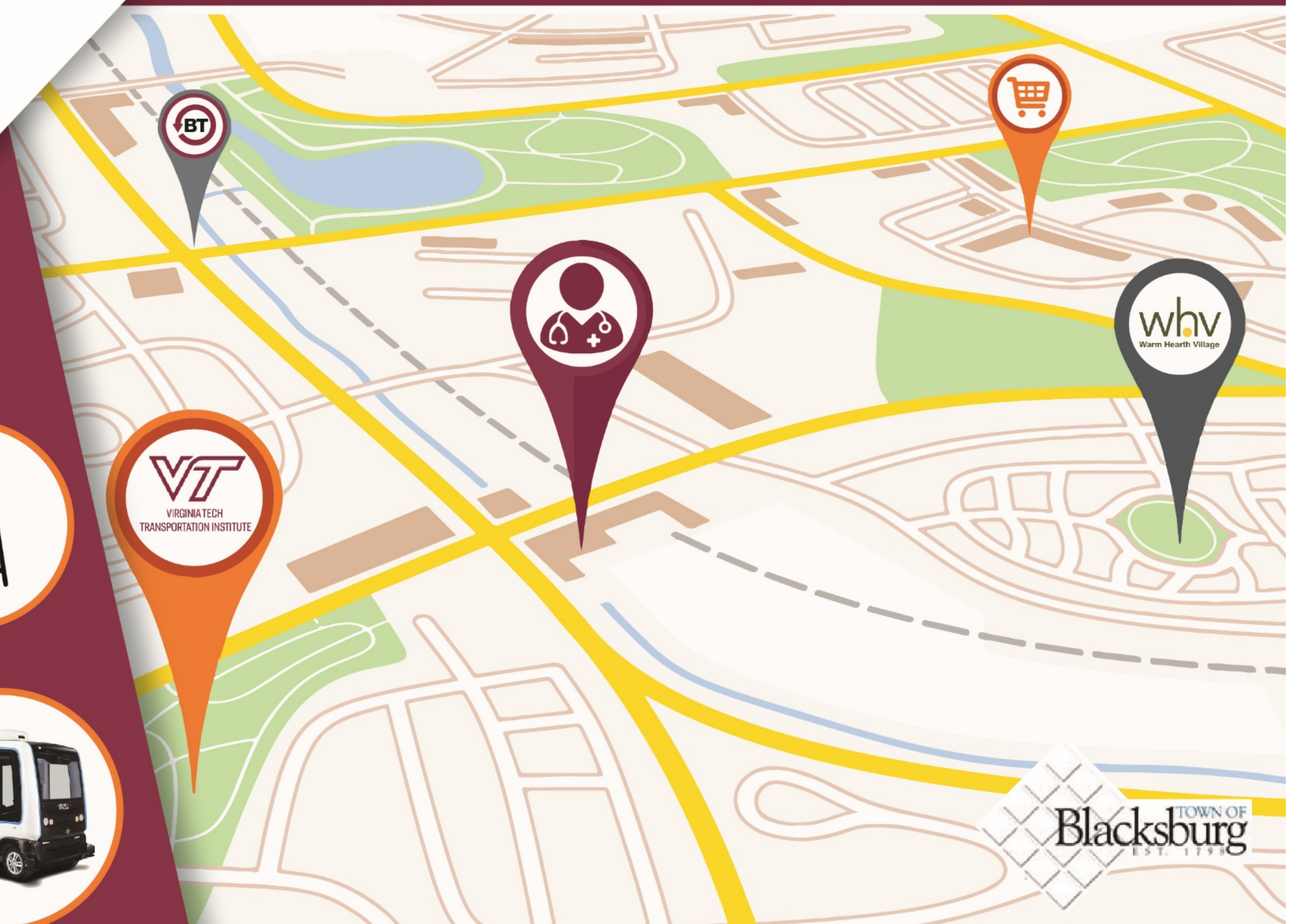
VT TRANSPORTATION INSTITUTE

Demonstration of a Transit-Integrated Automated Driving System - A Vision for Enhancing the Safe Mobility of Transportation-Challenged Populations



Automated Driving System Grants
USDOT NOFO #693JJ319NF00001

Submission Date: March 21, 2019

Budget: ***Federal*** $4,953,643 | ***Cost Share*** $942,841

Submitted by: Virginia Tech Transportation Institute

Principle Investigator: Andrew S. Alden, MS, PE

Co-PIs: Jonathan Antin, Ph.D., CHFP | Miguel Perez, Ph.D., CPE

EASY MILE | Blacksburg TRANSIT | VTRC Virginia Transportation Research Council | VDOT Virginia Department of Transportation | transdev the mobility company | CATM Center for Advanced Transportation Mobility | North Carolina Agricultural and Technical State University

VIRGINIA TECH
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March 18, 2019

U.S. Department of Transportation, Federal Highway Administration
ATTN: Sarah Tarpgaard, HCFA-32
1200 New Jersey Avenue, SE
Washington, D.C. 20590

Subject: Response to ADS Demonstration Grants, NOFO #693JJ319NF00001

Dear Sarah Tarpgaard:

The Virginia Tech Transportation Institute (VTTI) is pleased to present this proposal entitled *Demonstration of a Transit-Integrated Automated Driving System – A Vision for Enhancing the Safe Mobility of Transportation-Challenged Populations* to USDOT in response to NOFO #693JJ319NF00001. This project will demonstrate a comprehensive automated mobility system employing low-speed automated vehicles that will enable residents of a retirement community to access both within-facility locations as well as nearby resources external to the facility such as medical and retail facilities. While senior drivers experience a higher risk of causing and being injured in crashes compared to the general population, driving is still the primary means for them to remain mobile and independent. This project aims to improve the safety of seniors and other road users by augmenting available transit with ADS first/last mile transport, while also enhancing the mobility and independence of a large and growing portion of the U.S. population.

The team who will perform the proposed demonstration includes the following:

- **Virginia Tech Transportation Institute**, the nation's largest transportation safety research entity, with significant experience conducting large-scale field projects and research related to vulnerable road users, including seniors
- **EasyMile**, a global leader in providing ADS technology
- **TransDev,** a global transportation company and largest multi-modal transit provider in North America
- **Warm Hearth Village**, a large, full-service retirement community with approximately 600 residents that will serve as the primary setting for the demonstration
- The **Center for Gerontology** and the **Department of Biomedical Engineering and Mechanics** at Virginia Tech
- **North Carolina A&T State University**, largest HBCU in the U.S. and home to the Center for Advanced Transportation Mobility, a USDOT Tier 1 University Transportation Center.

We look forward to working with USDOT on this important project. Please do not hesitate to contact us with any questions.

Sincerely,

Andrew S. (Andy) Alden, M.S., P.E.
Group Leader – Eco-Transportation and Alternative Technologies
Executive Director – I-81 Corridor Coalition

Summary Table

Project Name/Title	Demonstration of a Transit-Integrated Automated Driving System – A Vision for Enhancing the Safe Mobility of Transportation-Challenged Populations
Eligible Entity Applying to Receive Federal Funding	Virginia Tech North End Center 300 Turner Street, Suite 4200 Blacksburg, VA 24061
Point of Contact	Andrew Alden, Research Group Leader – Eco-Transportation and Alternative Technologies aalden@vtti.vt.edu 540-231-1526
Proposed Location (State(s) and Municipalities) for the Demonstration	Town of Blacksburg, Montgomery County, Commonwealth of Virginia
Proposed Technologies for the Demonstration (briefly list)	Low Speed Autonomous Vehicle (LSAV) Personal Mobility Devices and Vehicle Accessibility Rider Ability Contextual Trip Planning Interface
Proposed Duration of the Demonstration	May 1, 2019 – April 30, 2023
Federal Funding Amount Requested	$4,953,643
Non-Federal Cost Share Amount Proposed	$942,841
Total Project Cost (Federal Share + Non-Federal Cost Share)	$5,896,484

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Acronyms

ADA	Americans with Disabilities Act
ADS	Automated Driving System(s)
AOR	Authorized Organizational Representative
CATM	Center for Advanced Transportation Mobility, University Transportation Center Program under the Fixing America's Surface Transportation (FAST) Act.
DAS	Data Acquisition System
DOT	Department of Transportation
FHWA	Federal Highway Administration
GPS	Global Positioning System
HBCU	Historically Black College or University
IRB	Institutional Review Board
LSAV	Low-speed Autonomous Vehicle
NDS	Naturalistic Driving Study
NRV	New River Valley
PAWS	Part-time Autonomous Wheelchair System
PI	Principal Investigator
PII	Personally Identifying Information
RFID	Radio Frequency Identification
SAE	Society of Automotive Engineers
SHRP 2	Second Strategic Highway Research Program
UI	User Interface
U.S. DOT	United States Department of Transportation
VA	Commonwealth of Virginia
VRP-PDTW	Vehicle Routing Problems with Pickup and Delivery with Time Windows
VRU	Vulnerable Road User
VRU-MAP	Vulnerable Road User Mobility Assistance Platform
VT	Virginia Tech
VTTI	Virginia Tech Transportation Institute
WHV	Warm Hearth Village

Part 1. Project Narrative and Technical Approach

Executive Summary

Background

By 2030, one of every five Americans will be retirement age, and seniors will outnumber children for the first time in history (U.S. Census, 2018; see Figure 1-1). For now, driving remains the primary means for seniors to stay mobile and independent (Davis et al., 2011). However, older drivers generally experience a greater safety risk of causing and being injured in crashes (Li, Braver, & Chen, 2003; Stutts, Martell, & Staplin, 2009). The Baby Boomers driving these demographic trends also have high expectations for remaining active and engaged as they age. Thus, the needs of older adults will increasingly challenge our transportation policies, processes, and infrastructure. Providing mobility alternatives for seniors and others with disabilities in a manner which is safe, efficient, and environmentally friendly is crucial, and this will remain a major challenge for our nation throughout most of the remainder of this century.

