VIRGINIA TECH TRANSPORTATION INSTITUTE

Trucking Fleet Concept of Operations (CONOPS) for Managing Mixed Fleets

U.S. Department of Transportation | Notice of Funding Opportunity (NOFO) Number 693JJ319NF00001
"Automated Driving System Demonstration Grants"

Submitted by: Virginia Tech Transportation Institute
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March 21, 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 Automated Driving System Demonstration Grants, NOFO # 693JJ319NF00001

Dear Sarah Tarpgaard:

The Virginia Tech Transportation Institute (VTTI) is pleased to present this proposal entitled "Trucking Fleet Concept of Operations (CONOPS) for Managing Mixed Fleets" to USDOT in response to NOFO #693JJ319NF00001. This project will develop and demonstrate a CONOPS that documents and describes Automated Driving Systems (ADS) characteristics from the viewpoint of truck fleets. While the introduction of ADS technology into heavy trucks is expected to have a profound effect on commerce in the U.S., road freight stakeholders do not know how ADS will be implemented into daily trucking operations. This project will provide the trucking industry with clear information on how to safely implement and benefit from ADS-equipped trucks. Meanwhile, the demonstration data will provide USDOT with critical data to inform rulemaking.

VTTI will complete this complex project as a collaborative effort among a variety of experts and stakeholders. The 17-member team assembled for the demonstration includes six state departments of transportation, the I-95 Corridor Coalition, three developers of ADS technology, two trucking fleets, the National Private Truck Council, and four additional supporting organizations. VTTI looks forward to working with USDOT on this important project. Please do not hesitate to contact us with any questions.

Sincerely,

Pascha Gerni
Chief Finance and Administration Officer
PGerni@vtti.vt.edu

Summary Table

Project Name/Title	Trucking Fleet Concept of Operations (CONOPS) for Managing Mixed Fleets
Eligible Entity Applying to Receive Federal Funding	Virginia Tech North End Center 300 Turner Street, Suite 4200 Blacksburg, VA 24061
Point of Contact	Dr. Martin Walker Senior Research Associate, VTTI MWalker@vtti.vt.edu 540-231-1500
Proposed Location (State(s) and Municipalities) for the Demonstration	The location of the demonstration will be the U.S. highway system. Our core demonstration is that of an ADS that will work on all the U.S. highways and integrate safely and seamlessly into the traditional trucking industry's interstate commerce operations. The demonstrations will focus on the nationwide deployment of ADS for long-haul trucking operations and will include, amongst others, the states across I-80 from San Francisco to New York.
Proposed Technologies for the Demonstration (briefly listed)	· End-to-end experience-based deep learning · Camera-based self-driving software stack · "Works everywhere" ADS · Experience-based training of neural networks · Advanced prediction and generalization algorithms (superior "edge-case" performance in snow, construction zones, thunderstorms, low visibility, direct glare, etc.).
Proposed Duration of the Demonstration (period of performance)	48 months
Federal Funding Amount Requested	$9,999,999
Non-Federal Cost Share Amount Proposed	$3,455,913
Total Project Cost (Federal Share + Non-Federal Cost Share)	$13,455,912

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Part 1. Project Narrative and Technical Approach

Executive Summary

Although automated driving system (ADS)-equipped trucks hold the promise of increased safety, productivity, and efficiency, it is not clear how these vehicles should be integrated into fleet operations with conventional trucks. Reflecting this issue is a question frequently asked by trucking executives: *How can I integrate ADS into my fleet operations*? The Virginia Tech Transportation Institute (VTTI) has assembled a team of experts in the fields of ADS, data collection, safety data analysis, data repositories, naturalistic driving, roadway infrastructure, statistical methods, and truck fleet operations to develop and demonstrate a pragmatic *Fleet Concept of Operations* or CONOPS. This CONOPS will provide the trucking industry with clear guidelines on *how* to safely implement, and benefit from, ADS-equipped trucks. Meanwhile, data from the real-world demonstrations of the CONOPS will provide the U.S. Department of Transportation (USDOT) with critical data to inform rulemaking regarding ADS-equipped trucks.

The introduction of ADS technology on heavy trucks (Class 8 vehicles) will profoundly affect all commerce in the U.S., as the U.S. moves more than 70% of our goods by truck. However, existing stakeholders in the road freight ecosystem (primarily for-hire and private truck fleets, but also shippers, brokers, truck manufacturers, and service and maintenance providers) do not have a clear picture of how they will implement ADS in their daily operations. At present, technical progress in this nascent but promising technology is outstripping the ability of truck fleets to keep up and plan for ADS deployment, which may adversely affect adoption by truck fleets and associated industries, resulting in the delayed achievement of safety, productivity, and efficiency benefits of ADS-equipped trucks. If ADS is to gain traction in the U.S. trucking industry, current stakeholders and new entrants need a rigorous, data-driven CONOPS.

The CONOPS is a comprehensive document that describes the ADS characteristics from the viewpoint of the truck fleets that will use the ADS. As shown in Figure 1-1, the CONOPS includes eight key sections: ADS Installation and Maintenance Guide for Fleets, ADS Inspection Procedures, Driver State Monitoring Technology and Protocol, Motor Carrier Guide to Insuring ADS-Equipped Trucks, Identification of ADS Safety Metrics/Variables, ADS Road Readiness Rating System, Data Security/Transfer Protocol, and Cybersecurity Best Practices. The proposed demonstrations build toward a network of fully deployed ADS trucks integrated into a truck fleet's traditional commercial operations that move freight in a safe, repeatable, and commercially viable manner. Each of the three CONOPS demonstrations will be completed in three phases during the 48-month project on highways across the continental U.S., culminating in a demonstration of SAE Level 4 and 5 (L4 and L5) ADS-equipped trucks in revenue-producing operations. The phases within each of the CONOPS demonstrations will validate increasing levels of ADS upon which more advanced ADSs will be deployed in a real-world CONOPS. Indeed, it is difficult to imagine how any research demonstrating more advanced ADS does not first begin with L2/3 to inform scaled-up, practical deployments of the technology. However, the three phases will not be sequential and will largely operate in parallel.

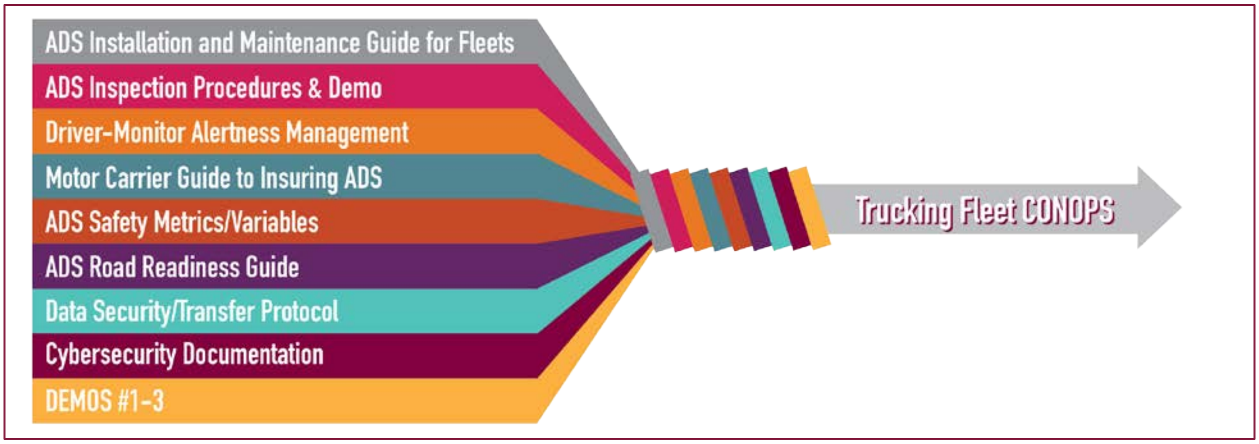

Figure 1-1. Illustration of How the CONOPS Documents will Inform the Development and Planning of the Demonstrations on Live U.S. Roads.

The comprehensive VTTI team includes 17 members: six State Departments of Transportation (Nebraska, Pennsylvania, Tennessee, Virginia, West Virginia and Wyoming) and the I-95 Corridor Coalition (alliance of transportation agencies from the State of Maine to the State of Florida); three ADS technology developers (Pronto.ai, Starsky Robotics, and Peloton); two trucking fleets (Schneider National and Hub Group); National Private Truck Council (NPTC, which represents 100's of private truck fleets); and four supporting organizations (Penske Truck Leasing/Logistics, Travelers Insurance, MRIGlobal, Commercial Vehicle Safety Alliance or CVSA) to provide the expertise and perspective necessary to collaboratively complete this complex project.