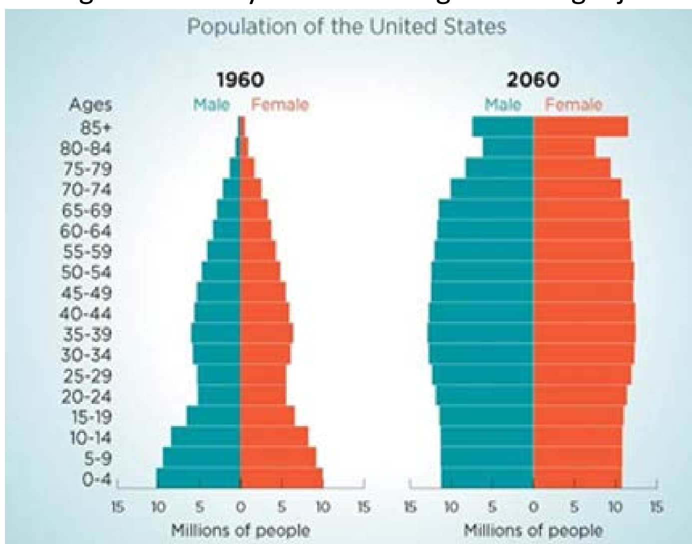

Figure 1-1. Our aging society – projected demographic shifts from 1960 to 2016 (from U.S. Census Bureau, 2018).

There is little doubt that automated driving system (ADS) technologies will play a key role in an envisioned future where older persons as well as others that are transportation-challenged can more safely access the resources needed to maintain their health, well-being, and sense of connectedness. As technology has evolved and our modes of transportation diversify, low-speed autonomous vehicles (LSAVs) have emerged as perhaps the most promising means of providing practical, safe, efficient, and convenient local mobility to meet these needs.

Project Vision

In our demonstration, we will implement a comprehensive automated mobility system that will enable residents of a retirement community (and their family, friends, and caretakers) to access the within-facility locations that they visit most often, along with more distant resources such as shopping, medical facilities, local and regional transit, railways, and airports. This implementation will be accomplished by a dedicated and integrated team of transportation professionals, engineers, researchers, and planners, facility administrators, technology providers, and others from the following organizations:

- **Virginia Tech Transportation Institute (VTTI)** – VTTI is the largest research institute at Virginia Tech and the nation's largest transportation safety research entity, widely renowned for successfully conducting large-scale field projects entailing thousands of vehicles and participants measured in real-world settings, and managing the petabytes of Big Data generated by those efforts. For instance, VTTI researchers, engineers, and staff played the leading role in planning and coordinating the Second Strategic Highway Research Program (SHRP 2) Naturalistic Driving Study (NDS; Antin et al., in press); this represented the largest national-scale, video-based NDS ever undertaken. The proposed project draws expertise from key areas within VTTI positioned to produce results with this demonstration, including the Eco-Transportation and Alternative Technologies Group, the Center for Vulnerable Road User Safety, the Center for Data Reduction and Analysis, and the Center for Technology Development.
- **Virginia Tech** – In addition to VTTI, the project team also leverages the strengths from the broader Virginia Tech community, including the Center for Gerontology and the Biomedical Engineering and Mechanics Department.
- **Warm Hearth Village (WHV)** – WHV is a large, full-service retirement community located in the New River Valley and the primary setting for the proposed demonstration. WHV leadership is fully engaged with the project; their approximately 600 residents represent a broad array of individuals, many of whom are transportation-challenged, and the facility itself represents a perfect setting to demonstrate the beneficial application of ADS technologies
- **EasyMile** – EasyMile is a global leader in providing ADS technology. EasyMile's EZ10, an advanced LSAV, is responsible for many "firsts" in providing autonomous transportation in real-world environments.
- **North Carolina A&T State University** – North Carolina A&T State University is the nation's largest historically black college or university (HBCU) and home to the Center for Advanced Transportation Mobility, a U.S. Department of Transportation (U.S. DOT) Tier 1 University Transportation Center in which VTTI is a key partner. The collaboration described in this proposal is one part of a continuing series of close partnerships between researchers at VTTI and North Carolina A&T State University over the past several years.
- **Blacksburg Transit** – Blacksburg Transit is a progressive transit provider serving the New River Valley and Virginia Tech, and a leader in transit technology including data collection, management, and distribution.
- **TransDev** -- The largest private provider of multiple modes of transport in North America and part of a global operation spanning 20 countries on five continents. TransDev operates bus, paratransit, bus rapid transit (BRT), streetcar, ferry, coach, taxi, and private driver shuttle mobility services serving 200 cities and communities with more than 200 million passenger trips yearly.

Through prior project experience, as well as recognition and study of emerging issues, the project team has gained a keen appreciation of the difficult issues facing transportation-challenged individuals. In formulating this demonstration, we targeted those issues that are most likely to hinder or prevent the adoption of ADS. The complex issues confronted by the proposed effort include rider safety and security, trust in automation, remote vehicle monitoring, accessibility, intermodal connection protection, and trip planning (Figure 1-2).

These and other issues are currently being investigated piecemeal in smaller studies conducted by many on the project team and elsewhere. This demonstration offers an extraordinary opportunity to gain insight on a host of factors that may affect the adoption of ADS in a comprehensive demonstration where relevant data will be collected to inform future policies and provide definitive proof of concept.

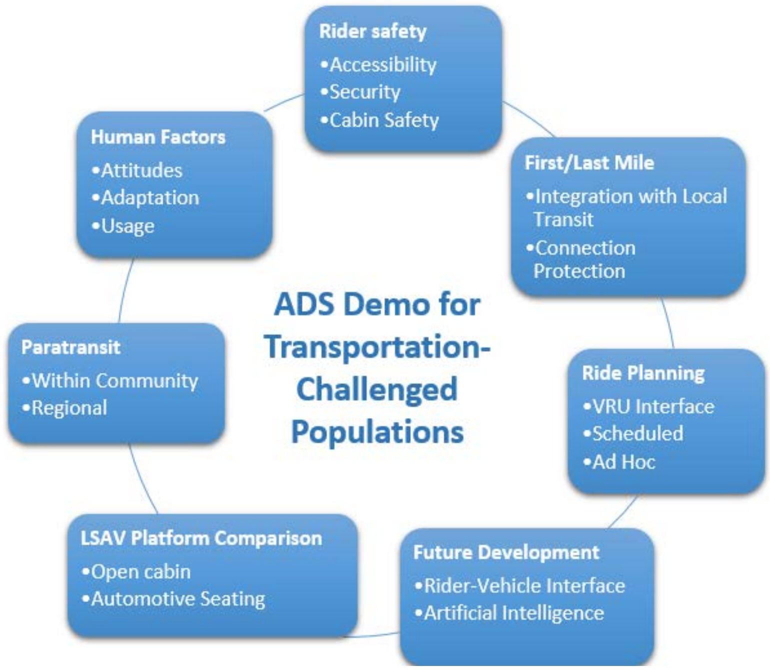

Figure 1-2. Key components of the proposed effort.

To accomplish this goal we will implement a fully functional LSAV-based mobility system serving the WHV retirement community located in the town of Blacksburg, Virginia. This unique setting provides a mix of rural and urban environments; a cross-section of socio-economic status demographics; weather and terrain obstacles; friendly local, regional, and state jurisdictions; and close proximity to the demonstration coordinator, VTTI.

Primary Project Goal: Demonstrate how LSAVs may be deployed as part of a comprehensive and integrated transit system, affording flexible mobility to transportation-challenged populations.

This demonstration will be planned, developed, and conducted over the course of four years to provide for the progressive implementation of LSAVs in semi-private and public environments and in a manner that will allow the project team to characterize the longer-term trends related to client acceptance and usage, mobility system performance, and economic and functional feasibility when compared to conventional analogues such as paratransit. The primary metrics of demonstration performance will include safety, level of service, client satisfaction, and comparison of capital and operational costs.

A timeline of planned activities and tasks is included in Table 1-1. Details associated with these plans may be changed per guidance from the sponsor's Authorized Organizational Representative (AOR) or as project exigencies emerge.

Table 1-1. Demonstration of a Transit-Integrated Automated Driving System: Project Timeline

		Project Months																	
Task Description	**Due Date After Task Award (ATA)**	**1**	**2**	**3**	**6**	**9**	**12**	**15**	**18**	**21**	**24**	**27**	**30**	**33**	**36**	**39**	**42**	**45**	**48**
Task 1. Initiate Project																			
1.1 Kick-off Meeting	3 Weeks																		
1.2 Project Management Plan	5 Weeks																		
1.3 Data Management Plan	2 Months																		
1.4 Project Evaluation Plan	3 Months																		
1.5 Quarterly Progress Reports	Quarterly																		
1.6 Annual Budget Review and Program Plan	2 Months Prior to Anniversary of Award																		
1.7 Annual Budget Review and Program Plan Meeting	1.5 Months Prior to Anniversary of Award																		
Task 2. Procure LSAV Vehicles																			
Task 3. Establish Environment & Infrastructural Elements																			
Task 4. Implement LSAV Modifications and/or Technology Add-Ons																			
Task 5. Real-time Scheduling and Routing Algorithm Development & Deployment																			
Task 6. Secure IRB Approval																			
Task 7. Develop Smart Phone Ride-Hailing App																			
Task 8. Recruit Participants																			
Task 9. Implement ADS Solution																			
Task 10. Data Aggregation and Analysis																			
Task 11. Anticipated Outcomes																			

Goals

The goals of this effort directly align with those of the program, to enhance safety and mobility for seniors and to provide data-driven support for governmental rulemaking bodies shaping the successful rollout of ADS into the U.S. fleet, infrastructure, and society at large.

Safety

Safety and mobility are the primary focus areas of the proposed demonstration (Figure 1-3). We must seek ways to increase safe mobility, especially for seniors, for whom maintaining mobility is the key to independence, aging in place, and sustaining the potential to enjoy a fulfilling life. ADS technologies are poised to be able to facilitate enhanced safe mobility for this rapidly growing segment of our population.

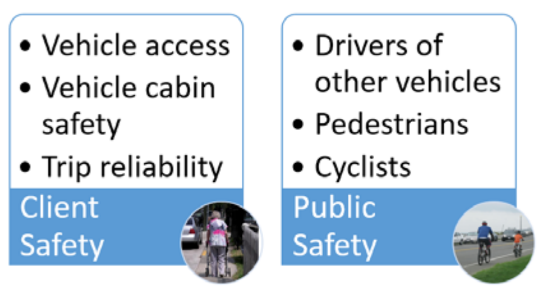

Figure 1-3. Safety priorities.

The proposed demonstration program will be implemented at WHV, a comprehensive retirement community that provides a continuum of care for the varying needs and conditions of its approximately 600 residents. The short and long-term safety of the residents, as well as all others on the WHV premises, is our primary concern, and we will closely collaborate with WHV leadership and staff on every step of the demonstration. The deployment of LSAV technologies will enhance mobility options and trip efficiency for many within this community, and, ultimately, these constructs, lessons learned, and best practices can be implemented within many similar facilities around the country. Not only are we looking at using ADS to prevent vehicular crashes, but we are also keenly focused on the safety of occupants within the ADS during non-crash safety-related events (e.g., when the shuttle stops short to avoid hitting a pedestrian or other perceived obstacle). The manner of safely restraining riders will be crucial, as will adhering to the stipulations of the Americans with Disabilities Act (ADA) throughout the development and deployment process.

Safety is also of paramount importance during the conduct of the study itself. All study protocols will be vetted and approved by the Virginia Tech Institutional Review Board (IRB) before any steps are taken to fulfill the demonstration. In addition to securing IRB approval, care will be taken by the team to assure safety with the stepwise nature of the implementation, featuring, at least initially, onboard support staff as well as remote human monitors who will be enabled and empowered to observe and stop the vehicle if necessary. It is anticipated that this implementation will demonstrate the viability and enhanced safety and mobility for seniors and others within a retirement community setting.

Data for Safety Analysis and Rulemaking

The project team is committed to sharing key safety-critical event (e.g., high g-force) data in as close to real-time as feasible. Other data will be uploaded in regular batch updates to a secure data repository featuring Web-based access. The VTTI team has strong experience with sharing data. For example, the InSight website (https://insight.shrp2nds.us/) was developed and implemented to provide qualified researchers across the globe access to high-level data within the SHRP 2 NDS database. Access to personally identifying information (PII) collected in the currently proposed effort will be governed by role-based security protocols, as appropriate. Aggregate data, scrubbed of all PII, will be posted to a website without access restriction. The project team will collaborate with the AOR to determine best practices in terms of format, access/security, timing, and periodicity of the sharing of project data.

Data collection will include data on rides provided (in aggregate) as well as rides taken by individuals, with known entry and disembarkation points. Safety metrics will include a variety of incident types. First, at the LSAV level, crashes, near-crashes, and other safety-related incidents (such as high-g-force stops) will be logged by the onboard data acquisition system (DAS) and analyzed. All problems or incidents participants experience while gaining access to the vehicle and getting securely seated will be logged as well. Incident numbers and rates (i.e., per person year, per trip, per mile traveled) will be compared with similar data collected prior to the implementation, providing a safety baseline for ADS implementations in this particular type of environment. Periodic surveys will ask riders how they feel about the implemented solution and how it has enhanced their safety, mobility, security, independence, and quality of life. Onboard cameras will capture access and egress, as well as onboard behavior and movement (i.e., especially during sudden, urgent higher g-force events). These data will directly inform governmental and other stakeholders in terms of rulemaking priorities.

Collaboration

The proposed demonstration will be a collaboration across higher education, state and local governments, state and local transportation agencies, automated vehicle manufacturers, and, most importantly, a full-service retirement community (Figure 1-4). VTTI, the largest transportation research center in the nation, will lead this collaboration. The principal investigator (PI) Andrew Alden, Center for Infrastructure-Based Safety Systems, and co-PIs Jon Antin, Director of the Center for Vulnerable Road User Safety, and Miguel Perez, Director of the Center for Data Reduction and Analysis Support, will lead the project. These leaders and their respective centers bring the right expertise and integrated focus areas to fulfill the goals of this project: infrastructure, vulnerable road users (VRUs), and Big Data analytics.

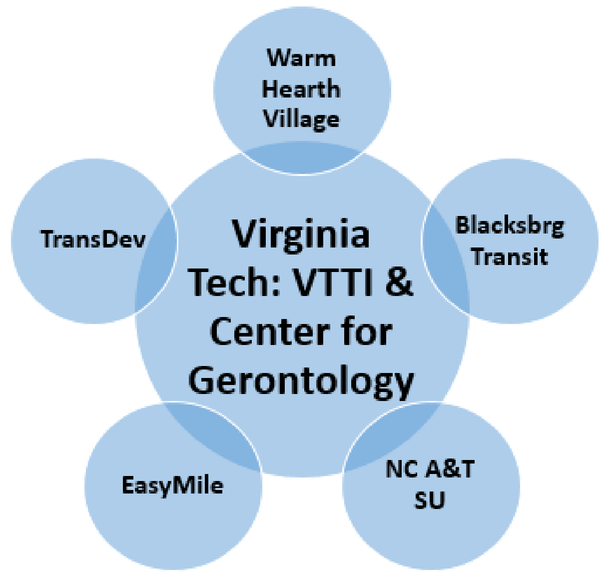

Figure 1-4. Organizational relationships demonstrate the collaborative effort.

In addition, this effort could not be accomplished without substantial, integrated collaboration across several organizations outside of VTTI, including two universities (Virginia Tech and North Carolina A&T State University, the largest HBCU in the nation); the Virginia Department of Transportation – Virginia Transportation Research Council; a private company, EasyMile; and a non-profit agency, WHV, a full continuum of care retirement community.

Focus Areas

Assuring safe mobility for seniors, one of our most transportation-challenged population groups, will continue to grow in importance as our society ages over the next several decades. Providing robust transportation, especially for those seniors who no longer can or no longer wish to drive, affords the opportunity for independence and aging in place, two key aspects of aging with dignity. The proposed implementation will clearly demonstrate how an ADS—an LSAV in this instance—can be deployed to greatly expand and enhance safe mobility for seniors living within a retirement community setting, and it will illustrate how such technologies might be deployed in other types of environments as well. While similar technologies have been implemented as parts of transit systems in Europe and elsewhere, market forces have failed to address the special and varied needs of seniors in such implementations. This is the goal of the proposed project (Table 1-2). One reason the market has failed to produce consistent results in this arena is the extreme complexity involved. Serious questions relating to safety, in-vehicle stability, security, access/egress, routing, hailing, acceptance, wheelchair suitability, and dementia must be addressed. These are included within the goal structure of the proposed effort. Assuring safe mobility for seniors will also have a major impact on economic vitality. This group, especially Baby Boomers, will have unprecedented buying power, but safe transportation will be crucial to fulfilling their potentially massive impact on the economy.