Critically, the selected ADS platform will be "platform neutral" and "backwards compatible," ensuring that the project focuses on demonstrating and evaluating ADS performance rather than "picking winners" with respect to truck original equipment manufacturers (OEMs). The ADS technology of Pronto.ai does not rely on LIDAR sensors or high-definition maps; thus, the Pronto.ai ADS will be orders of magnitude less expensive than most currently available ADS. This is possible as Pronto.ai's technical approach includes a novel experience-based, end-to-end deep-learning model for training the neural networks that make driving decisions. With this project, Pronto.ai's strong technical foundation will be progressed to where the ADS allows driving in the above edge-case conditions in a manner that is comparable in performance to human driving. Other key strengths of our proposed approach to develop and demonstrate a CONOPS for fleets with ADS-equipped trucks are highlighted below:

- ✓ The ADS demonstrations will touch a large segment of the continental U.S., including a cross-country L4/5 demonstration from San Francisco to New York across I-80.
- ✓ Three hands-on ADS demonstrations (or roadshows) will be held across the U.S. to allow end users, stakeholders, and the public to experience ADS technology on closed test tracks.
- ✓ Four different demonstrations of a "realistic autonomous," or real-world, practical integration of increasingly sophisticated ADS into today's U.S. road freight will be made with live traffic (see Figure 1-2):

- Cross-country trip in an L4/L5 ADS-equipped truck; and
- Three demonstrations using the CONOPS:
  - Truck queuing in ports (Demo #1);
  - Drayage operations (Demo #2); and
  - Exit-to-exit scenarios (over the road and/or intermodal; Demo #3).

✓ The team will provide the most reliable and valid safety analysis for potential USDOT rulemakings by using VTTI's existing naturalistic truck driving datasets as a comparable human baseline (existing data include 688 instrumented trucks, more than 800 drivers, and more than 16 million miles of continuous video and kinematic data).

✓ The team will develop and integrate a phased approach in the CONOPS demonstrations with increasing levels of ADS on top of existing foundations staring at the end of Year 1 (L2, L2+, and L4/5 in Phases 1, 2, and 3 respectively).

✓ The demonstrations will show how traditional truck fleets can integrate more ADS functionality into their current fleets and business models.

✓ Upload demonstration in near-real time to a VTTI-supported data repository, the FHWA CONOPS Dataverse, for storage and access.

✓ Public outreach activities (in addition to the roadshows) throughout the project.

Figure 1-2 shows how the CONOPS will be applied in the three demonstrations on live U.S. roads in revenue-producing freight operations (truck queuing, drayage, and exit-to-exit).

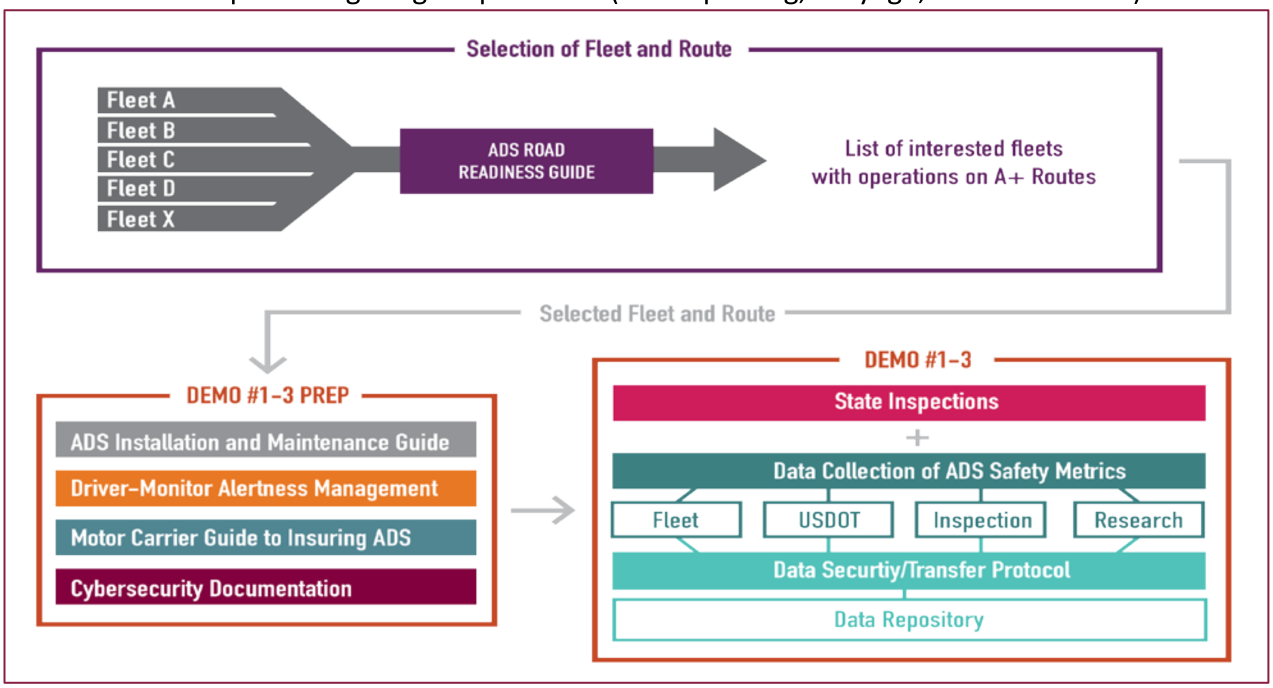

Figure 1-2. Applying the CONOPS to Revenue-Producing Operations (Exit-to-Exit, Truck Queuing in Ports, and Drayage Operations).

Objectives

The overarching goals of the proposed project are to: (1) demonstrate the safe integration of ADS-equipped trucks into the U.S. on-road transportation system; (2) provide USDOT data for safety analysis and rulemakings to help modernize regulations; and (3) demonstrate how to integrate ADS-equipped trucks in a productive, cooperative way into the existing road freight ecosystem. We anticipate the completion of the hands-on demonstrations (roadshows) in Year 1, with the demonstrations on live U.S. roads at the end of Year 1 and culminate in late Year 3 to early Year 4.

Summary

A key aspect differentiating our CONOPS research focus from other demonstrations of L4 technologies is that we are not developing or demonstrating an idealistic autonomous deployment of a one-off “robot truck.” Rather, we are demonstrating a “realistic autonomous” deployment that relies on a mixed-fleet model, where truck fleets simultaneously own and operate trucks with different levels of ADS. This project focuses on the development and demonstration of a CONOPS for ADS-equipped trucks, which will ensure the results translate directly to real-world settings that are of practical importance to the trucking industry, regulators, and the public at large. To date, the focus of nearly all ADS demonstrations is technical feasibility. However, as impressive as these demonstrations have been, they are not sufficient to promote widespread adoption of ADS-equipped trucks or inform policymaking. Our proposed demonstrations will be technically feasible and show how ADS can be implemented in trucking fleets in a manner that is *(1) safe, (2) repeatable, and (3) commercially viable.* Thus, the data gathered in the demonstrations and provided to USDOT will reflect real-world trucking operations; such data will be invaluable for real-world safety analysis and rulemaking.

We will not require an exception under the Buy American Act. Although for most of the demonstrations we expect a driver to be in the driver seat, we will ask for an exemption of the Federal Motor Vehicle Safety Standards (FMVSS) and/or Federal Motor Carrier Safety Regulations (FMCSR) when the driver is not in the driver seat and the truck is involved in interstate commerce. We will seek clarification from the Federal Motor Carrier Safety Administration (FMCSA) regarding existing FMCSR and the National Highway Traffic Administration (NHTSA) regarding FMVSS, if an exemption is needed. We will provide data to demonstrate the safety of these vehicles before the vehicles will operate on U.S. roadways.

Goals

The proposed Trucking Fleet CONOPS for Managing Mixed Fleets project will meet the following goals described in the Notice of Funding Opportunity (NOFO) Section A:

1. **Safety:** As indicated above (and elaborated below), the proposed CONOPS targets crosscutting issues related to many aspects of safety. The project transcends a simple technology demonstration and includes areas critical to the safe integration of ADS into the U.S. on-road transportation system. These challenges include maintenance, inspection, driver state monitoring (especially for L3 ADS), insurance, identification of safety metrics, roadway infrastructure rating, data security/transfer, and cybersecurity. The proposed CONOPS will address each of these areas, using the demonstration to refine and inform additional development. The capstone goal of this project is to

demonstrate a safe, repeatable, commercially viable deployment of L4/L5 ADS technology that moves freight without the aid of the human operator.

2. **Data for Safety Analysis and Rulemaking:** The VTTI team is well positioned for safety analysis. Traditional safety metrics include the number of disengagements, crashes, harsh maneuvers, traffic violations, miles traveled, and driver inattention (or attention) along with crash severity and crash preventability. We can compare these safety metrics in the demonstrations with VTTI's naturalistic truck data, the largest naturalistic truck data set in the world, as a comparable human baseline (more than 16 million miles of continuous video and kinematic data). No other proposal team has access to this much naturalistic truck driving baseline data. However, these metrics may not be sufficient to address all aspects of the safety of the ADS. Thus, the VTTI team will develop a process that provides sensor data from all crashes to a third party to determine preventability and to audit if continued testing on public roads is appropriate. Under this paradigm, third-party auditors will regularly assess the safety of the program and deployability. The VTTI team proposes to share data with US DOT and the public in near-real time through VTTI's proposed data repository (FHWA's CONOPS Dataverse).

   The proposed CONOPS for ADS-equipped trucks will be related to a variety of topics relevant to safety and rulemaking (maintenance, inspection, driver state monitoring, insurance, identification of safety metrics, roadway infrastructure rating, data security/transfer, and cybersecurity).