Table 1-2. How We Are Addressing Key Focus Areas

Key Focus Area	**How Focus Area is Met by Proposal**
Significant Public Benefit(s)	Enhances safe mobility for seniors and other transportation-challenged populations; can be extended broadly.
Addressing Market Failure and Other Compelling Public Needs	Market forces have thus far failed to address special and varied needs of seniors. The proposed project sets a path for success and broad implementation.
Economic Vitality	Assuring safe mobility for seniors in an aging society will have a major positive impact on the economy and help to avoid the enormous negative economic consequences if we fail to successfully address this problem. ADS are expected to be a major part of any successful solution for seniors and all other transportation-challenged populations.
Complexity of Technology	Many complex and interrelated problems must be resolved to achieve successful implementation and dissemination. This project affords the opportunity to fully explore and address these complex issues.
Diversity of Projects	The proposed focus on transportation-challenged populations will complement demonstration projects in other domains such as personal ADS vehicles, commercial ADS-based platooning, ADS impacts on the environment, and throughput.
Transportation-challenged Populations	Set primarily within a retirement community, the proposed project is squarely focused on the application of ADS to enhance safe mobility for seniors and other transportation-challenged populations.
Prototypes	Fully functional LSAVs will be modified and developed as prototypes for meeting the special needs of transportation-challenged populations, especially senior riders.

Demonstration Requirements

Our proposed demonstration satisfies each of the requirements contained in Section A of the Notice of Funding Opportunity (NOFO). These will be clearly delineated in detail within the text of the proposal. However, in addition we will address each of the requirements in brief here. First, our proposed demonstration will involve the physical deployment of a fully functioning LSAV (SAE level 4) within a retirement community setting. The Draft Data Management Plan (Part 3) includes plans for how all the data will be collected and shared with the U.S. DOT for at least ten years after the expiration of the project. Our planned implementation will include user interfaces within the LSAV shuttle, as well as on a ride-hailing smartphone app. Each will be tailored to the unique needs of the senior population. Once the implementation has been shown to be successful, issues encountered and solutions devised will be shared broadly to facilitate the rapid deployment of ADS technologies to facilitate safe mobility for seniors and other mobility challenged individuals and communities.

Approach

The following tasks summarize the expected technical approach that will be used to gather data and support the ADS demonstration. As previously noted, the focus of this proposed research is to gather data and demonstrate the feasibility, benefits, and risks of using ADS technologies to support the transport of seniors living in and commuting near WHV, home to over 600 resident seniors ranging in ability from those requiring 24-hour nursing care, through varying levels of assisted living, to active adults. Authorization from NHTSA is required before any autonomous vehicle can be operated on public roads. VTTI is already in the process of seeking this authorization for the LSAV implementation on its campus, thus, we will be well suited to commence implementation as described in this proposal in the near future

The demonstration will be conducted in three progressive phases over four years using two distinctly different LSAV platforms as illustrated in Figure 1-5. The use of two vehicle types will provide operational and research benefits as described in Task 2 below. In general, for both vehicle types:

- Route types for both vehicle types will progress from restrictive point-to-point, to more flexible point-deviation, to fully on-demand (ad hoc) operation.
- Ride scheduling will progress from fixed times to a hybrid of fixed and demand-responsive service, to fully demand-responsive service.

The two platforms differ in their ability to accommodate riders with special needs, which will require that the scheduling system account for their individual dependency level. This also dictates that an onboard attendant will always be present on the more accessible EZ10 to assist passengers and ensure operational safety. Because issues regarding the need for onboard attendants or safety drivers are integral to this demonstration and its provision of providing rulemaking data to the Federal Highway Administration (FHWA), later phase operations in the EasyMile GEM will be performed using a remote safety operator. The absence of an onboard safety operator requires that all riders be fully independent during that phase of demonstration.

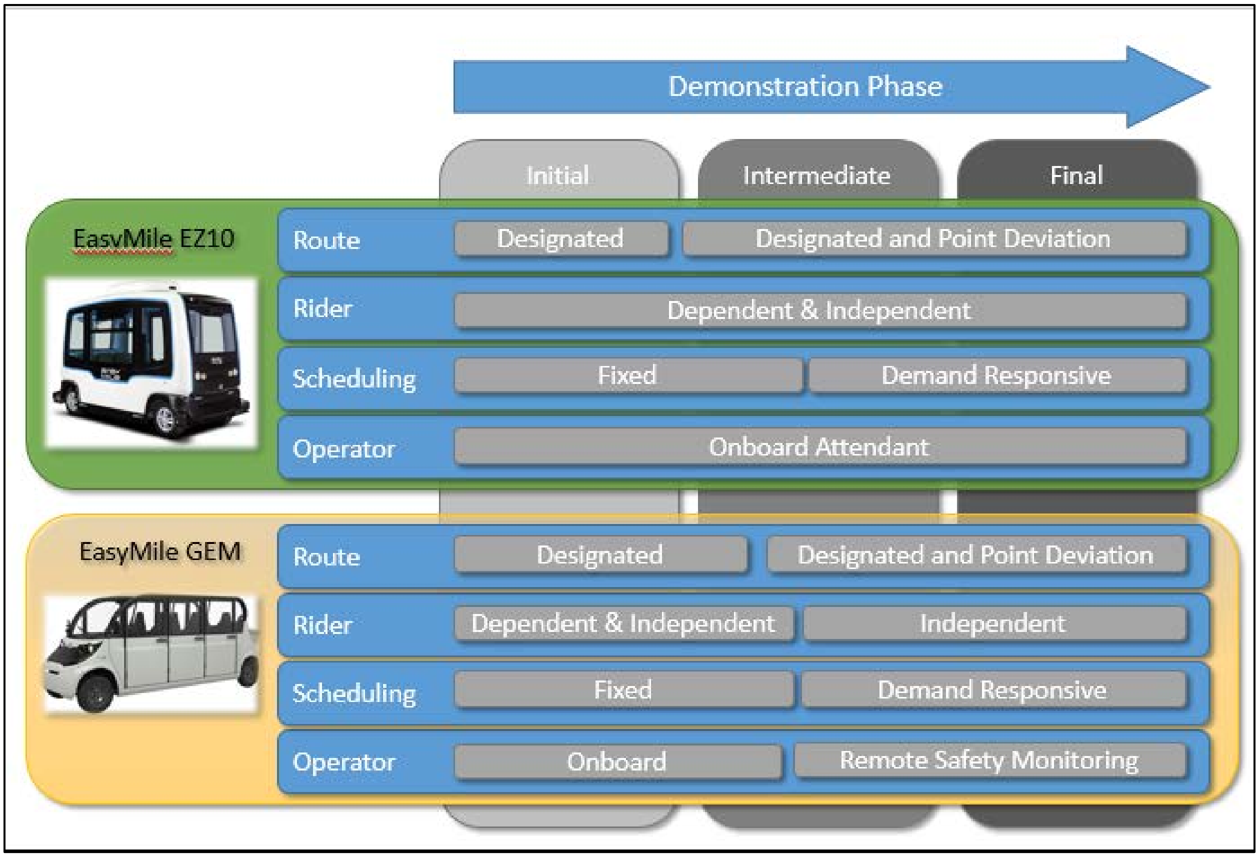

Figure 1-5. The demonstration will be performed in phases which may involve criteria changes and rider eligibility.

Task 1: Initiate Project

Task 1 incorporates the following study deliverables and will be initiated upon the successful notification of award. An Implementation Plan will be developed for all tasks as discussed below:

Kick-off Meeting with Sponsor

Within three weeks after the date of award, a kick-off meeting will be scheduled with the sponsor's AOR at a mutually agreeable location or via other virtual media.

Determine Data to Be Collected

A variety of sources will be tapped in support of FHWA's mission to facilitate sound rulemaking based on actual data collected from a real-world implementation. The types of data to be collected will be determined in conjunction with the sponsor's AOR during planning phases of the project. Strong candidates include rider demographics, rider trips, focus groups, rider attitude, LSAV in-vehicle incidents, and LSAV crash/near-crash/high g-force events.

- Rider Demographics – Factors here will include age, gender, race, ethnicity, family status (e.g., marital status, children), country of origin, health/medical conditions, medications, disabilities, slips/trips/falls history, driving history, and WHV information (e.g., which type of living arrangement, how long they have lived there).

- Trips Provided – The operational data tracked for each LSAV and each rider-participant will include number of trips taken overall and over time, trip rates (i.e., per day, week, or month), trip origin and destination, and trip duration.
- Rider Attitude – Rider-participants will be given regular opportunities to express attitudes towards the LSAV, including factors of trust, acceptance, and trepidation. Information will be collected up front, prior to riding, and during the course of the demonstration so we can evaluate how attitudes, acceptance, and trust change over time and usage rates.
- Focus Groups – The development and evaluation of the Part-time Autonomous Wheelchair System (PAWS) will be informed by an initial focus group of wheelchair users who could be users and beneficiaries of this technology. A second group of users that have experienced the system will also be convened to understand reactions to the system features and gather suggestions for future improvements.
- LSAV In-Vehicle Incidents – Slips, trips, and falls while in the vehicle as well as during access or egress will be counted and investigated to determine precipitating and contributing factors in each case.
- LSAV Crash/Near-Crash/High g-Force Events – Each crash that the LSAV experiences will be counted and investigated to determine precipitating and any contributing factors. A crash is determined to have taken place where the LSAV makes contact with a vehicle, pedestrian, bicyclist, animal, or any other object. In addition, the onboard DAS permits a unique form of data collection whereby some near-crashes can also be detected via recorded video and kinematics data analysis. A near-crash is defined to have taken place when the LSAV (or another entity) was forced to make a radical maneuver to avoid a crash. High g-force events are measured by the inertial measurement unit onboard the DAS and will be cataloged as well.