3. **Collaboration:** The VTTI team is a broad and diverse group that includes government entities, a university, trucking associations, and private partners. As shown in Part 4: Letters of Commitment, the VTTI team comprises 17 organizations, including: six State DOTs and the I-95 Corridor Coalition, three ADS technology developers, two trucking fleets, NPTC, and four supporting organizations. Upon project award, we expect additional entities, primarily technology companies, to join the project as part of the Task 19 hands-on demonstrations. Coordination of all team partners will occur through the VTTI Center for Truck and Bus Safety.

Focus Areas

The proposed Trucking Fleet CONOPS for Managing Mixed Fleets project will meet the following focus areas described in NOFO Section A:

1. **Significant Public Benefit(s):** Given the tremendous potential safety, efficiency, and productivity benefits of automated trucks and the fact that 100% of all consumer goods are delivered via truck, the proposed study will ultimately benefit all road users and consumers in addition to those working in the trucking industry. Reductions in traffic congestion and the associated pollution will be significantly reduced with ADS-equipped trucks. Beyond the costs associated with reduced efficiency and increased pollution, trucks represent a safety concern. Compared to the general U.S. working population, heavy-truck drivers are 12 times more likely to die on the job and three times more likely to suffer an injury involving time off work. In 75% of fatal interactions between heavy trucks and passenger vehicles, it is the driver and/or passenger(s) in the

passenger vehicle that are killed. All these effects degrade the quality of life of the general public. ADS-equipped truck have the potential to prevent and mitigate these issues.

2. **Addressing Market Failure and Other Compelling Public Needs:** Increasing demand for consumer goods and just-in-time inventory strategies (i.e., receiving goods only as they are needed) place a significant demand on truck drivers and the U.S. highway system as increasing amounts of goods are delivered by trucks. In 2016, the American Trucking Association estimated the truck driver shortage at roughly 63,000 drivers. The driver shortage is now the trucking industry's top concern. In its annual survey, the American Transportation Research Institute found truck fleets are most concerned about the lack of qualified drivers to carry the Nation's freight. The current shortage of quality drivers along with the high turnover rates inherent in the trucking industry put tremendous pressure on human resources to find quality drivers.
   Many other ADS technology developers propose a specific OEM platform and/or ADS-platform installed only on new truck purchases. We will install the Pronto.ai ADS as a bolt-on aftermarket retrofit, which means that it will be "backwards compatible" with the current generation of trucks. Thus, its benefits can readily extend to most trucks already on the road today, regardless of OEM (as opposed to having to wait for the entire trucking fleet to turn over and purchase new equipment from a particular OEM).
3. **Economic Vitality:** Approximately 3.5 million professional truck drivers haul more than 10 billion tons of freight annually in the U.S., grossing more than $700 billion in freight revenues. Since 2010, demand for freight services has increased, and truck drivers have needed to move more goods throughout the U.S. As of 2015, 551,150 interstate motor carriers were actively operating in the U.S. The trucking industry contributes significantly to the nation's economic portfolio, employing approximately 8.7 million people and hauling more than two-thirds of the total freight transported in the U.S. Thus, delivery of goods via trucks is vital to the health of the U.S. economy, and ADS-equipped trucks have the potential to significantly increase economic output. The VTTI team is also cognizant of the potential disruptive yet beneficial impact of ADS-equipped trucks on the U.S. economy (VTTI led a National Science Foundation [NSF]-funded workshop on this issue; see Part 2 team capabilities for additional information). Although not a focus of the CONOPS, we will try to identify critical unanswered questions and potential solutions related to the effects ADS-equipped trucks will have on the U.S. economy, such as how ADS-equipped trucks will affect the current and future truck workforce.
4. **Complexity of Technology:** The ADS technology of Pronto.ai does not rely on LIDAR sensors or high-definition maps; thus, the Pronto.ai ADS will be orders of magnitude less expensive than most currently available ADS. More importantly, the Pronto.ai technology can readily work on nearly all U.S. highways rather than on selected, highly constrained, and extensively mapped individual segments of roads. Thus, it is the closest to an "L5" solution that any ADS technology developer has offered to date. This is possible as Pronto.ai's technical approach includes a novel experience-based, end-to-end deep-learning model for training the neural networks that make driving decisions. Rather than using complex sensors, maps, and other hardware to gain additional (mostly superfluous) precision about a vehicle's surroundings at the present moment,

Pronto.ai uses smarter software to better predict what will happen in the next instant and the seconds ahead for the vehicle and surrounding traffic. In other words, the binding constraint for ADS technology developers today is not whether their software can "see" what's happing right now, but rather if the software has the "artificial instincts" to predict what will happen next (akin to defensive driving). Pronto.ai is unique in addressing this critical software problem by developing smarter neural networks, rather than trying to compensate or avoid this issue via additional hardware. This approach has already resulted in what is demonstrably the industry-leading performance in so-called "edge cases" like rain, thunderstorms, snow, direct glare, construction zones, and other traffic conditions that have so far been avoided by nearly all other ADS technology developers due to their complexity. With this project, Pronto.ai's strong technical foundation will be progressed to where the ADS allows driving in the above edge-case conditions in a manner that is comparable in performance to human driving.

5. **Diversity of Projects:** The VTTI team proposes a variety of projects to develop the CONOPS, with incremental steps informing the revision and development of the next steps. The initial CONOPS guides (see Figure 1-1) will be developed by the entire VTTI team. Moreover, the CONOPS will be informed and revised by the results in the demonstrations, including the hands-on demonstrations (i.e., ADS roadshows), cross-country L4/L5 ADS truck demonstration, and the three CONOPS demonstrations (exit-to-exit scenarios, truck queuing in ports, and drayage operations).
6. **Transportation-challenged Populations:** Not applicable in proposed study.
7. **Prototypes:** As indicated above, the Pronto.ai ADS has already been the foundation of many ADS milestones (see Part 2). The goal of the CONOPS is to go beyond a one-off "robot truck." Rather, we are demonstrating a realistic autonomous deployment that relies on a mixed-fleet model, where truck fleets simultaneously own and operate trucks with different levels of ADS.

Requirements

The proposed Trucking Fleet CONOPS for Managing Mixed Fleets project will meet the following requirements described in NOFO Section A:

1. **Demonstrating L4/L5 Automation Technologies:** The VTTI team will use Pronto.ai's platform in the demonstrations (and various other ADS technology vendors in the hands-on demonstrations). This technology will function initially as "L2+," with a driver always in the seat and paying attention (as opposed to waiting for a request to intervene). We will use a driver monitoring system to monitor the drivers' levels of attention and provide them with opportunities for engagement where they will share information about the conditions of the current roadway. This will be similar to apps such as Waze. When used in combination with connected-vehicle technologies, the "L2+" ADS will lay the foundation for demonstrating realistic autonomous L4/L5 gradually in a safe, repeatable, and commercially viable manner. This deployment will rely on a mixed-fleet model, where truck fleets simultaneously own and operate trucks

with different levels of ADS, where drivers continue to have a critical role, and where L4/L5 trucks share the roads with conventional vehicles.

2. **Physical Demonstrations:** The VTTI team proposes five different demonstrations, one performed on closed test tracks and the other four performed in live-traffic environments on U.S. roadways. The VTTI team will conduct three hands-on demonstrations (or roadshows) across the U.S. to demonstrate various ADS technologies with the public. Another demonstration will involve a cross-country trip in an L4/L5 ADS truck. The last three demonstrations will apply the CONOPS in revenue-producing operations in three different carrier operational environments (each lasting at least three months): exit-to-exit scenarios (over the road and/or intermodal), truck queuing in ports, and drayage operations. Within each demonstration, we will deploy increasing levels of advanced ADSs in a phased approach.
3. **Sharing Data**: The VTTI team will share all relevant and required data with US DOT in near-real time using a data repository created specifically for the proposed project, termed the FHWA CONOPS Dataverse. These data will be available to the public for more than five years after the award period.
4. **Input/Output User Interfaces**: The Pronto.ai ADS will be used like cruise control. A button by the steering wheel will be pressed to engage and pressed again to disengage (or by applying torque to the steering wheel, pressing the brake, and/or throttle pedals). There will also be audio and visual alerts to make drivers aware of road hazards or when to intervene. Driver engagement is included in the driver monitoring system.
5. **Scalable and Public Outreach:** The goal of the proposed study is to develop a trucking fleet CONOPS for the deployment of ADS-equipped trucks that move freight. This will involve the identification of best practices for maintenance, inspection procedures, driver state monitoring, insurance, safety metrics, infrastructure readiness, data transfer, and cybersecurity. Throughout the proposed study, and with permission from FHWA, the VTTI team will conduct public outreach activities via webinars, conferences, roadshows, and exhibitions.

Approach

The 28 tasks that the VTTI team will complete during the 48-month period of performance are detailed below.

Task 1: Kick-off Meeting

Within three weeks of contract award, the VTTI team will participate in a kick-off meeting with FHWA personnel at USDOT Headquarters in Washington, DC. Although holding the meeting via webinar will reduce costs, the VTTI team believes a face-to-face meeting will increase rapport between the VTTI team and FHWA personnel, as we will be closely working together during the proposed project.

The purpose of the kickoff meeting will be for the VTTI team and FHWA to discuss the technical approach for the project, review the schedule, and discuss any questions or issues related to the project. The Contracting Officer’s Representative (COR) will provide the introduction and rationale for the project, and the VTTI team will present its planned approach for conducting the project. The approach will include information from the NOFO, this proposal, and any negotiations made during the procurement process. Within two weeks of contract award, the VTTI team will submit its briefing materials (including a PowerPoint slide deck) to the COR for review. The COR will provide comments within one week of receipt of these documents.

Task 2: Project Management Plan (PMP)

Based upon the discussion and decisions reached during the Task 1 Kick-off Meeting and agreements negotiated with FHWA during the procurement process, the VTTI team will produce a detailed PMP that outlines the team's plan for implementing the study. This PMP will include (at a minimum) details for: (1) Statement of Work, with a description of tasks and subtasks by which the project work activities will be organized, executed, and monitored; (2) An updated project schedule (see proposed Gantt chart in Part 2); (3) description of major project milestones and deliverables (see proposed project milestones/deliverables below); (4) staffing table, which identifies project staff and/or consultants who will lead and support each task (see Part 2 for proposed staffing plan); and (5) project budget, displaying planned expenditures by task, with a further breakdown by cost element for each task, and by the Federal share versus non-Federal share (see Part 6 for the proposed budget). Within five weeks of contract award, the VTTI team will submit the PMP, which will provide the foundation for the specific tasks that compose this proposed project. Within two weeks of receipt of the PMP, the COR will provide the VTTI team with comments. The team will then adjust the PMP as necessary and submit a PMP within two weeks of receipt of the COR's comments. This review cycle will continue until the COR approves a Final PMP.

Task 3: Data Management Plan (DMP)

Task 3 will describe the final DMP and will be delivered to the COR by 60 days after contract award. The proposed study will include outputs from the automated trucks (including video, kinematic, GPS, and other sensors) and questionnaire data from the hands-on demonstrations (see Task 19). All proprietary information will remain with team member Pronto.ai. Non-proprietary data (e.g., vehicle and questionnaire data streams), which will be stripped of personally identifiable information (PII), will be housed on the FHWA CONOPS Dataverse (detailed in Task 16). This data repository is maintained by VTTI based on the Dataverse platform. The VTTI team successfully used a DMP in prior funded efforts and will leverage those efforts in the proposed study (e.g., the USDOT-funded and VTTI-led Safety through Disruption [Safe-D] National University Transportation Center [UTC], FMCSA Data Repository [CMVSight], and the Insight Data Repository used for the Second Strategic Highway Research Program Naturalistic Driving Study [SHRP2 NDS]).

Data from the automated trucks will be stored on an encrypted hard drive. These data will be removed from the automated truck by Pronto.ai and stored on its secure servers. Proprietary information will be stripped from these data, and the remaining data will be sent on an encrypted hard drive to VTTI. Upon arrival at VTTI, these data will be decrypted and stored on VTTI's secure server. We will remove PII, and, if necessary, the data will be filtered, smoothed, and uploaded to the FHWA CONOPS Dataverse for public access/viewing. Questionnaire data, which will be collected and stored by VTTI, from the hands-on demonstrations in Task 19 will also be stored on the FHWA CONOPS Dataverse. A strawman description of the data to be collected and access policies is provided in Part 3: Draft Data Management Plan.

Task 4: Project Evaluation Plan

In Task 4, the VTTI team will provide FHWA with the Project Evaluation Plan, which will include: (1) statement of project objectives; (2) a list of evaluation criteria; (3) description of data collection procedures; (4) outline/summary of the Project Evaluation Report (one page); and (5) description of data repository. The naturalistic data collection and analysis methodologies pioneered by VTTI are now used and recognized worldwide for their advantages over other methods, and VTTI was recognized by the White House in 2013 as a Champion of Change in the transportation field based on the institute's innovative naturalistic approaches. We will leverage this approach in the proposed study to evaluate the ADS-equipped trucks.

VTTI has been at the leading edge of naturalistic driving evaluations. VTTI recently completed a NHTSA-funded study that investigated driver interactions with L2 and L3 ADS to see how drivers transition between automated and non-automated vehicle operations. VTTI also compared the crash rate of Google's Self-Driving Car (Waymo) to the SHRP2 NDS data. This study illustrated the crash rate for the ADS-equipped vehicles (when in autonomous mode) was lower than human-driven cars across three different crash severities. The same approach can be used with VTTI's naturalistic truck data. We can leverage VTTI's naturalistic truck driving data sets, the largest in the world, as the comparable human baseline. These data sets include 688 instrumented trucks, more than 800 drivers, and more than 16 million miles of continuous video and kinematic data. This allows the VTTI team to match its baseline safety data with the operational driving domain of the ADS-equipped trucks in the proposed demonstrations. Moreover, VTTI is currently investigating (via an ongoing FMCSA-funded study) a safety performance baseline or benchmark for ADS-equipped trucks based on crashes and less-severe events/behavior measures in a large event-based data set that includes more than 4,000 naturalistic truck crashes and an extensive amount of continuous naturalistic truck driving data collected in previous VTTI studies.

However, current metrics used by ADS technology developers to track progress may not be enough in tracking safety. Traditional safety metrics include the number of disengagements, crashes, harsh maneuvers, traffic violations, miles traveled, and driver inattention (or attention), as well as crash severity and crash preventability. An improved system for measuring the safety of highly automated vehicles can contribute to safer testing and ADS deployment. Miles per incident and miles driven are commonly used metrics. However, they may not be the best safety metrics and are not applicable after the development and demonstration stages. The miles-driven metric is commonly used to show progress, which incentivizes programs to put the public at additional risk by driving more than necessary. Progress does not equal overall safety and should be viewed separately.

ADS are likely good at avoiding at-fault crashes but do a poor job of avoiding preventable crashes. The ADS-equipped shuttle crash in Las Vegas (2017) is a perfect example. A large truck backed into the ADS-equipped shuttle, which resulted in a crash where the truck driver was at-fault. However, this crash was easily preventable if the shuttle would have backed out of the truck's path. Yet, it stopped and made no effort to avoid the crash.

Currently, the best method of identifying if an ADS is safe to track the rates of injury crashes and property-damage accidents and compare them to humans driving in the same operational driving domain. However, this only indicates the ADS is safer than the average human, which means a segment of the population is safer and another segment is less safe. The VTTI team believes all ADS testing programs should routinely be audited to show their systems are safe to be on public roads and to show they are not driving an excessive amount on public roads based on the current progress of the system. Thus, the VTTI team will investigate the potential of a third party to audit the Pronto.ai ADS. The purpose will be to justify the amount of public road testing and to determine if testing is being performed in a safe manner. If a Pronto.ai truck is involved in a crash, near-miss, or experiences an unsafe behavior, we will stop public roads testing and investigate. The VTTI team will investigate creating a process so sensor data from all crashes will be provided to a third party to determine preventability and to audit if continued testing on public roads is appropriate.

Task 5: Fleet Derived Specifications for CONOPS Demonstrations

The key driver of the VTTI team's proposal is a focus on the application of ADSs from the end-user's perspective (i.e., the truck fleet). Our industry-first approach is focused on how truck fleets will be able to integrate ADS-equipped trucks into their existing fleets. In the near-term, it is unlikely a company will have an entire fleet of ADS-equipped trucks. We believe a segment of truck fleets will be ADS without a driver, but much of the fleet will remain conventional trucks and ADS-equipped trucks that require human driver involvement.

The proposed project outlines three separate CONOPS technology demonstrations on live U.S. roads. Discussions with our truck industry partners have identified the exit-to-exit, truck queuing at ports, and drayage use cases having the most appeal to truck fleets. The VTTI team includes two individual trucking companies along with the NPTC. In Task 5, the VTTI team will develop a set of specifications, based on industry needs, which Pronto.ai can integrate into its ADS. Specifically, the truck fleets on our team will specify their needs (which will be defined as a function of their real-world operations), and the technology development will focus on addressing those needs in the technology platform using the phased approach described in Task 6. This user-centered design paradigm will ensure the needs of the end users drive the ADS technology design.

Task 6: ADS Truck Technology Specification Document

Key members of the technology partner for this project (i.e., Pronto.ai) have been at the forefront of prior ADS demonstrations, including a series of DARPA-sponsored competitions (2004-2007), the first autonomous urban drive (2009), the first autonomous delivery by a truck (2016), and the first cross-country drive without any driver disengagements (2018). The CONOPS focus of the proposed research ensures the results will translate directly to real-world settings that are of practical importance to the trucking industry, regulators, and the public at large. To do that, a demonstration needs to not only be technically feasible but also be: (1) safe,

(2) repeatable, and (3) commercially viable. The ADS Truck Specification Document will outline the capabilities needed in each phase of the ADS development and will largely be informed with input from the entire VTTI team.

During each of these phases, Pronto.ai will develop and integrate increasing automation on top of the existing foundations. However, the three phases will not be sequential and will largely operate in parallel. Thus, rather than moving from one automation level to the next simply for the sake of demonstrating technical feasibility in the abstract, the VTTI team will focus on demonstrating the ability of traditional truck fleets to integrate increasing ADS functionality into their current fleets and business models. Pronto.ai offers a unique approach that can provide functionality that is the closest to L5. By not relying on high-definition maps or LIDAR sensors (which nearly all other ADS technology developers do), the ADS will be able to drive on all highways, as opposed to certain pre-specified and highly constrained stretches of highway, and under all weather conditions, as opposed to only optimal times). Below is a summary of each phase, which will be implemented within each of the three CONOPS ADS demonstrations.