Project Management Plan

In the two weeks following the kick-off meeting, a detailed Project Management Plan will be submitted to the AOR. The Project Management Plan will incorporate the following elements:

- Statement of work including task and subtask descriptions
- Project schedule which visually outlines tasks and due dates for completion
- Project milestones and description of deliverables with anticipated dates for completion to include:
    - Reports (special and quarterly)
    - Important dates representing select phases of the project or key events
- Staffing table to include project manager as well as project team members and consultants associated with the relevant task(s) to which they are assigned
- Project budget to show planned expenditures per task, cost element breakdowns by task, and Federal versus non-Federal share.

Data Management Plan

Within 60 days of project award, the Draft Data Management Plan included as Part 3 of this proposal will be updated to include the following:

- Detailed description of how data will be managed during and after the project, including both public and non-public data to be shared with the U.S. DOT and in accordance with paragraph 7.4.2 of the U.S. DOT Public Access Plan
- Delivery of data and documentation

The Data Management Plan will be updated throughout the project as protocols are refined.

Project Evaluation Plan

Within 90 days following the successful award, a Project Evaluation Plan will be submitted which includes:

- Statement of project objectives
- Evaluation criteria whether qualitative or quantitative metrics as they relate to project outcomes
- Description of data collection procedures including metrics or tools used to monitor data collection, whether kinematic, from surveys and interviews, etc.
- Outline of evaluation report
- Description of data system

Annual Budget Review and Program Plan

Within 60 days prior to anniversary date of award, a budget review and program plan will be drafted.

Annual Budget Review and Program Plan Meeting

Within 45 days prior to anniversary date of award, a budget review and program plan meeting will be scheduled.

Task 2: Procure LSAV Vehicles

Two distinct LSAVs will be used in the demonstration: the EasyMile EZ10 and the EasyMile GEM. This approach is planned to best address the diverse travel and accessibility needs of the community and to better inform subsequent safety analysis and rulemaking efforts. Figure 1-6 provides a comparison of the major features of the two LSAVs. The EZ-10 is one of a new generation of open-cabin type shuttle vehicles that are seeing increased usage worldwide. It has a capacity of 15 passengers with six seated and nine standing. It is a battery-electric vehicle that features four-wheel drive and steering that yields clean and quiet efficiency with high hill-climbing traction and maneuverability. The EZ10 also lowers, or “kneels,” when a built-in entrance ramp is extended to provide enhanced accessibility. The EZ10 features an onboard, electrically operated system for securement of personal mobility devices such as wheelchairs. The vehicle also features SAE level 4 driving automation with fixed-route and on-demand (e.g., demand-responsive and point deviation) operational capabilities.

In an ongoing two-year collaboration, VTTI has acquired an EasyMile EZ10 and is in the process of performing the route preparations and extensive training currently required to implement and operate the LSAV to support a transit-integrated first/last-mile mobility study that focuses on VRUs. Figure 1-7 shows the vehicle path between the nearest Blacksburg bus stop and the VTTI campus that will eventually shuttle VTTI students and staff along the half-mile route.

The EasyMile GEM is a more conventional LSAV built on the Polaris GEM platform. It has an automotive-style cabin with forward-facing seating. It has two-wheel drive and steering, along with six conventional hinged doors serving six individual seats. While this cabin and seating configuration may not be as flexible with respect to accessibility, there may be advantages for those seeking more-defined personal space and the safety of conventional seat belts secured to automotive-grade seats. The vehicle also features SAE level 4 driving automation with fixed-route and on-demand operational capabilities. The EasyMile GEM is also significantly less costly than the EZ10.

LSAV Comparison		
	EasyMile EZ10	**EasyMile GEM**
Cabin Configuration	Open	Automotive Style
Directional Ability	Bidirectional	Unidirectional
Drive Configuration	4-Wheel Drive	Rear Wheel
Steering Configuration	4-Wheel	Front Wheel
Seating	Perimeter - Inward Facing	Forward Facing
Entry/Exit	Single Entry Point – Dual Opposed Sliding Doors	Six Conventional Forward-Hinged Doors
Access	Extendable Ramp, Kneeling	
Cabin Securement	Wheelchair Only	Seat Belts

Figure 1-6. Each LSAV vehicle features unique configurations.

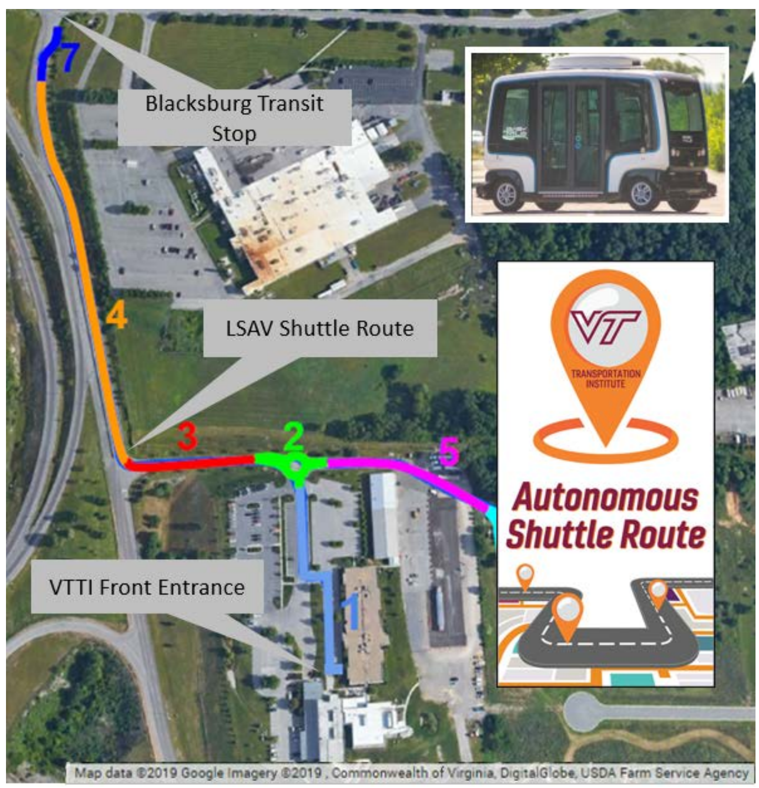

Figure 1-7. Autonomous shuttle route project already in progress at VTTI.

Task 3: Establish Environment & Infrastructural Elements

Several significant steps are required to implement the project, including significant coordination with project partners to prepare the site, route, and other infrastructural components.

Close Collaboration with WHV

Dr. Brossoie of the Virginia Tech Center for Gerontology has a history of working with WHV leadership, staff, and residents as stakeholders in prior research focused on resident healthcare, housing, use of robotics in healthcare, and staff training needs. Her working relationship has included community participatory engagement in which residents and leadership are engaged with the research team in generating research questions, goals, and strategies, and providing feedback on a regular basis.

Dr. Brossoie also serves as a member of the WHV Research Oversight Committee that approves research projects in the community led by area faculty and students. WHV residents are typically genuinely interested in meeting the needs of future residents. As a result of that dedication, they frequently participate in research projects. Because WHV leadership also recognizes the value of resident and community-wide participation in research, the community is an ideal partner for this project.

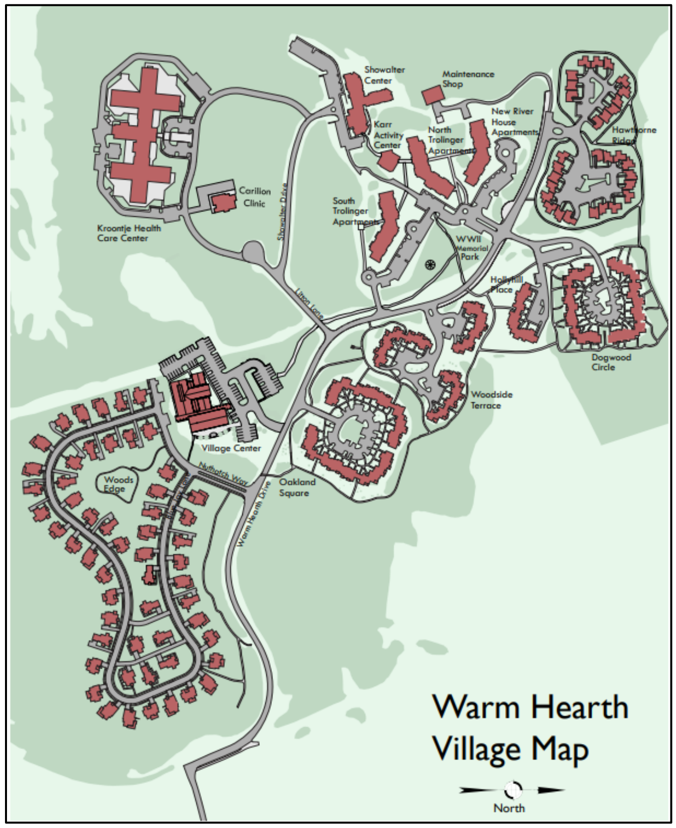

Figure 1-8. WHV map showing spatial relation of residences over 220 acres (from Warm Hearth Village, 2019).

Warm Hearth Village (WHV) and Other Key Locations

Demonstration Setting. The setting for this study is the New River Valley (NRV) region of Southwest Virginia, a non-urban area in the southcentral portion of Virginia's Appalachian mountain range. The NRV spans 1,458 square miles and is home to approximately 184,000 people residing in five county jurisdictions (Radford, Pulaski, Floyd, Giles, and Montgomery). Town populations range from less than 100 to over 40,000 residents. The NRV boasts two major universities (Virginia Tech and Radford University), which are located along the US Interstate 81 corridor. The student population in Montgomery and Radford provides racial and ethnic diversity to the region, which is otherwise predominately White, non-Hispanic (94%) with a median age of 45. The population aged 65+ is notably aging in place. In Floyd, Giles, and Pulaski, older adults constitute 20%–22% of the population, a much higher percentage than found in student-occupied Montgomery County and Radford (10%–11%) and across Virginia (14.6%), which is expected to reach 20% in 2030. The NRV is ideally located and situated to study the challenges and needs of the older population because they are currently experiencing the same challenges with mobility that are anticipated for older adults nationwide in the future.

Community of Focus. Within the NRV is WHV, a continuing care retirement community located on 220 acres in Montgomery County near Virginia Tech (Figure 1-8). The mission of WHV is "to enrich the lives of seniors of all socioeconomic backgrounds through a wide range of choices in housing, services, and care." Its 600 residents represent diversity in socioeconomic status, educational background, and health care needs. WHV currently supports a staff of 305 employees, most of whom are employed in its two nursing facilities serving 200 residents. The remaining 400 residents live independently and occupy 314 apartments, townhomes, or single-family dwellings. They are typically active in the WHV community and the surrounding NRV. Many residents include retirees from academia or the parents of current faculty members at Virginia Tech and Radford University.

Community Engagement

The research team will engage the community in the use of LSAV vehicle(s) using a strengths-based community-capacity building approach that builds on the available knowledge, interest, awareness, and perceptions of utility among community residents and the community infrastructure (Davenport & Seekamp, 2013). Our multi-level collaborative engagement of residents, staff, and community leaders will occur in phases to gain a better understanding of the implementation and community adoption processes needed to be successful in program implementation (Kollmann, 2004; Mancini et al., 2005). We will utilize an ongoing evaluation feedback loop, which is unlike typical community projects in which researchers have an idea and seek assistance from communities for task-specific preassigned activities (e.g., access to data). Our proposed side-by-side collaboration has emerged from identified community needs and interests, which naturally aligns with the expertise of our research team.

After the groundwork has been laid for successful implementation, the research team will provide a series of introductory education and awareness workshops throughout the campus to familiarize residents and staff with the project as well as the vehicle and its planned operation on campus. Community leadership will support and help coordinate each session, which will be led by members of the research team. The interactive sessions will familiarize residents with the vehicle and provide demonstrations of its operation. At each session, participants will also receive project information and individuals wishing to utilize the vehicle will be matriculated into the program under the oversight of the Virginia Tech IRB. Enrollment in the program will also be available on an ongoing basis. All persons enrolled in the program will be able to use the vehicle free of charge.

Each person will be issued a means of electronic identification (i.e., a card with a readable magnetic strip or a radio frequency identification [RFID] device embedded in a card or wearable fob) to enable the collection of ride tracking data at an individual level.

Participant and community level data will be collected on a regular basis through an established feedback loop. Riders will be routinely asked about their satisfaction with their trip and the transit system so that alterations to the system can be made quickly if warranted. After each operational phase of the project ends, participants and community leaders will also be asked to rate their acceptance of and trust in the vehicle, and the perceived safety of the vehicle and the transit service. The resulting panel data from multiple informants will be used to refine each iteration of implementation.

Connectivity to Key Locations Outside of WHV

WHV transportation staff report that residents typically require transport to several key locations in the region that may be accessed either by LSAV or connection to Blacksburg Transit. A medical complex that includes a regional hospital and other medical offices is located about one mile southeast of WHV. The Blacksburg Transit stop nearest to WHV is also located in the hospital parking area. A large shopping area lies several miles south of WHV and hosts a regional mall, several multi-national retail chains, grocery stores, many restaurants, and other retail locations. Kroger grocery and other retail/restaurant locations, as well as a large movie theatre complex, are located several miles northeast of WHV. Located just east of, and adjacent to WHV, is access to a rail-to-trail walking and cycling path. The locations of WHV and these other sites, as well VTTI nearby, are shown on the map in Figure 1-9.

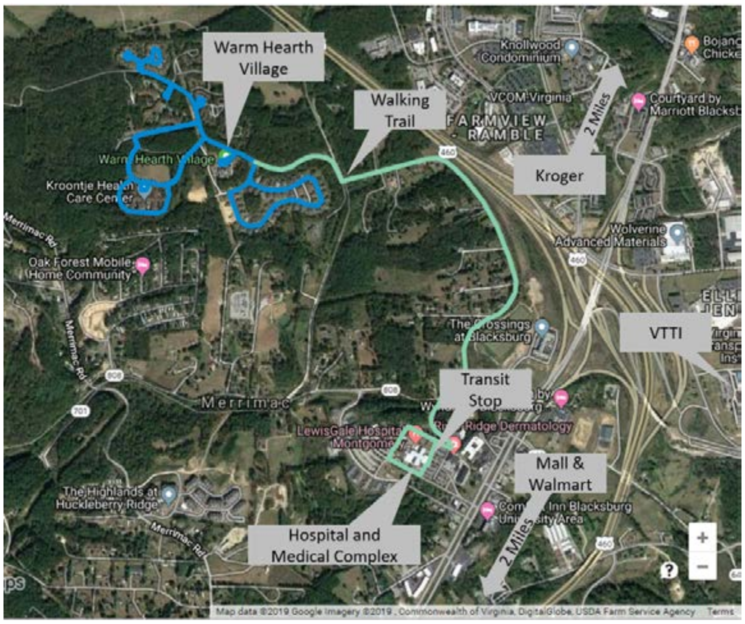

Figure 1-9. Map of demonstration locality.

Establish Infrastructural Elements

In order to establish safe and reliable operation of an LSAV within the boundaries of the facilities, the research team will perform a comprehensive review of the routes and their environments. The review will divide the routes into segments in order to identify the potential interactions the LSAV could encounter and identify unique challenges that each segment presents. Mitigation strategies will be developed for each segment in order to address these challenges, as well as an analysis of the criticality of the challenges and any factors that could compound the challenges. The mitigation strategies will focus heavily on infrastructure updates that will remove the LSAV from hazardous interactions, protect the LSAV against hazardous interactions, or warn nearby vehicles and pedestrians about potential hazardous interactions. The infrastructure updates will also serve a dual purpose of providing routing assistance to the LSAV and improving reliability (for example, a sign notifying traffic about an autonomous vehicle being in operation can also serve as a navigational way point for the shuttle itself).

Signpost Guides

The LSAV's primary method of localization (i.e., understanding its current location relative to its destination) is through signposts. These signposts will be positioned in key locations that allow the vehicles to navigate each segment's unique road features. For example, relatively straight segments will require signposts approximately 200 feet apart, while curved segments will require signposts on the inside and outside of the curve. Both the height of the posts and the area of signage attached to the posts will be clearly defined to meet the visual requirements for LSAV localization.

Other Signage

In addition to navigation and localization, the comprehensive site assessment will identify signage needs for hazardous interactions between the LSAV, pedestrians, and other vehicles. This includes signage informing road users of LSAV operations, indications of LSAV routes, indications of changes in road characteristics, indications of changes in speed limits or lane markings, or other information which will help road users safely interact with the LSAV.

Charging Station

One major infrastructure need will be a charging station where the vehicle can be plugged in. This will require a special adapter, and preferably a sheltered location where the vehicles can charge without exposure to traffic or weather. The feasible charging locations will be identified during the comprehensive site assessment, and the best locations will be selected based on additional criteria such as space, traffic, and visibility considerations.

LSAV Garage

In addition to charging infrastructure, a secure location for storage and maintenance will be necessary. This location can also serve as a charging station, but other considerations may necessitate separate locations for charging and storage. The research team will assess feasible locations for garage storage during the comprehensive site assessment, and will select the best locations based on suitability.

Route Preparation

One final infrastructure consideration is improving existing roads or adding roadway in critical locations. This could be done to improve lane marking visibility, to add turnaround space at one or more stations, or to provide additional travel lanes on or around LSAV operation. The research team will consider improvement options as a way to address major safety concerns that are identified during the comprehensive site assessment, and will consider the needs of all road users when considering paving options.

Vicinity to VTTI

One important feature of the WHV site is that it is in close proximity to VTTI's research facilities. This allows VTTI's facilities to act as alternative charging stations or garage spaces and adds flexibility when testing and deploying the LSAVs. VTTI's close proximity also allows for rapid responses to issues encountered during testing or deployment with specialized tools and knowledge that may not be available at the on-site LSAV storage facility that will be constructed as part of the project.