Phase 1 – Partial Automation (L2)

The ADS will be in a driver assist mode and available for all aspects of the dynamic driving task (e.g., throttle, braking, and steering), but a fully alert driver will always be required to actively control and monitor the system. In short, this phase will demonstrate the capability of an ADS that is becoming increasingly commonplace in new luxury passenger vehicles but not found in trucks. This is important not only because it helps trucking catch up with current state-of-the-art ADSs, but also because it lays the foundation upon which more advanced ADSs can be deployed in a real-world CONOPS perspective. Indeed, it is difficult to imagine how any research demonstrating more advanced ADS does not first begin with L2 to inform scaled-up, practical deployments of the technology.

Phase 2 – Highly Advanced Partial Automation ("L2+")

The ADS will be able to perform all aspects of the dynamic driving task and continuously control throttle, braking, and steering for extended periods of time and on lengthy highway segments. Even if the human driver *fails* to respond to an intervene request, the ADS will attempt to safe harbor. This phase will provide critical learnings with: (1) driver engagement and alertness monitoring; (2) vehicle-to-vehicle and vehicle-to-infrastructure-enabling technologies; and (3) driver safety, productivity, and implications for hours of service (HOS) limits.

Phase 3 – High/Full Automation (L4/L5)

The ADS will perform all aspects of the dynamic driving task under all roadway and environmental conditions for the relevant deployment (e.g., on highways and queueing in ports). There will be no requirement to have a human driver present in the vehicle, or the expectation for a driver in the vehicle to be attentive or take over at any time. However, there will be a requirement for the use of L4/L5 trucks in conjunction with L2+ trucks and conventional vehicles. This is another key aspect differentiating our CONOPS research focus from other demonstrations of L4 technologies. That is, we are not developing or demonstrating an idealistic autonomous deployment of a one-off "robot truck." Instead, we are researching a *realistic autonomous* deployment that relies on a mixed-fleet model, where truck fleets simultaneously own and operate trucks with different levels of automation, drivers continue to have a critical role, and L4/L5 trucks share the roads with conventional vehicles.

Task 7: Truck Selection

In Task 7, the VTTI team will identify the trucks to be used in the demonstrations. Team members Penske and Pronto.ai have access to trucks from each of the four truck OEMs. We anticipate that two of these tractors will be designated as early development mule vehicles, with one located at the Pronto.ai headquarters in California and the second located at VTTI in Virginia. Each of these two locations will also have one of the trailers. The third tractor will serve as a back-up vehicle in case one of the other tractors becomes disabled. The vehicle specs from those tractors will be provided to Pronto.ai so they can customize their ADS for these vehicles.

Task 8. ADS Installation and Maintenance Guide

Maintenance and documentation of ADSs will be a critical issue once these systems are introduced in the truck market. The VTTI team will develop a guide for fleets to support the installation and maintenance of ADS. VTTI recently completed an FMCSA-funded study to assess the relationship between maintenance violations and crashes as part of a new operational definition of “systematic maintenance.” This ongoing study also evaluated the effectiveness of current regulations regarding: (1) preventative maintenance intervals, (2) preventative maintenance inspections with adequately trained/equipped mechanics, and (3) adequacy of inspection facilities. The primary output of the FMCSA study will be the development of minimum standards for inspection intervals, mechanic qualifications and training, and certification of maintenance facilities. Thus, the VTTI team has already laid the critical groundwork for completing Task 8.

As part of the CONOPS for ADS-equipped trucks, our fleet partners strongly believe an installation and maintenance guide to support fleets will be a critical component. Penske Truck Leasing will play a key role in this task. As the nation's largest leased truck fleet, Penske Truck Leasing operates and maintains more than 270,000 vehicles within a network of 705 locations and more than 2,300 truck rental locations. As the leading truck fleet leasing company in the U.S., Penske Truck Leasing is the expert in truck maintenance and is at the leading edge of installation and maintenance requirements with new truck technology.

Task 9: ADS Inspection Procedures

In 2018, the CVSA’s Enforcement and Industry Modernization committee, in cooperation with FMCSA, established a working group to address the inspection process of ADS-equipped trucks. This working group is developing a matrix of ADS-equipped truck inspection procedures for each of the SAE levels of automation and will make recommendations to possible changes in FMCSA/NHTSA regulations and CVSA policies and training. The VTTI team will work with CVSA in the demonstration projects to determine how these new inspection procedures could be implemented in ADS-equipped trucks. It is likely the inspection of the ADS components could be made via a Level VIII – North American Standard Electronic Inspection. An electronic inspection should include: if a vehicle has a driver, a descriptive location (including GPS coordinates), USDOT number (or National Safety Code in Canada), power unit registration, operating authority, Unified Carrier Registration compliance, federal out-of-service orders, and an indication that the components of the ADS are functioning properly. However, if a driver is present, the inspection should include electronic validation of driver identity, driver's license class and endorsement(s), license status, Medical Examiner's Certificate and Skill Performance Evaluation Certificate, current driver's record of duty status, and HOS compliance (if necessary). The Level VIII Electronic Inspection is an inspection conducted electronically or wirelessly while the vehicle is in motion without direct interaction from an enforcement officer. The VTTI team will determine what sensor data are needed from truck fleets and CVSA and FMCSA for wireless roadside inspections. The VTTI team will determine how often these data should be transmitted to state roadside personnel. Moreover, this task will explore strategies and techniques for enforcement personnel and police to stop an ADS-equipped truck while driving on the road.

Task 10: Driver State Monitoring Technology and Protocol

As ADS technology has improved, the need to monitor against driver inaction and boredom has increased. All state-of-the-art programs will need to require their test operators to continuously remain attentive in the face of increased automation of the vehicle. Further, there is growing industry understanding that even intensive vehicle test operator training does not guard against the dangers of inattention behind the wheel. In L2, L2+, and L4 technology testing and development, Pronto.ai approaches these challenges by deploying a driver-facing camera and custom software to monitor driver attention levels. This technology can recognize if a driver is maintaining forward attention and detects cell phone usage and other objects that signal inattentiveness. Inattention can result in several actions, including driver alerts that increase in frequency and notification of excessive inattention to external parties (test fleet management, fleet operations). The output of Task 10 will be a driver state monitoring technologies protocol for use in truck fleet operations, including real-time alerts and back-office data analytics/feedback/coaching.

Although early versions of driver monitoring technologies have increasingly been incorporated over the past several years into "dashcam" products used in the trucking industry, the technology used in the proposed research will have three distinguishing features that will advance the state of the art and hold the prospect of meaningfully increasing safety during the development and deployment of ADS:

- The use of advanced end-to-end deep-learning algorithms, similar to those used to make driving decisions for the vehicle. This enables dynamic rules for driver engagement that adapt to road conditions encountered . By contrast, dashcam products today use simple rules-based algorithms that are static and do not distinguish between proper driver behavior and attentiveness (e.g., rush hour traffic in good weather on a busy urban corridor, a nighttime thunderstorm on an open stretch of highway).
- Moving beyond "just monitoring" and "avoiding bad behavior" to actively engaging the driver by encouraging he/she to provide input to the system through a custom user interface. This "gamification" of the driver monitoring tech in L2+ systems rewards drivers for proactively showing they are aware of road conditions and potential hazards even as the ADS does most of the driving. The input they provide into the system can be

used with connected-vehicle technologies to support greater safety for all vehicles on the same stretch of road, including unmanned L4 vehicles in a mixed fleet, rather than just the driver of the L2+ ADS.

- If a driver is detected as being inattentive or completely unresponsive even after repeated warnings and requests to take over the driving task, the Pronto.ai driver monitoring system will trigger an attempt to bring the vehicle to a safe harbor as soon as practicable. Although some driver monitoring systems attempt to “sound the alarm” when bad behavior or an unresponsive driver is detected, none can take over the vehicle and attempt to safe harbor. Implementing such a system will be an important step toward potentially saving the lives of truck drivers and surrounding motorists.

Taken together, the proposed research will shift driver state monitoring technology from being a primarily reactive system to becoming a primarily proactive one.

Task 11: Motor Carrier Guide to Insuring ADS-Equipped Trucks

The Travelers Institute outlined unresolved policy questions and challenges in its 2018 report, *Insuring Autonomy: How Auto Insurance Can Adapt to Changing Risks*. Although the report focused on light vehicles, trucking fleets face similar insurance and policy questions. To assist truck fleets in navigating these issues, the VTTI team (led by Travelers Insurance) will develop a guide for truck fleets. Using the 2018 report to inform Task 11, this task will explore the following topics: (1) the current state of the ADS truck market, projections for future development, and early policy responses; (2) truck insurance in an ADS world; and (3) specific insurance-related recommendations for a legal and regulatory structure.