Task 4: Implement LSAV Modifications and/or Technology Add-Ons

Modifications to LSAV

The research team anticipates that there will need to be modifications to the vehicle in order to ensure the specific VRU population in the research will be safe and comfortable. This could include monitoring and communication technology, physical modifications to the vehicle, or signs/notifications with context-specific information. The research team will conduct pilot research with representative participants to develop specifications for the safety and comfort of the expected users.

Remote Monitoring Technology

It will be important for the research team to monitor the vehicle remotely in order to handle edge cases or adverse events quickly and safely. The research team sees three main areas that will need to be addressed as part of the research effort: onboard vehicle monitoring, remote operator shutdown, and communication. The research team will have a trained operator either onboard the vehicle or directly connected to the vehicle via onboard monitoring at all times. The trained operator will have authority to override the vehicle's controls in order to safely navigate a situation which the vehicle cannot navigate. It is expected that the team will encounter edge cases which require remote operator control during research, and understanding how these situations impact user trust will be critical to the research effort. The trained operator will also have the capability to shut down the vehicle if any situations dictate this for safety or a user wishes to leave the vehicle for any reason. As part of defining the functional safety requirements of the vehicle, the research team will define the safety criteria for shutting down the vehicle. Finally, the research team will define the communication requirements for users of the shuttle. This will include communication in order to summon or schedule the vehicle, communication prior to entering the vehicle, communication within the vehicle, and communication when exiting the vehicle. The means of communication (video, voice, text, etc.) will be defined for different situations, as well as mediums of communication (digital displays, touchscreens, speakers, etc.).

Onboard DAS

VTTI has experience instrumenting sensors, cameras, monitoring equipment, communication equipment, and DASs in a variety of vehicles. The research team plans to instrument additional equipment beyond the LSAV's onboard sensors in order to facilitate research into human-machine interactions, LSAV-traffic interactions, and LSAV-pedestrian interactions. The research team will review the research requirements and design a custom DAS solution to meet the study's needs. The research team expects that the DAS will include independent kinematic sensors to verify speeds, decelerations, and lateral/longitudinal forces within the LSAV. The research team also expects the DAS will include cameras to monitor users within the LSAV, vehicle traffic around the LSAV, and pedestrian traffic around the LSAV. The DAS is configurable and decisions will be made with the AOR to see if other sensors, cameras, or capabilities should be considered for inclusion.

Additional LSAV Safety Considerations and ADA

Occupant safety will be a primary focus of this demonstration project. The public allowance for breakdowns in safety as it pertains to autonomous vehicles is much stricter than for traditional means of transportation. Therefore, it is imperative to ensure that not only "traditional" risks (e.g., collision with another vehicle) are identified and mitigated, but that novel risks emerging from new use cases (e.g., vehicle failing to provide sufficient time for a passenger to enter and fasten their seatbelt) are carefully considered. These novel risks are the focus of this section, and will have to be identified with an eye toward mitigation as we move through the process.

Passengers with disabilities due to age-related functional impairment or other conditions are expected to be a subset of the population that greatly benefits from LSAV technology. Therefore, these risks have to also be considered in the context of passengers with different types of abilities. Existing laws are helpful in this regard. Particularly, the ADA addresses the needs of people with disabilities, prohibiting discrimination in employment, public services, public accommodations, and telecommunications. Specifically, the ADA Accessibility Guidelines for Transportation Vehicles serve as the basis for enforceable standards implemented by the U.S. DOT. Unfortunately, most, if not all, current LSAVs fail to comply with ADA guidelines.

The team will use well-established hazard detection and classification approaches to perform a complete analysis of potential hazards present to passengers during the LSAV operational envelope suggested for this demonstration. The analysis will consider access to the LSAV, egress, emergency egress, and emergency response protocols. While it will be unfeasible within the scope of the demonstration to perform a full crashworthiness analysis (i.e., including crash testing), part of the assessment will include the ability of the LSAV to provide crashworthiness countermeasures (e.g., seatbelts, wheelchair attachments) that are in line with other public transportation options. Physical differences among the LSAV and comparable traditional options are expected to be important. For example, a public bus and an LSAV operating in the same way and exposed to the same crash or emergency braking scenario are likely to expose riders to different deceleration levels due to their marked differences in vehicle mass and means of securement.

Within these activities, the team expects to devote considerable attention to wheelchair users, 3.6 million of which live in the U.S. (not including 11.6 million individuals using a cane, crutches, or a walker) (PantsUpEasy, 2016). In a recent study (Bezyak, et. al, 2017), 7.6% of wheelchair users reported an inability to secure their wheelchair as a barrier encountered while using public transportation systems. Over 17% of users reported problems with the lifts to access the vehicle. Of course, an LSAV without an operator may exacerbate these and other issues, since an immediate response, and particularly action, may not be available. Therefore, we propose, under this demonstration, the development of a system that potentially mitigates many of these issues.

The system is referred to as the Part-time Autonomous Wheelchair System (PAWS). The team will design, develop, and prototype PAWS as an add-on system for an existing wheelchair. The system will allow a wheelchair user that approaches an LSAV to switch to an autonomous mode. At that point, PAWS will (1) communicate to the LSAV that a wheelchair user is trying to enter the vehicle, (2) wait for confirmation by the LSAV that there is space available for the wheelchair, (3) wait for/verify the deployment of an ingress ramp at a suitable location, (4) navigate the wheelchair user to the section of the LSAV suitable for wheelchair restraint, and (5) facilitate the latching of the wheelchair to the LSAV, along with any necessary safety restraints for the wheelchair occupant. The process would be reversed when the wheelchair user signals a request to exit at the next stop. This concept could be applied readily to an electric wheelchair, and the add-on approach would greatly increase the potential number of users and reduce cost. The periodic nature of the use should allow the team to maintain power supply and electric motor loads at reasonable levels so that the usability of the wheelchair in traditional environments is not hindered. The design of PAWS will be completed by an interdisciplinary team of engineers at VTTI well versed in interface design, mechanical and electrical systems, control algorithms, sensors, and communication protocols. The design and development process will be informed by an initial assessment of wheelchair user needs, an assessment of the LSAV's capabilities, and identification of resulting gaps.

Data obtained from these activities will include perceptions of passenger safety (from surveys). Focus groups will also be conducted with wheelchair users during the design phase and after the demonstration. These focus groups may be recorded for later transcription. Notes from the focus group moderator that indicate summaries of passenger perceptions may also be stored.

Security Concerns

The team will also identify and develop mitigation strategies for security concerns that may be present for LSAV passengers. Mitigation strategies will draw from (1) existing deployments, if available, (2) "people mover" deployments (PantsUpEasy, 2016), and (3) local, regional, and state police organizations with experience of crime in low-density areas (which could potentially be more representative of the conditions in which these LSAVs will operate). Some logical mitigation options are expected to include (1) ability of passengers to easily indicate an emergency—with immediate notification to local authorities, (2) ability of passengers to quickly communicate with a remote operator to request assistance, (3) presence of cameras and microphones (and salient labeling) that indicates that the area in and around the LSAV is continuously monitored, (4) ability of the remote operator to talk to passengers at any time, and (5) increased lighting at LSAV stops so that nighttime operation is supported.

Data obtained from these activities will include perceptions of passenger security (from surveys and focus group activities).

Task 5: Real-time Scheduling and Routing Algorithm Development and Deployment

Coordinated Blacksburg Transit Plan

We will develop paratransit vehicle routing and scheduling algorithms to efficiently pick up riders from the WHV campus and drop them off at nearby locations, and vice-versa. Specifically, we are looking at multimodal solutions where the LSAV (not configured to travel at higher speed) coordinates with the prescheduled arrival of other modes of transit vehicles. This problem can be conceived in static as well as dynamic perspectives. While the static problem keeps a set of original solutions, the dynamic version extends the solution space further to consider unexpected cancellations or new requests while still meeting the time-based requirements of other riders (with their accessibility characteristics). We will investigate efficient formulation approaches by separating or combining scheduling and routing and find a balance between solution and computational efficiency for finding optimal solutions that accommodate rider needs with different accessibility characteristics, realizing the limited numbers of vehicles.

Static Formulation

The static version of the problem assumes that rider information is fully known, including all its input information for the time period (e.g., demand, travel times). This will be a static version of the vehicle routing problem with pickup and delivery within time windows (VRP-PDTW), where all the requests are known in advance (e.g., all the riders call at least one day before their desired trips in a VRP-PDTW scenario), and travel times are predictable. The traditional windows on pick-up time of inbound requests and on the drop-off time of outbound requests will be applied where passenger profile, pick-up location, and time of day may change the planned arrival time. As the trips are round trips, the outbound part of the trip will be planned a day in advance. On the return trip issues may arise at the appointment to change the time of pickup, such as a backlog at the doctor's office or a medical emergency such as unforeseen bleeding at a dialysis clinic.

Dynamic Formulation with Various Time Windows

We will extend the formulation to various time windows wherein *N* users specify pick-up requests between given origins and destinations. Users may provide a time window on their desired departure and/or arrival time. The aim is to design a set of least-cost vehicle routes capable of accommodating all requests under a particular set of constraints. We will formulate this VRP-PDTW using stochastic methods to account for a cascading effect of scheduling. The main objective will be minimizing the cost (e.g., operation cost or delay cost) constraints on (i) waiting time at each location; (ii) upper bound on route duration, service duration, and service beginning time; and (iii) required return time to WHV. The algorithm can be executed once at the beginning of service. In a dynamic version, passengers call for trip requests throughout the day. Thus, the vehicle routes and schedules are adjusted in real-time.