Task 12: Identification of ADS-Equipped Truck Safety Metrics/Variables

Following the Task 4 Project Evaluation Plan, the VTTI team and FHWA will identify appropriate safety metrics and variables. The goal of this task is to provide guidance on which variables will be used to evaluate the safety of the ADS, which in turn will be used to inform rulemaking. Current metrics include the number of disengagements, crashes, harsh maneuvers, traffic violations, miles traveled, and driver inattention (or attention), as well as crash severity and crash preventability. However, as indicated above, these metrics may not be sufficient. The VTTI team will investigate creating a process so sensor data from all crashes will be provided to a third party to determine preventability and to audit if continued testing on public roads is appropriate. This new paradigm focuses on third-party auditors regularly assessing the safety of the program and deployability.

Task 13: ADS Road Readiness Rating System

The VTTI team will develop a system for rating the readiness of specific road segments for ADS-equipped trucks (see Figure 1-3). The system may be adaptable to ADS for other vehicle types. The system will be similar in concept to the U.S. Road Assessment Program (usRAP) method for rating safety infrastructure improvement needs for roadways (developed by MRIGlobal), but it will likely differ in the way some specific roadway attributes are defined and considered. usRAP’s existing methods involve coding roadway geometric design and traffic control through review of aerial and street-level roadway photographs and using those data to identify and perform a benefit-cost analysis of roadway improvement needs. The VTTI team (led by MRIGlobal) will identify roadway attributes critical to effective ADS—including attributes such as presence and quality of pavement markings, number of lanes, shoulders, intersections, and channelization—and develop a method for using those roadway attributes to assess the readiness (or lack of readiness) of specific road segments for ADS. This task will be completed via consultation with highway engineers and ADS technology developers on the VTTI team. The end product of this task will be the development of a tool (and supporting documentation) that can be used by State DOTs and other roadway network managers to assess their own roadway networks with respect to ADS readiness. The tool will also provide specific, prescriptive indicators for how a State DOT can improve the ADS readiness of its roadway network.

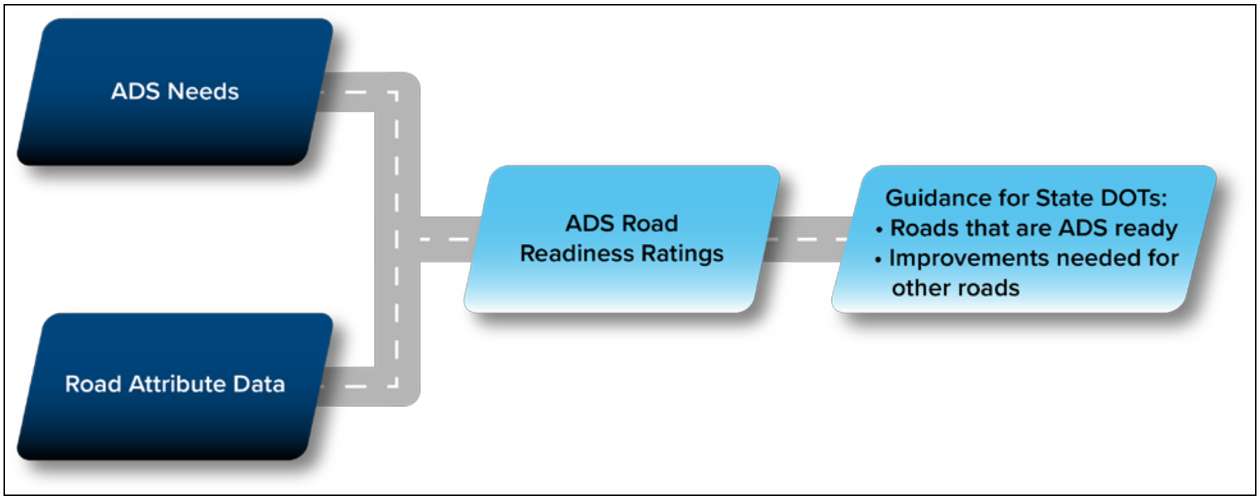

Figure 1-3. Flowchart of the Development of the ADS Road Readiness Rating System.

Task 14: Data Security/Transfer Protocol

Task 14 will outline data security and transfer protocols at the ADS technology developer and truck fleet levels. Data from the ADS-equipped trucks will be captured in real time on encrypted hard drives. Data from these trucks will be removed from the ADS-equipped truck by Pronto.ai and transferred on to its secure servers. Stored data will follow a retention policy to reduce unnecessary long-term storage of data. Access to data on the secure servers is limited to necessary personnel, and access is monitored. Data may be transferred off the secured servers to third parties, in which case the data will be stripped of any proprietary and PII data. Data will only be transferred when security of the data can remain intact, using encrypted hard drives and other mechanisms. The outputs of this task will assist ADS technology developers and truck fleets in securely transferring data to evaluate safety metrics, ADS performance/issues, etc.

Task 15: Cybersecurity Best Practices

Cybersecurity best practices will be outlined in Task 15. Cybersecurity continues to be a top-of-line concern in the ADS industry. Cybersecurity topics of interest include prevention of theft of data, prevention of misuse of vehicles, and minimizing external attack surfaces. Pronto.ai manages cybersecurity by following best practices: (1) in-cabin vehicle technologies are designed to include limiting external access wherever possible; (2) data sent or received from remote servers are encrypted in-transit; and (3) Pronto.ai vehicles are not openly accessible to the wider Internet and require a secure tunnel to access. These and other challenges and solutions to cybersecurity will be explored in Task 15. The VTTI team is also open to a security demonstration, where independent researchers attempt to remote hack the Pronto.ai system, with the results of their efforts published.

Task 16: FHWA CONOPS Dataverse Preparation

The FHWA CONOPS Dataverse will house all the non-proprietary data collected in the proposed study. The purpose of Task 16 is to develop, maintain, and operate the FHWA CONOPS Dataverse, which will include complete raw data sets and public-use data sets from the proposed study. The potential forms of the data to be stored are expected to include structured, tabular, geospatial, and audio/video.

The primary objectives of this task are to:

1. Develop a data repository to store FHWA CONOPS data sets;
2. Enhance existing procedures to allow VTTI and non-VTTI researchers to obtain custom non-PII data sets for local use; and
3. Develop a data access and management system that includes oversight, support, and tracking.

Since VTTI began managing SHRP2 NDS data, the institute has successfully processed more than 200 global researcher requests for such data and provided information and support for many more. VTTI has also created an FMCSA Data Repository website that matches the look, feel, and functionality of the VTTI InSight website, which provides access to SHRP2 NDS data (https://insight.shrp2nds.us/). The FHWA CONOPS Dataverse will serve as the interface for users accessing the data produced by this CONOPS study. The VTTI Dataverse has four separate dataverses consisting of 94 different data sets and 185 files.

Due to the existing infrastructure of VTTI's Scientific Data Warehouse, we have the experience to include the CONOPS data sets in the Dataverse. In terms of data privacy and security issues, VTTI will draw on its own experience with naturalistic driving data sets and data sets containing sensitive information. A critical aspect to the success of the FHWA CONOPS Dataverse will be its usability, easy access to background project information, and accessible documentation and training related to the website's query tool.

The VTTI Dataverse will feature fields that provide an overview of the data set, including a description of the project, subject, and keywords. Below this information will be fields for the data sets, data directories, metadata, terms, and versions. A strawman description of the data to be collected and access policies is provided in Part 3: Draft Data Management Plan.

Task 17: Develop Questionnaires

The VTTI team will develop questionnaires that can be used to investigate attitudes toward truck automation, use cases where automation will provide economic and/or safety benefits, and the ways in which truck drivers and the driving public can expect to interact with truck automation. The surveys will also gather demographic data to understand how different segments of truck fleets view ADS. The questionnaires will be developed so they can be given at two different time points (i.e., before and after participants experience ADS-equipped trucks in Task 19). The goal of the surveys will be to collect data that will inform the CONOPS developed in Tasks 8-15, improving clarity and completeness from the end user's perspective. The results will be critical to recognizing current gaps in the industry's understanding of truck ADSs and how outreach activities can address this gap to improve attitudes toward truck ADSs.

Task 18: Institutional Review Board (IRB) Application

Within 13 months after contract award and prior to submission to the Virginia Tech IRB, the VTTI team will submit a draft IRB package to the COR for review. This IRB package will include a summary of the proposed study, proposed methods, participant rights, risks and benefits, anonymity, data security, and informed consent procedures. Within two weeks of receiving the IRB package, the COR will review the package and provide comments to the VTTI team. After addressing all the COR's comments, the VTTI team will submit the IRB package to the Virginia Tech IRB. IRB approval is required when conducting research with human participants.

Additionally, the VTTI team will work with FHWA to secure or confirm appropriate exemption from the Office of Management and Budget (OMB) Reduction of Paperwork requirements relating to surveys and focus groups (re: use of Joint Program Office ITS/CVO exemption). The VTTI team will comply fully with 49 CFR Part 11, the USDOT regulation governing Protection of Human Subjects, which sets forth the Agency's policies and procedures for the protection of human subjects participating in research supported directly or indirectly through contracts, grants, and cooperative agreements. Note that Virginia Tech's Federal Assurance number is FWA00000572, which expires on January 29, 2021.

Task 19: Closed Track Hands-On Demonstrations (Roadshow), Public Outreach, Technology Refinement

Public outreach will be critical so that customers and users will understand the functionality, benefits, and limitations of ADSs. Outreach will also be critical with government, insurance, and inspection agencies, as well as the general public, who are likely to shape policy in this area. As ADSs are new and most truck drivers have not encountered or operated an ADS, outreach must include the opportunity for direct interaction with the different technology solutions being developed. To this end, the VTTI team will host a series of outreach events where the public, with a focus on truck drivers and truck fleet managers, will have the opportunity to meet ADS technology developers and OEMs. The outreach will also provide opportunities to participate in hands-on technology demonstrations, such as in-vehicle demonstrations and closed-course scenarios.

The VTTI team proposes leveraging existing truck shows and conferences for outreach, such as the Mid-America Trucking Show, the Great American Trucking Show, Consumer Electronics Show, Automated Vehicle Symposium, SAE COMVEC™, or the North American Commercial Vehicles Show, all of which have strong participation from the trucking industry. The research team will explore these industry events for opportunities to provide hands-on experience with automation technologies. This could include bringing ADS-equipped trucks to the events and providing closed-course demonstrations to a wide variety of participants. The hands-on experiences will also allow surveys to be administered before and after experiencing the ADSs in an effort to gauge how experiences may change perceptions and acceptance of the technology. The industry events will also be opportunities to get industry feedback on the use cases for different automation technologies and document industry concerns that need to be addressed in the CONOPS.

Using our existing contacts, we will publicize the events, with emphasis on fleet managers and other fleet personnel, truck drivers, government officials, insurance and inspection personnel, and the general public. As shown in Part 2, the VTTI team has significant experience in promoting and hosting these types of technology events, along with participation from national and local news media. To assist the VTTI team in the outreach, 17 organizations have agreed to participate in this opportunity in the event the VTTI team receives the award (see Part 4 letters of support/commitment). However, we believe that other ADS technology developers and truck OEMs will also agree to participate.

The hands-on demonstrations will consist of separate stations for each participating technology vendor/OEM, with participants' registering and completing demographic and baseline ADS acceptance information prior to participating in any of the stations. The items in the Demographic Questionnaire will be heavy-vehicle focused, including any ADS-related technologies installed on work vehicles or personal vehicles, experience operating heavy vehicles, and the types of routes or loads they typically haul. The baseline ADS Acceptance Questionnaire will document current knowledge and attitudes relating to ADSs, as well as cost/benefit information. Each station will offer an in-cab demonstration of the technology vendor/OEM technology, including secondary vehicles driven by staff (if necessary) to complete the experience. After completion of one or more stations, participants will complete a Follow-up ADS Acceptance Questionnaire. The Follow-up ADS Acceptance Questionnaire will assess if knowledge and attitudes toward the automation technologies have changed (improved) as a result of their hands-on experiences. The Follow-up ADS Questionnaire will also ask participants to describe concerns and barriers regarding the technology and how they would use the technology in their real-world operations.

We will collect a rich panel data set from motor carriers covering the challenges and opportunities for deploying current and future ADS into their operations. Learnings from this demo will influence all three phases of the proposed research to ensure the CONOPS developed is true to real-life fleet operations. Thus, the purpose of the hands-on demonstrations is two-fold: (1) expose truck fleet managers and other personnel, truck drivers, government officials, insurance and inspection personnel, and the general public to ADSs; and (2) collect valuable qualitative data on participants' opinions and perceptions regarding ADSs. The data from the latter will be especially useful, as each participant will have direct knowledge and experience with the ADS. The data from the questionnaires will be compiled and used to inform the relevant aspects of the CONOPS developed in Tasks 8-15. The results will also be used to gauge the effectiveness of the hands-on approach in disseminating knowledge and perceptions of ADSs.

Task 20: Collection and Upload of Hands-on Demonstration Data to FHWA CONOPS Dataverse

In Task 20, data from the Task 19 hands-on demonstrations will be uploaded to the FHWA CONOPS Dataverse. Data to be included in the FHWA CONOPS Dataverse may be a blend of survey/questionnaire data, vehicle time-series data (e.g., GPS, accelerometer, radar, and other instrumentation/sensor data), video data, and other data collected in the Task 19 hands-on demonstrations.

Task 21: L4/5 Cross-Country Road Testing

This demonstration will be the first of its kind to exhibit an unmanned truck safely undertaking an uninterrupted coast-to-coast journey across the U.S. An autonomous cross-country drive is the last major technical proof-of-concept for ADS-equipped trucks, but it has not been achieved by any vehicle. Pronto.ai has been at the forefront of nearly all the ADS major technical demonstrations. Members of Pronto.ai were behind the first autonomous truck delivery (October 2016 in Colorado in a live-traffic environment) and the first cross-country drive with a safety driver that did not require human intervention (October 2018 from San Francisco to New York; see https://pronto.ai/).

We will achieve this milestone with a novel approach in developing ADS-equipped trucks. Rather than using industry-standard high-definition maps to enable so-called "straight-to-L4" highway operations with trucks, Pronto.ai will take an evolutionary approach that begins at SAE L2 and goes to L5. Although high-definition maps are useful in an urban setting, they are difficult to maintain in terms of complexity and cost during long-distance trips (such as those in fleet operations). As such, the traditional approach in developing ADS-equipped vehicles (which the Pronto.ai team pioneered over a decade ago) will not work for the CONOPS model in today's trucking ecosystem. In addition, this demonstration will be the first of its kind to exhibit the use of connected-vehicle technologies in a mixed-fleet model, which will overcome the vexing issue of "edge cases." ADS technology developers have wrestled with this issue for years, which is the primary reason this milestone has yet to be achieved.

Task 22: Collection and Upload of Limited Road Testing to FHWA CONOPS Dataverse

In Task 22, data from the limited road testing will be uploaded to the FHWA CONOPS Dataverse. Data to be included in the FHWA CONOPS Dataverse may be a blend of vehicle time-series data (e.g., GPS, accelerometer, radar, and other instrumentation/sensor data), video data, and other data collected in the Task 21 L4/5 Cross-Country Road Testing.

Task 23: Application of CONOPS with Fleet Demonstrations

In Task 23, the VTTI team will perform a series of demonstrations that display how various levels of ADS can be simultaneously deployed by fleets in a safe, repeatable, and commercially viable manner. These demonstrations will most directly inform the CONOPS deliverables of the research proposed. We will explore three use cases (see below) and implement at least one (and likely two) in partnership with a truck fleet using the phased approach described in Task 6.

Working closely with our fleet consortium, the VTTI team will identify fleets that have the required operations (i.e., truck queuing, intermodal yard/drayage, and exit-to-exit) and will participate in this task by agreeing to integrate two to four ADS-equipped trucks in their daily, revenue-producing operations. With a list of interested fleets, the VTTI team will use the ADS Roadway Infrastructure Guidelines (Task 13) to identify A+ rated roads that match the use case of interest. The resulting list of potential roadways will be cross-referenced with interested fleets that conduct operations on these roadways. Thus, the VTTI team will identify a fleet-roadway combination to evaluate in Task 23.

Application of the Pronto.ai ADS platform will be installed on at least two of the participating fleets' trucks. We will review the Task 15 Cybersecurity Documentation and Task 11 Motor Carrier Guide to Insuring ADSs with the participating fleets at the beginning of the demo. The demo will include actual state inspections using the Task 9 ADS Inspection Procedures.

The two ADS-equipped trucks will make revenue-producing deliveries over a period of at least three months during each of the Task 23 demonstrations. During this time, the ADS Safety Metrics (Task 12) will be collected and parsed (as needed) for use by the participating fleet, FHWA, and inspectors (following the guidelines in the Task 3 Data Management Plan). Moreover, other data, including proprietary data and data that include PII, will be used by the VTTI team. This naturalistic driving data set will allow for the analysis of numerous additional research questions (e.g., the effectiveness of the Task 10 Driver State Monitoring Technology Protocol). The collection of data will follow the Task 14 Data Security/Transfer Protocol.

Task 23 is the culmination of all previous tasks and is the capstone in the proposed study (i.e., applying the CONOPS developed in the previous tasks within real-world fleet operations). The diagram in Figure 1-2 provides a high-level overview of what is involved in this demonstration.

Task 23A: Automated Truck Queueing Operation

There is a growing problem of increasing wait times at U.S. ports and other major shipping facilities. One major concern is wait times for truck drivers can be four hours. Although truck drivers use working hours and are subject to HOS limitations during the waiting time, they are generally not compensated while waiting. ADSs offer the potential to allow the vehicle to drive itself in "L4" mode while queueing to be loaded or unloaded. With an ADS, a driver could go off-duty and rest in a sleeper berth or leave the ADS and obtain rest in a motel or port facility. Therefore, the waiting could be used for rest and not count against the driver's HOS, thereby increasing the driver's overall productivity, the carrier's bottom line (more distance could be covered in the day), and safety (drivers would be better rested and less pressured by time).