Solution Search with Real-time Application

The sequential implementation of the static model will inform the dynamic model solution. The previously developed insertion algorithm will be extended to accommodate the online adaptation to the new requests. Compared to previous research, the uncertainty in on-time arrival provides complexity in the time windows that will make the solution search challenging. The main complexity comes from the inclusion of service duration as a factor of the ride requests, doctor's appointments, weather, and locations. Starting with existing commercial solutions, we will find heuristics to resolve the problem of dimensionality.

Task 6: Secure IRB Approval

The Virginia Tech IRB will thoroughly review and vet all study protocols from an ethical perspective and to ensure protection for the rider-participants and their data. IRB approval is necessary prior to initiating any of the planned activities involving rider-participants, including contacting or recruiting them. The protection of participants and the integrity of their PII in the conduct of research involving human subjects is of paramount importance. These protections extend beyond the elimination or mitigation of risk to all aspects of the study, including all recruiting materials and participant consent forms in such a manner that the study purpose, procedures, risks, potential benefits, and compensation scheme are clearly articulated and communicated to potential participants. Further, prospective participants are afforded adequate time for review of consent forms before providing written consent.

The research team will explain all policies related to protection of participant data, as well as procedures for secure storage and responsible disposition of study data during and following the data collection period. In that interest, researchers will submit a thorough study protocol document to the Virginia Tech IRB, exhaustively detailing research questions to be explored and the methodologies to be employed in conducting the research and ensuring the privacy and confidentiality of participants and their data. Included with this submission will be all recruiting materials, assessment instruments, and the Informed Consent Form. No individual will be entered into any study protocol until she or he has signed the Informed Consent document. Once initial approval is secured, the study team will secure additional approvals of amendments from the Virginia Tech IRB for any adjustments made to study procedures or documentation.

Accommodating Non-Participant Riders

An important element of the IRB protocol will include determining how to handle non-participant riders. Provisions will need to be made such that suitable non-participants (e.g., spouses, children, healthcare attendants, or WHV staff) can accompany participants or otherwise ride the LSAV for legitimate reasons. In these cases, identifying information will be excluded and such non-participants will not be included in any subsequent data analyses.

Task 7: Develop Smart Phone Ride-Hailing App

A smart phone application and user interface will be developed to assist participants in scheduling shuttle ride services. Planned features of the app will include an LSAV ride-hailing application, general system information, current system status, ride requests, and individualized rider needs. The interface will be developed with strong consideration into the unique needs of a senior population.

LSAV Ride-Hailing Application

Crucial to the success of any program aimed at providing seniors mobility through automation is the development of a way to allow them to learn more about current and future states of the system; for this, we envision development of an interactive smartphone application (Figure 1-10). Such an application will serve several purposes, including enabling users to obtain information about the system in general (such as routes and schedules), learn the system's current status, and allow push requests to the system for custom pickups and drop-offs. We envision each of these functions will be in a separate functional module within the app; each function will be explained briefly below.

General System Information

Here, the app will provide basic information about the LSAV system, including the fundamentals of how to ride: what identification is needed, what in-vehicle support is provided to riders, current schedule and stop information, and ways that riders can contact help.

Current System Status

The status module will provide an overview of LSAV status, including where it is currently, what time it is expected to arrive at the user's location, and any other information pertinent to the user such as current availability of wheelchair accommodations. This status information is important to the rider as it will help tailor expectations of the system as well as increase understanding and trust of the LSAV system overall.

Request Handling

Finally, the app will enable users to schedule rides or hail the LSAV to their current location. This will enable real-time on-demand functionality that will provide a significant improvement to traditional paratransit models, combining the focus on special-needs transportation with flexibility and responsiveness.

Figure 1-10. Hailing app user interface mock-up.

Interface Development

The population under consideration has special interface needs relative to the general population due to a combination of less exposure to advanced technology and declining perceptual-motor capabilities, which indicate a need to specially tailor the interface design of the control application. Information will be worded in a straightforward manner; pictures, text and controls will be large enough to be easily recognized; and the general design will be broad enough to allow tasks to be completed with a minimum of "drill-down" interactions. This interface design will be supported by the researchers' experience in designing for seniors and people with disabilities in the Vulnerable Road User Mobility Assistance Platform (VRU-MAP) project, an application currently being designed to improve the safety and efficiency of mobility for people with a broad array of disabilities who walk and use public transit in urban as well as suburban environments.

Task 8: Recruit Rider-Participants from WHV Residents

Recruiting efforts and materials will be distributed in close cooperation with the management of WHV.

Develop Recruiting Protocols

VTTI has been successfully recruiting senior drivers for over 20 years using a dedicated recruiting team who employ study-specific traditional and novel recruiting methods based on the individual needs of research projects.

- **Media:** Due to the desired participant pool's residential location within a closed retirement community, it is not expected that radio or newspaper media will be necessary; however, those media will not be excluded as a recruitment tool.
- **Methods:** Approval for a wide range of methods will be sought through the IRB application. It is anticipated that flyers, brochures, social media, community newsletters, and posters will be utilized. If these traditional methods do not yield a sufficient participant pool, alternative measures may be utilized (e.g., letters to residents).
- **Ad copy:** The recruitment ad copy will feature a straightforward and honest approach. It will be written in plain terms. The eligibility criteria and the purpose of the project will be clearly stated as well as the compensation scheme. Lastly, contact information will be included so that individuals who are interested in participating have a direct way to ask questions and express their interest in participating.
- **Information/Recruitment sessions**: As needed to build or maintain the sample of participants, one or more information/recruitment sessions will be held at WHV to inform and recruit potential participants from the resident community. Study staff will be available to describe the study, provide informational materials, and gather information about interested recruits. If feasible, a demonstration of the LSAV will be provided.

Task 9: Implement ADS Solution

Upon successful alignment of project focus areas (e.g., participant, vehicle, system, and app related), the project team will implement LSAV ride operations along with the data collection and dissemination protocols described elsewhere in this proposal.

Task 10: Data Aggregation and Analysis

As noted in Task 1, data from a variety of sources will be collected and aggregated, from subjective rider information gleaned from surveys and focus groups to time-series kinematic, Global Positioning System (GPS), and video data collected onboard the demonstration vehicles. Each of these and the other types of data naturally lead to different analysis protocols. These will be applied as appropriate. Knowledge will be extracted from the individual results, and then these will be integrated to yield key takeaways relevant to the mission of FHWA in this area.

Task 11: Anticipated Outcomes

Results of this study will inform policy in a variety of areas. Implementation within a retirement community will demonstrate how emerging ADS can support safe mobility for some of the most transportation-challenged individuals. Data will show how usage rates and attitudes of a wide variety of riders changes with time and exposure. Safety-related information will be collected both in terms of the vehicle's interactions with other vehicles, pedestrians, animals, and other objects on the roadway, as well as in terms of rider access, egress, and securement within the vehicle during normal as well as emergency operations.

Risk Management

The proposed research will require thorough risk management in order to ensure project success. In addition to project risks, it will be critical to identify and manage risks in terms of user safety and public safety throughout the research effort. LSAV technology is still in the early stages of deployment, VRU populations such as the WHV community carry higher risks than the general public, and each environment carries unique risks that will need to be addressed. The research team will conduct a thorough review of risks to project success as part of the project management plan (Task 1). After reviewing the risks, the research team will create a risk register to document the types of risks identified, the potential impacts of the risks, the probability of the risks, and the research team's ability to mitigate the risks. Where the research team has identified the ability to mitigate risks, mitigation plans will be created to minimize the probabilities or impacts where possible.

Because LSAV technology is in its infancy and deployments thus far have been limited, the research team anticipates that a number of risks to user safety/trust and public safety/trust will be identified during the Environmental Review (Task 3) and Vehicle Review (Task 4). These risks will also be risks to overall project success and will be critical to identify, manage, and mitigate. During these tasks, the research team will perform thorough reviews of the operational environment, the user requirements, and the LSAV requirements. Risks identified during this process will be added to the risk register along with assessments of their probabilities, impacts, and ability to be mitigated by the research team. The research team will develop mitigation plans as necessary to ensure safety and maintain trust during operation.

The taxonomy of risk categorization and assessment will be similar to other projects VTTI has managed involving deployments of safety-critical technologies. A sample taxonomy for defining risks is provided in Table 1-3. This taxonomy will be customized as necessary for the types of risks identified during the review.

Table 1-3. Sample Taxonomy for Risk Register Used in Project

Rating	Impact on Cost, Schedule, and/or Scope	Probability	Mitigation Ability
4	Catastrophic: Major impact	High Risk (>10%)	None
3	Critical: Significant impact	Medium Risk (5%-10%)	Low
2	Marginal: Low impact	Low Risk (1%-5%)	Medium
1	Negligible: Insignificant impact	Negligible Risk (<1%)	Excellent

Cost Sharing

Non-federal cost-share is offered in this proposal as shown in the included Part 6 Budget Detail.

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