Task 23B: Intermodal Yard-to-Exit Operation

Another source of significant inefficiencies in the current freight ecosystem is at ports and rail yards where cargo gets moved from rail or ships onto trucks (referred to as drayage). There is often a severe driver shortage and, as a result, long delays associated with the repetitive batch processing that is required to quickly and efficiently load/unload trains and/or ships. ADS offers the opportunity to fully automate a portion of the trucks that drive the repetitive loops between a rail yard (or port) to a nearby distribution center. If there is a critical density of trucks on such routes that adopt "L2+" automation, it is technically feasible to use connected-vehicle technologies to upgrade a portion of the trucks operating the same route to L4 functionality. Importantly, implementing ADS is dependent upon maintaining a threshold density of human-supervised trucks with fully engaged drivers. Thus, providing incentives to continue employing truck drivers and even directly benefit financially from helping to alleviate the driver shortage problem at intermodal facilities. For example, two human-supervised trucks helping a third truck operate autonomously; a fair wage may mean the two drivers share in some of the cost savings associated with not having a person in the third truck).

Task 23C: Long-Haul Exit-to-Exit Operation

It is now increasingly expected that some of the earliest deployments of ADS-equipped trucks will occur on long, open stretches of highways (especially in the western and southern U.S.) rather than in urban areas, such as cities. That assumption is based on the technical feasibility of being able to safely automate driving on highways in the near-term. However, technical feasibility is not enough as most advocates of exit-to-exit operations imagine fully ADS-equipped trucks operating on a handful of highly mapped roads while being entirely non-functional in other lanes, even lanes adjacent to the lanes where autonomous driving can occur. These advocates incorrectly assume there will be significant infrastructure investments for so-called transfer hubs, where trailers will be switched between traditional and autonomous trucks, as well as transitioning drivers from long-haul occupations to local ones.

Such proposals fall largely into the category of long-term or “idealistic autonomous” as they rely on trucking companies and shippers to make heavy investments to transform their current operations such that they can accommodate a small fraction of heavily mapped roads where autonomy can be technically implemented. By contrast, our near-term or “realistic autonomous” CONOPS proposal does not require any of those additional changes. Rather than relying on high-definition maps, infrastructure investments, and moving drivers to new kinds of jobs, our evolutionary approach relies on carriers adopting a mixed-fleet approach to automation, advanced driver monitoring systems, and connected-vehicle technologies to deploy some L4 and L5 capabilities within their existing operations. This means some of the trucks will be fully automated from origin to destination while sharing the road with other trucks where drivers will stay in the same kinds of jobs where they are currently employed and fleets will not have to dramatically change their business models and operations to accommodate exit-to-exit operations.

Task 24: Collection and Upload of Fleet Demonstration to CONOPS FHWA Dataverse

In Task 24, data from the fleet demonstration will be uploaded to the FHWA CONOPS Dataverse. Data to be included in the FHWA CONOPS Dataverse may be a blend of vehicle time-series data (e.g., GPS, accelerometer, radar, and other instrumentation/sensor data), video data, and other data collected in the Task 23 Fleet Demonstration.

Task 25: CONOPS Outreach

Throughout the proposed study, the VTTI team—with approval from FHWA—will provide updates on draft and/or completed tasks to the public. This outreach task will share demonstration status, results, and lessons learned with other jurisdictions and the public, in furtherance of technical exchange and knowledge transfer. This will be accomplished via webinars organized through FHWA and webinars and presentations organized via industry partners, including: American Trucking Association, Truckload Carriers Association, Owner Operator Independent Drivers Association, NPTC, American Trucking Association, Trucking Alliance, Travelers, various state trucking associations, National Association of Small Trucking Companies, and the Truckload Carriers Association.

Task 26: Draft Final Evaluation Report: CONOPS Document Finalization and Final Report

Within 43 months after contract award, the VTTI team will submit a detailed Draft Final Evaluation Report consisting of the following sections: (1) Executive Summary, (2) Introduction, (3) Methodology, (4) Results, (5) Guidelines (derived from Tasks 8-15), (6) Discussion and Conclusions, (7) References, and (8) Appendices (if necessary). The Draft Final Evaluation report will detail the project methods, data relied upon, analyses, results, and conclusions. The VTTI team will also draft a technical brief that provides a summary of the report. The Draft Final Evaluation Report will be concise (up to 50 pages, not including Appendices) and written for a variety of audiences, including those unfamiliar with research methods. Within three weeks of receipt of the Draft Final Evaluation Report, the COR will provide comments to the VTTI team, including requests for additional analyses, if necessary.

Task 27: Final Evaluation Report: CONOPS Document Finalization and Final Report

Within 46 months after contract award, the VTTI team will submit the Final Evaluation Report, along with a Technical Brief based on feedback from the COR. The VTTI team will submit the final report in electronic format using Microsoft Word. The final report will be Section 508 compliant, and all figures will be accompanied by an Excel spreadsheet with descriptions for each figure. The VTTI team will be responsible for incorporating all FHWA and COR comments into the Final Evaluation Report. If the COR does not approve the Final Evaluation Report, the VTTI team and the COR will engage in an iterative review cycle until COR approval is obtained.

Task 28: Final Briefing to FHWA

Within 47 months after contract award, the VTTI team will provide briefing materials (e.g., PowerPoint slides) to the COR. The COR will provide comments to the VTTI team within two weeks of receipt. Based on these comments, the VTTI team will revise and re-submit the final briefing materials to the COR within one week of receipt of the COR’s comments.

Within 48 months after contract award, the VTTI team will conduct a project briefing at FHWA Headquarters in Washington, DC, covering the study’s objectives, methodology, and results. The VTTI team will conduct the meeting in person using the revised PowerPoint slides. Handouts based on the revised PowerPoint slides will be provided for all meeting attendees.

Milestones/Deliverables

Table 1-1 shows a Gantt chart of the proposed tasks across the 48-month period of performance.

Table 1-1. Gantt Chart of Proposed Tasks

Task #	TASKS
1	Kickoff Meeting
2	Project Management Plan
3	Data Management Plan
4	Project Evaluation Plan
5	Fleet Derived Specifications for CONOPS Demonstrations
6	Automated Truck Technology Specification Document
7	Truck Selection
8	ADS Installation and Maintenance Guide
9	ADS Inspection Procedures
10	Driver State Monitoring Technology and Protocol
11	Motor Carrier Guide to Insuring ADS-Equipped Trucks
12	Identification of ADS Safety Metrics/Variables
13	ADS Road Readiness Rating System
14	Data Security/Transfer Protocol
15	Cybersecurity Best Practices
16	CONOPS Dataverse Repository Preparation
17	Develop Questionnaires
18	IRB Application
19	Closed Track Hands-On Demonstrations
20	Collection and Upload of Hands-on Demonstration Data to CONOPS Dataverse
21	L4 Cross-Country Road Testing
22	Collection and Upload of Limited Live Road Testing to CONOPS Dataverse
23	Application of CONOPS with Fleet Demonstrations
24	Collection and Upload of Fleet Demonstration Data to CONOPS Dataverse
25	CONOPS Outreach
26	Draft Final Evaluation Report: CONOPS Document Finalization and Final Report
27	Final Evaluation Report: CONOPS Document Finalization and Final Report
28	Final Briefing to FHWA
	Quarterly Reports
	Annual Budget Review and Program Plan
	Annual Budget Review and Program Plan Meeting

Risk Management

VTTI developed a detailed risk management plan for the proposed study. In this plan, the potential risks for the project are identified and rated based on their likely impact, probability, and mitigation ability (Table 1-2). Preliminarily identified potential risks along with their risk category, ratings, and corresponding mitigation strategies are shown in Table 1-3.

Table 1-2. Rating Scale for Potential Risk Impact, Probability, and Mitigation Ability

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

Table 1-3. Summary of Anticipated Risks and Corresponding Mitigation Strategies

Risk	Category	Risk Rating	Prob. Rating	Mitigation Rating and Strategy
Testing facility backlogged	Technical	3	2	1 – Multiple team members have testing facilities, so backup locations are available.
Vehicles unavailable	Technical	4	2	2 – VTTI will coordinate with participating carrier/industry groups to ensure a backup vehicle is available.
Vehicle malfunction/damage	Technical	2	2	2 – All testing equipment will be installed and maintained by trained personnel.
Technology malfunction/damage	Technical	2	2	1 – Proven technology will be used; replacement parts will be available.
Delays/changes in funding	Funding	4	1	2 – VTTI will work closely with FHWA to agree on the specifics of the project and resolve funding issues.
Lost test sessions due to adverse weather	Environm ental	1	1	1 – In cases of adverse weather, indoor facilities will be used when possible.
Loss of key project personnel	Personnel	3	1	2 – Brief multiple individuals on the project so that they can quickly step in if needed.
Injury during testing	Personnel	4	1	1 – Extensive training; VTTI has emergency protocols in place.

Cost Sharing

The project team is committed to contributing and managing non-Federal resources as cost share to supplement the proposed Federal sources (Table 1-4). Team members have committed $3,455,913 in cash and in-kind cost share. As a result, each member has a stake in the successes of the proposed project. Additionally, pubic stakeholders will provide resources throughout the, these contributions are not captured in the cost share total. See the budget in Part 6 for more specific details of the cost share.

Table 1-4. Summary of Cost Share Resources Provided by Team Members.

Cost Share	Resources Provided as Cost Share
VTTI	Data sharing and storage.
Pronto	Truck leasing; data logs and machine-learning resources; hardware, equipment, and software for ADS; test track fees; fuel; server storage.
Penske	Travel, labor in developing Task 8, and testing facilities.
MRIGlobal	Labor in developing Task 13.